Rice Husk Study

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Part I Summary

This assessment was undertaken by the LSU AgCenter as a part of the requirement for the Cooperative Agreement Grant No: 688-G-00-04-00049-00 funded by the United States Agency for International Development Mission for Mali, and the West Africa Regional program, under sub agreement with Schaffer & Associates International, L.L.C. 1020 Florida Blvd., Baton Rouge, LA 70802. The main purpose of the assessment was to review the rice production and post harvest operations including the milling of rice to gauge the availability and quality of rice hulls for potential cogeneration systems. The premise for the assessment was that the production of electrical power from off-grid and independent sources utilizing a renewable resource will enhance the availability of electricity for the rural population, and reduce the dependence of the country on imported fuels.

The assessment was conducted in November 2004 by two specialists from the LSU AgCenter with expertise in the production and post harvest operations of rice. The staff of Schaffer & Associates International in Mali provided all in-country support to conduct the assessment. Although the main focus of the assessment was the Segou region within the purview of the Office du Niger, the Mopti region where a significant area is under rice cultivation was also visited. Interviews and visits were conducted at ministries, agencies, with rice traders, millers, farmers, and village associations. A summary of the key findings are provided below, organized under 1) Rice Production, and 2) Rice Milling/Rice Hulls Utilization for Energy.

1) Rice Production

In seeking to determine the status of rice production in Mali for the recent years, the reports vary according to source. The area under cultivation from the reports range from 350,000 to 400,000 hectares. The paddy production is stated from 700,000 tons to over 960,000 tons. The yield per hectare varies from below one ton per hectare, to more that six tons per hectare. The national average is 2.2 to 2.5 tons per hectare. Of the seven production regions, the highest yield per hectare and the highest total production is in the Segou Region (Office du Niger and Office du Riz). The Markala dam constructed many years ago permits the controlled irrigation in much of that area, which probably contributes to increased paddy yields and production. Field yields of 3.8 to 4.7 tons per hectare are produced in the Segou Region, and it is estimated that the production of paddy from that Region is about one-half of the total Malian paddy production. The size of household planting of rice ranges from 0.25 hectares up to 12.0 hectares, with the average about 1 to 3 hectares.

In the two Regions we visited, Segou and Mopti, the rice production practices are about the same. Seed beds are planted to obtain plants (seedlings) for transplanting. After transplanting, commercial fertilizer is applied when it is available, with a split application of nitrogen at panicle initiation. Weeding is primarily a hand operation, but a few growers reported using chemical herbicides.

No insecticides or fungicides are applied. The days from planting to harvest ranges from 120 to 135. When the paddy is matured (moisture level of the grain about 18 to 20 percent), the paddy is harvested by hand in the field, stacked, and allowed to dry for 2 to 3 days, and then threshed with a mechanical thresher. The grain is then spread on drying mats and allowed to dry in the sun until it reaches a safe storage moisture content of about 12-13 percent. The paddy is then sacked into 70 to 80 kg bags, and stored at the growers home until it is milled by the small fixed location and portable mills. The milled rice from these inefficient machines consists of mostly broken white milled rice, and a mixture of ground hulls and bran which is then used for animal feed.

Suggested recommendations:

- Maintain and improve controlled irrigation in the Markala dam areas of rice production.
- Seek advanced technology for rice production from the Institut D=Economie Rurale, including high yielding varieties, cultural practices and plant protection.
- Continue the development of farmer cooperatives/associations to promote better production and milling.
- Make an effort to stress higher quality in both paddy and milled rice.
- Search for means to increase production on existing land used for paddy production by the proper use of applied chemical fertilizers, and perhaps the growing of a second crop during the dry season if water is present for controlled irrigation.

2) Rice Milling/Rice Hulls Utilization for Energy

a. The Rice Post harvest System

The rice post harvest system is currently handled by a combination of manual means with very little energy use, and small scale threshers and rice mills run by diesel power. The timing of harvesting and threshing practices could be modified to reduce internal breakage of the rice kernels, and subsequent low mill yields and food losses. An awareness program mainly through training of trainers, and low cost rice quality assessment laboratories can be one solution to address past harvest losses, currently estimated to be about 38,000 tons of milled rice equivalent valued at 16 million U.S. Dollars per annum.

b. The Rice Milling Industry

Since the privatization of the processing and trade in rice in the early 1990s, most of the larger mills with an estimated total annual milling capacity of 115,000 tons have been closed for operations. This situation has been caused by a variety of factors including lack of finance for paddy purchases, competition from the smaller mills for paddy purchases, and possibly lack of management efficiency. Despite this, one miller plans on continuing operations, and has even purchased another government mill, while another company is planning to establish a new large rice mill. Further, groups of villages have invested in improved rice milling systems that are capable of producing quality rice for the local markets.

As far as milled rice quality is concerned, by far the most striking observation was the amount of broken rice, overall about 50%, and in some cases even 100% brokens. Due to the low purchasing power of the rural populations, there is no present recognition for higher quality, and hence a higher price for milled rice. However, there appears to be a growing market for quality milled rice in the major cities, and discussions have revealed that those who can afford it will purchase the higher quality rice at a higher price. Mali currently imports a small quantity of rice from Asia, and this rice is sold at a price that is slightly lower than the locally produced rice. However, it is believed that the local population prefers the Malian rice.

Through an awareness and education effort referenced in subsection (a) above, a focus on rice quality improvement will result in reduction of food loss, which in turn will reduce rice imports. Concurrently, the focus on improved rice quality will encourage a move away from the current milling systems that are largely the cause for the broken rice component. This move will also result in a purer bran component, and rice hulls, more suited for cogeneration systems.

c. Rice Husk Availability

Given the current status of milling systems in the country, the availability of rice hulls for cogeneration systems is limited. The only operating large mill at Segou city currently produces approximately 2000 tons of rice hulls per annum, while in a group of villages in the Niono area are currently operating ten 2 t/h mills currently producing 15,000 tons rice husk per annum. This latter group of mills is within a ten to fifteen kilometer radius making husk collection for a cogeneration unit feasible. Further, discussions with this village association revealed that they are planning to add another ten mills of similar capacity, thereby enabling a total husk availability of 30,000 tons per annum. Assuming a 1.2 MW cogeneration unit (consuming 45 tons husk per day) is viable, the present amount of rice husk of 15,000 tons per year will be sufficient to run the power plant for approximately 330 days/year. Other systems of lower capacity, particularly steam engine based systems need to be explored.

d. Potential for Cogeneration from Rice Hulls

As a backdrop to this assessment, there is considerable agreement that electrical energy availability is a serious constraint to economic development in Mali. Due to funding and maintenance issues, and the delay in the Manatali Power Unit coming on stream, grid power is limited and transmission losses are high, estimated at 25% for a country that can ill afford this loss. Thus off-grid, independent sources of electrical power are encouraged by the authorities. Secondly the country with no known fossil fuel resources is currently importing 200 million liters of refined petroleum products for power generation, transportation and domestic use. Thus not only capital costs for cogeneration systems but also the corresponding reduction of diesel fuel for power generation needs to be considered. While high pressure steam turbine systems are more efficient, smaller capacity cogeneration systems driven by steam engines should not be ruled out.

Part II Rice Production

1. Overview of agricultural development and rice production in Mali

a. Country Background and Agricultural Production

The production of agricultural commodities, livestock and fisheries in the agricultural sector, and the continued development of the mining sector are key to Mali's wealth and economic well being. About 70% of the labor force in Mali is engaged in agricultural activities contributing about 42% of the nation's GDP. Agricultural production in Mali is dominated by small producers using traditional farming methods, particularly to produce cereals, including rice, sorghum, millet and maize (1).

b. The Rice Industry in Mali – An Overview

Rice is a major agricultural crop in Mali, and holds great potential for expansion, enhancement of quality and possibly exports to neighboring nations that are experiencing a deficit in terms of this crop. The most productive region for rice lies along the Niger River basin between Bamako and Mopti, and extends south to the borders of Guinea, Cote d'Ivoire, and Burkina Faso. Rice is grown extensively along the banks of the Niger between Segou and Mopti, and the most significant part of this is found in the areas under the purview of the Office du Niger north of Segou. This region accounts for nearly one third the production of rice in Mali. Table 1 below provides rice production data:

Table 1. Rice Production Data

Region	2002/2003			2003/2004 (forecast)		
	Area (Ha)	Yield (Kg/Ha)	Production (T)	Area (Ha)	Yield (Kg/Ha)	Production (T)
Kayes	979	1276	1249	3890	828	3222
Koulikoro	17751	2193	38927	12996	1365	17741
Sikasso	62085	1624	100814	63348	1170	74094
Segou	116315	4701	546856	114970	3815	438610
Mopti	134681	1281	175552	107648	634	68228
Tombouctou	26918	2980	80204	27571	2454	67662
Gao	27222	976	26571	26188	903	23646
Totals/Mean	385952	2513	970173	356611	1943	693203

Source: Malian Chamber of Agriculture, Official Bulletin, January 2004

As seen from the above data, Segou region by far has the highest yield on a per hectare basis, and produced approximately 56 and 63 percent of the national production respectively for the two seasons as calculated from the above table. The above data predicted a national decrease of 276,970 Tons in 2003/2004, and the decrease appears to be due to predicted decreases in all the regions except Kayes. The major reduction seems to be from the Mopti area. The production in Tons/Ha and land area in hectares of paddy harvested differ greatly as presented from several reports, publications and Internet sources. The variation in the data seems to indicate significant differences in reported yields, production, and harvested area for Mali. However in all cases, there is a consistent relationship. The Segou area has the highest yields and area under paddy production. Although the Mopti area is relatively higher in hectares planted to paddy, the uncertainty of water excesses and droughts result in low yields per hectare. The present and future production of rice in Mali looks promising, and will depend on many factors, but the most important is controlled irrigation.

Although Mali's rice production is close to being sufficient for its own internal use, it still imports some rice from Asia. In like fashion West African countries including Ivory Coast, Senegal, Guinea, Mauritania, Burkina Faso and Niger, all import a total of nearly 2.0 million tons of rice per year (2). Mali's neighbors in West Africa have a combined deficit of nearly 1.2 million tons per year, providing an opportunity for exports of quality milled rice from Mali. Although Mali's rice production, including its irrigation systems have an impressive record, the full potential for exports from Mali to its neighbors can be realized through programs aimed at enhanced production and post harvest operations that promote the processing of quality milled rice. Discussions at various levels indicate that at present even though the imported rice is cheaper than the locally available milled rice, the population prefers the local rice. This implies that a market for local rice exists, and will continue to grow concurrently with increased grain quality.

c. Status of Rice Production in Mali

Rice production areas in Mali are divided into seven (7) regions: Kayes, Koulikoro, Sikasse, Segou, Mopti, Tombouctou and Gao. The land area for rice production is reported to range form 350,000 to 386,000 hectares (depending on the reporting source). Field yields of paddy (rough rice) range from less then one ton per hectare up to more that 5 tons per hectare. The average is 2 to 2.5 tons/ha. Total national production in tons also varies according to different reports (600,000 to 970,000 tons).

Differences in statistical data regarding land area in hectares of paddy (rice); national production data in tons of paddy; and field yields in tons per hectare from Table 1 Rice Production Data are shown in the following seven instances.

- An IRRI (International Rice Research Institute) publication, ***Rice Almanac***, published in 2002 listed the following for Mali.

Table 2. Mali Rice Production Data

Year	Area Harvested	Yield T/A	Production (time)
1999	350,000	2.2	809,555
2000	350,000	2.3	869,555

Source: Rice Almanac, IRRI, 2002

- A report prepared for USAID/Mali Mission for USAID Global Bureau Center for Environment, Office of Energy and Environment and Technology, November 2001 listed "relevant rice production" as 700,000 tons. The assumption is that this referred to paddy or unmilled rice.

- An internet source (www.irri.org/science/ricestat/index.asp) reported the paddy rice yield for Mali in 2002 as 2.05 tons/ha; and the rice area as 453,000 ha.

- Another internet document, MALI, stated the 1997 rice statistics as 613,965 tons; 400,000 ha (harvested area); and a yield of 1.6 tons/acre. Another internet access for MALI showed 350,000 harvested ha; yield 2.3 tons/ha; and a production of 809,555 tons.

- Still another internet accessed document by WARDA (West Africa Development Association) for 2002 showed Malian rice production as 926,000 tons.

- A paper, ***Analyse des Filieres de Production Agricole au Mali: Cas du Riz*** October 2004 reported that the highest production regions were as follows: Segou region produced 438,610 tons of paddy in 2002/03; whereas the Mopti region produced 68,228 tons, a decrease from 205,733 tons in 2001/02; the Sikasso region produced 74,094 tons, down from 89,054 tons in 2001/02; and the Tombouctou region 67,662 tons, down from 99,613 tons in 2001/02.

- In a publication, ***Recuil des Statistiques du Sector Rural***, Minister du Development Rural, Republique du Mali, March 2001, presented the following information for 1999/2000.

Table 3. Rice Production Data

	Hectares	Production	Tons/ha
Kayes	3,345	2,638	0.789
Koulikoso	21,779	25,599	1.175
Sikasso	78,695	119,194	1.515
Segou	100,493	396,902	3.950
Mopti	69,799	88,271	1.265
Tombouctou	25,589	78,702	3.078
Gao	25,407	15,834	0.623
MALI	**325,107**	**727,140**	**2.237**

Source: Recuil des Statistiques du Sector Rural, Minister du Development Rural, Republique du Mali, March 2001

The variation in the data seem to indicate significant differences in reported yields, production, and harvested areas for Mali. However, in all cases, there is a consistant relation. The Segou area has the highest yields and area in paddy production. Although the Mopti area is high in hectares planted to paddy, the uncertainty of water excesses and droughts result in low yields per hectare.

The present and future production of rice in Mali will depend on many factors, but the first is controlled irrigation. The future looks promising for increased rice production in Mali.

According to one report downloaded form the internet, the percent of the total national land cultivated for rice by the seven regions was as follows.

Table 4. Percent of the Total National Land Cultivated in Rice

Region	Percentage
Kayes	3.9 %
Khoro	4.7 %
Sikasso	10.8 %
Segou	7.9 %
Mopti	59.2 %
Tombouctou	7.8 %
Gao	6.5 %

Source:

The largest region (Mopti) produces much less rice because of low yields, and the Segou region produces the most (almost one-half of the national production) because of high yields.

Again, of the seven rice regions, the highest field yields are produced in the Segou Region. This involves controlled irrigation in the NIONO, MACINO, MOLODA, and N'DEBOUCOU areas (see attached plat, perimeters amenages). The second plat illustrates the ZONE D'INTERVENTION Office Riz Segou and the hectares available for the production of irrigated rice.

The main season rice is planted May to July, and harvested October to December. Off season rice is planted January to March, and harvested May to June. Deep water rice is planted July to August and harvested December to January.

Planted varieties are classified as (1) irrigated; (2) rainfed lowland; (3) upland; (4) deepwater; and (5) tidal wetland. Variety development and testing is done primarily by the Institut d'Economic Rural under the leadership of Dr. Mamadou M'Baré Coulibaly, Chef Programme Riz Iriqué, CRRA, Niono. He does have a network of cooperation in receiving germ plasma from WARDA and IRRI. I am informed that he developed the variety Kogoni 99-1 Gambiaka, now grown on about 80 percent of the areas planted in rice.

Yield performance, by variety and region, was listed in one publication for 15-20 other varieties. The reported yields ranged from 2 to 8 T/ha. We assume that the yields are relative to their yielding ability, and small plots, and we expect those listed as 6-8 tons/ha to perform about 20 to 25 percent less under average field production practices.

In another report, fertilizer use of supplied nitrogen, phorphorus (P_2O_5), and potash associated with testing varieties ranged as follows:

0 – 100 kg/ha nitrogen
0 – 163 kg/ha phosphorus fertilizers
0 – 100 kg/ha potash

with resulting yields ranging from 1.9 T/ha to 5.86 T/ha as a result of fertilizer applications levels.

Another report from the irrigated Office du Niger showed nitrogen responses as follows:

0 kg N/ha – 3.26 T/ha
60 kg N/ha – 5.55 T/ha
100 kg N/ha – 5.9 T/ha

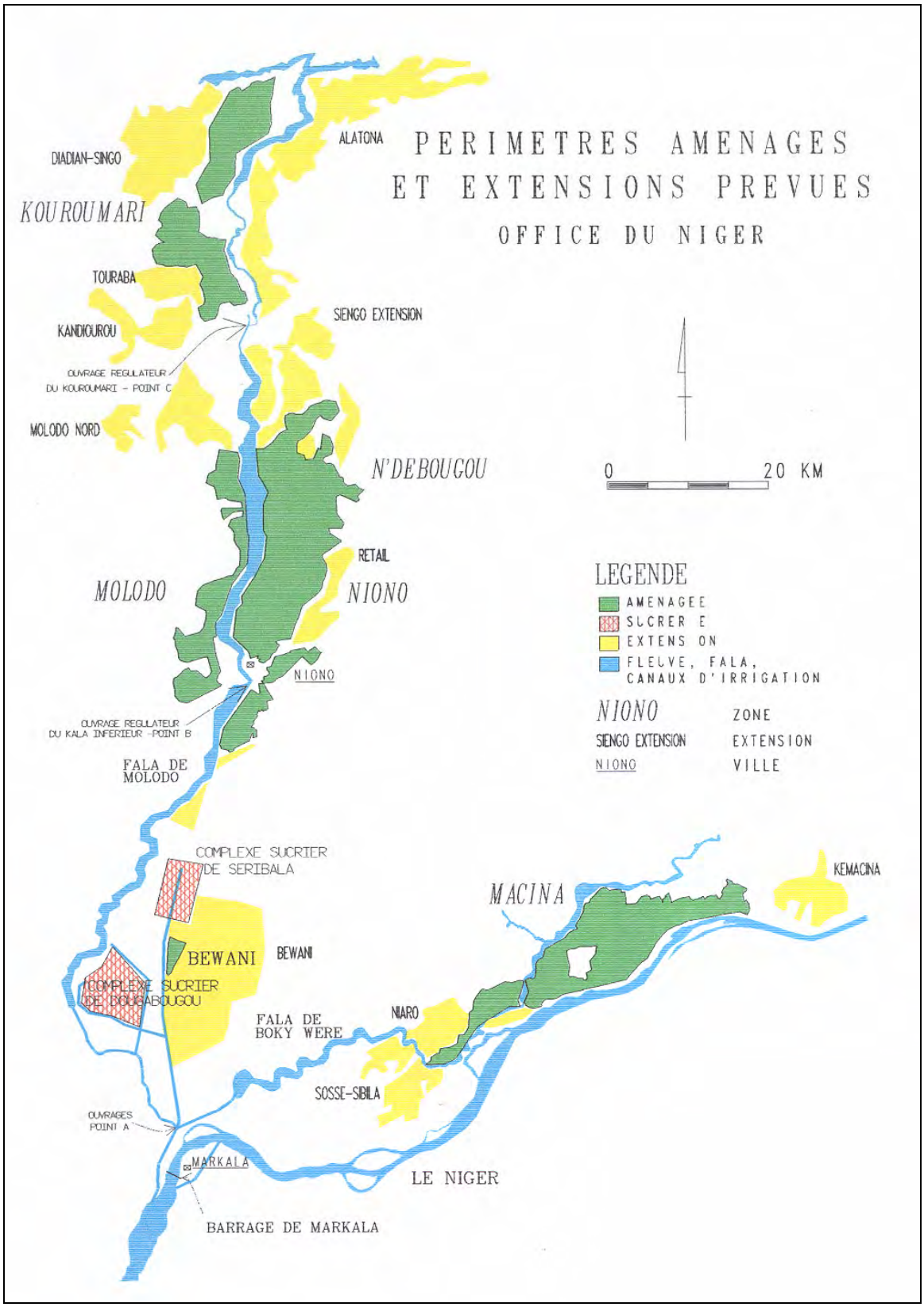

Figure 1. Office du Niger Area of Intervention. Source: Office du Niger, D.A.D.R., May, 1997

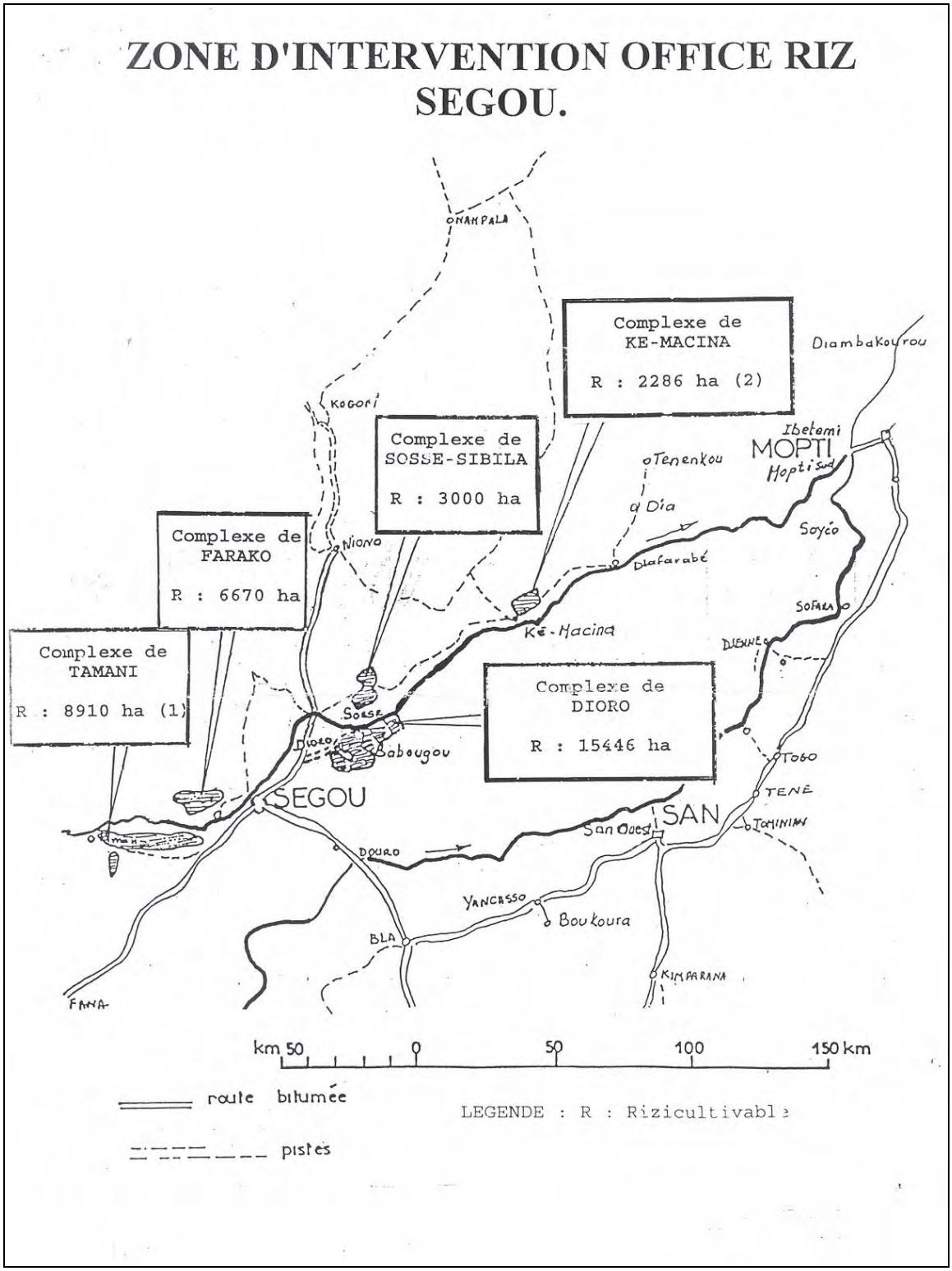

Figure 2. Office du Riz Area of Intervention in Segou. Source: Office du Niger, D.A.D.R.

Most rice farmers use fertilizer if it is available and recognize the increase in yields as a result of applied inorganic (commercial) fertilizers. A few added organic wastes (from animals) to the land planted to rice if it were available. In regard to commercial fertilizer, there were consistent reports about its lack of availability, or the lack of funds to purchase fertilizer. However, from our intensive travel in both the Segou and Mopti regions, we did not detect poor nutrition of the rice plants, or extremely poor yields resulting from lack of fertilizer applications.

According to all reports, insects and diseases of rice in Mali were not of economic importance. We had read 2004 reports of severe infestation of locust in West Africa, including Mali, but I was told that locust destroyed other crops in certain regions, but not rice. So, the use of applied insecticides and fungicides was not a production expense for Malian rice growers.

However, instances of yellow dwarf virus were noted. The decision was then made not to go into the field until harvest so that the virus would not spread.

There were reports of the use of herbicides for weed control, but data on this use was not available to us. We suspect that hand weeding is the primary means of removing unwanted weeds and grasses.

Reports of problems in Malian rice production were listed as:

a. Low temperatures during off-season in irrigated areas.
b. Drought/flooding in some regions.
c. Shortage of water in the dry season.
d. Weeds.
e. Lack of maintenance of irrigation facilities.
f. Production costs.
g. Inadequate production inputs.
h. Transportation.
i. The need for more research and extension.

Of the seven regions of rice production, the highest "average" yields were in the Office du Niger region, ranging from 3.26 tons/ha to 5.9 tons/ha. This greatly contrasted with yields of 1.72 to 2.63 T/ha in the Mopti-South region.

The Office due Niger and the Office du Riz offer the best potential for the proposed rice cogeneration project if it can be designed using the small, fixed location 2 ton mills in a designed series.

There are no large scale rice mills now active in Mali except for the 50 ton mill at Segou, which operates at 30 percent capacity. Actually, there is another 75 ton mill "across the street" from that mill but it is not operating now. Neither mill uses rice husks for energy. The mill owner reported power cost at 4,000,000 CFA/month to operate.

In those two regions (Niger and Riz), there is an express desire to expand rice cultivation to an area of 240,000 hectares. Land is available, but first, they wish to attempt increased production per hectare of the existing paddy (rice) before expanding land areas.

The goal of rice production increase in the Segou Region (Office du Niger) will require high yielding varieties, agricultural extension, involvement of the private sector, and policies for energy in the agricultural sector. But, we would hasten to add that the future planned development for increased rice production will be limited unless there is an increase in controlled irrigation.

With available water resources for the dry season, the increase in rice production could easily double by planting two crops per year. However, we were informed that the water flow is too low from the Niger River in the dry season, and subsurface water sources are not known, nor could be easily produced without power for the pumps and subsurface wells.

The days from rice planting to harvest in the irrigation areas range from 125 to 140 days, thus providing ample time for two crops if irrigation is available during the dry season. Unfortunately, the information in the preceding paragraph makes that difficult to achieve.

The production practices in the Segou region are discussed in the trip report, but presented here in summary form:

1. Seed beds from broadcast rice seeds.
2. Transplant, by hand, on 20 cm x 20 cm spacing.
3. Apply fertilizer in split applications (two).
4. Harvest at about 18 – 20 % grain moisture by hand in the field and tie in bundles to dry.
5. Wait 2 to 3 days for available machine thresher.
6. Spread grain on drying floor for sun drying to safe moisture for storage (about 12%).
7. Bag the paddy in 70 to 80 kg bags.
8. Store at home.
9. Mill as needed, and/or sell any of the production not needed for household food consumption.
10. Mill 1 to 3 bags as needed using primarily small, portable mills or fixed location small mills. The problem with the latter is transportation even though the quality (percent broken grains) is better in the fixed location mills than the portable mills.
11. Use the bran/hull mixture for animal feed.

Part III Rice Post Harvest System and Rice Husk Utilization

1. Rice Post harvest System

a. Overview

Most rice is hand harvested at maturity, and at a grain moisture level of 18% to 20%. The farmer then leaves the harvested panicles in bundles in the field to dry for 2 to 3 days and then based on the availability of mechanical threshers the paddy is threshed. The paddy is then taken to the farmer's home and sun dried by spreading on the ground directly or on woven mats (Figures 3 ~4). The farmer then sells a portion to a large mill or has it milled at a small huller type mill for sale at the local market. Depending on the area, family size and other considerations, some farmers may not have sufficient paddy for sale. In this case they mill the paddy on an as needed basis, keeping the rest of the grain at home. Storage at the farmer's home is generally in mud structures (Figure 5).

Figure 3. Hand Harvesting Paddy

Figure 4. Hand Harvesting/Threshing

Figure 5. Paddy Storage Structure

Observing the rice quality at various mills and markets, it is apparent that by far the most visible aspect is the large number of brokens. For example, rice from a mobile huller mill run by a diesel engine in Sasendang town near the Macina area, appearedto be nearly all broken, and the bran-hull mixture had many small brokens. In general rice samples revealed a greater than 50% Observing the rice quality at various mills and markets, it is apparent that by far the most visible aspect is the large number of brokens. For example, rice from a mobile huller mill powered by a diesel engine in Sasendang town near the Macina area appeared to be nearly all broken, and the bran hull mixture had many small brokens. In general rice samples revealed a greater than50% breakage. At the same time, the grains appeared to be very sound, and devoid of any heat damage, insect damage, or otherwise discolored. This indicates that if the issue of breakage is addressed, then the quality of the rice would be good.

Since 1994, when the government of Mali privatized rice processing and trading, there has been a trend for the closure of the few large rice mills and the growth of a large number of small huller type mills. Of the eight large rice mills, six were visited. At present only one mill at Segou city is functioning albeit at about 30% capacity. Most of these large mills have been closed for 10 or more years. The smaller mills are of two types. The most common is the huller type in which paddy enters at one end, and two products, a) milled rice and brokens, and b) bran and hulls leave the machine. A second type of mill recently introduced in the Niono area is the combination of the rubber roll sheller (to remove the rice hulls) and steel polisher to remove the bran. The

former huller type mill is generally powered by diesel engines, and is either a mobile unit going to various locations in a village to mill farmers' paddy, or exists in a fixed location where farmers bring the paddy for processing. Some farmers believe that the fixed mill produces better results in terms of rice quality.

b. The Milling Industry

The rice milling industry in Mali underwent major changes after the sociopolitical events in 1991. Eight large mills with a total estimated capacity of 115,000 tons per annum that were in operation at the time were privatized. By 'privatized' it is meant that these mills were sold on tender and some were bought mainly by traders engaged in the imports and distribution of sugar and rice (Mali still imports a small quantity of rice despite being fairly close to self sufficiency). Table 5 shows data gathered during the study on all of the 'large' mills in Mali – six of the eight were visited during the study. At the present time (November 2004), only two mills at Segou city located across the street at the same location were operational.

Table 5. Large Rice Mills in Mali (in the Segou and Mopti Areas)

Location	Owner	Year Built	Capacity	Distance to Segou	Notes
1. Diore/Segou	Bakore Silla	(?)	(?)	50 Km	Closed[1]
2. Segou City	Modibo Keita	(?)	50 T/day	0 Km	Working[2]
3. Segou City	Modibo Keita	(?)	75 T/day	0 Km	Closed
4. Kolongo du Macina	(?)	1948	1200 T/yr	91 Km	Closed
5. Molodo/Niono	(?)	1950	30,000 T/yr	113 Km	Closed[3]
6. Dogoferi/ Diabali	(?)	1968	21000 T/yr	80 Km	Closed
7. Debougou	(?)	1976	21000 T/yr	120 Km	Closed
8. Savare/Mopti	Modibo Keita	1973	6 ~ 9000 T/yr		Not working[4]

Notes:
1. This plant has a low pressure steam cogeneration system utilizing rice hulls from the mill. The mill is currently closed due to owner not being able to purchase paddy caused by competition from small huller millers in the area; lack of funds for paddy purchases, etc.
2. The owner says 30 % of the combined capacity of the mills in item 2 and 3 above. These mills are located across the street. He also says that most of the milling is done at the 50 T/day mill. Conclusion – 30% of the combined capacity (50 + 75) is 37.5 T/day at mill in item 2 above.
3. This mill, now long closed, had a Chinese rice hull gasifier system to produce power for milling operations. A gasifier plant was located inside the building, and another abandoned gasifier and diesel engine was found outside the premises.
4. This mill was recently purchased by Mr. Modibo Keita in November 2003. Officials of the government at Sevare, Mopti say that he has not turned up at the site yet. Mr. Keita says he bought it "at a very low price". An estimate would be that the price paid was much less than $ 400,000.

Rice hulls based cogeneration systems were installed at two of the mills (Bakore Silla mill at Segou city, and Molodo mill at Niono) that are presently not operating. One mill had a steam boiler/turbine system coupled to a generator for the needed electrical power, while the other had utilized a Chinese gasifier unit coupled to a diesel generator set to produce the required power.

Of all the mills visited during the study, all but one (Kolongo du Macina location) showed that the facilities could be upgraded and renovated if large scale operations in milling rice were to be given consideration by investors. The mill and premises at the Kolongo du Macina location were in a poor state of repair. Given this status of rice milling in the country, most rice processing is left largely to the smaller mill operators who utilize the Engleberg type huller units with small hourly throughput, powered by diesel engines. These mills were fairly common in the village setting, and were either available to producers as portable units (the diesel engine/mill were skid mounted and drawn by a donkey, Figure 6), or fixed at a central location in the village for use on a custom milling basis. In one group of villages (Seriwala, KM 30 in the Niono area) the village association has invested in ten mills (each of 2 tons per hour capacity, totaling an estimated 7500 tons per annum) that were more advanced (in terms of producing a better quality milled rice) than the Engleberg type huller mills referenced earlier. These are of the rubber roll sheller/steel polisher type mills, and are capable of producing a better quality of milled rice (less brokens), while at the same time producing two by products – hulls and bran.

Figure 6. Moveable Engleberg Type Huller Mill

Given the above scenario, by far the most striking feature was the quality of the milled rice. The better samples of rice seen during the visit at best showed nearly 50 to 60 percent brokens, while in some cases, the rice from the portable smaller units appeared to be nearly 100 percent broken. There are several points to note in this regard. The sale price of broken rice is generally half that of unbroken rice; when rice breaks in the mill, not only is the quality lowered, but also the total yield is reduced. This is caused by the fact that a significant part of the brokens also are abraded in the mill producing in effect rice flour that goes to the bran/hulls mixture the mill produces. This results in economic and food loss estimated at between 5 to 7 percent to the farmers. Using the annual production in the Segou are as 473,000 tons, the above loss translates to about 23,000 tons of milled rice per year valued at about 5.0 billion CFA or about 10 million dollars per year. This estimate increases to about 38,000 tons of milled rice for the nation valued at about 16 million dollars per annum (an annual production of 800,000 tons was used for this estimate).

A secondary issue is the quality of the byproducts produced by the smaller mills. Due to the nature of the design of these small huller mills, they produce two outputs – a) milled rice and brokens, and b) a mixture of partially ground hulls and bran. A considerable amount of small brokens were also noted in the second output from these mills confirming the notion that there is at present food loss (lower total milled rice yield). While at the present the by product (mixture of bran and ground hulls) is returned to the farmers for use as animal feed, as production increases, a focus on mills that produce a purer bran component may be necessary. This will result in a higher value by product in comparison to the present mixture of rice bran and ground hulls. Of course a move in this direction will also result in pure rice hulls that are suited for energy production (the current mixture of bran and ground rice hulls is unsuitable for cogeneration purposes).

The closure or non operation of most of the larger mills in the country prompted an exploration of the reasons for closure by speaking to many representatives of the milling industry. The key issues/reasons are: a) Sociopolitical events in 1991, and a dry spell at the time caused a reduction of paddy available to the large mills; b) the privatization process took some time and in this period the mills closed operations; c) competition from small millers - they offered a better price than was possible for the larger mills at the factory gate (the large mills can compete if they went to the villages to collect and purchase paddy), and small millers gave back the bran-hull mixture to the farmers for use as animal feed; and d) lack of capital to purchase paddy. In addition to these reasons, it was felt that good management or the lack there of could also be a cause for the closure of most of the large mills in the country.

c. Rice Milling Facilities

In this section, data on mills representative of the different categories are presented. As discussed previously, there are three major categories of mills in Mali. The first category is the now largely non operational large mills; the second category is the rubber roll type mills; while the third category is the most common Engleberg huller type mill.

i) Modibo Keita Rice Mill, Segou City

There are two mills located across the road from each other at this location, and are both owned by Mr. Modibo Keita, a prominent sugar and rice trader in Bamako. Last November Mr. Keita also purchased on tender the Savare Mill in the Mopti area for a "very low price", but has not taken any interest to begin operations at this location. The following are pertinent data on the Segou mill and its operations:

Mill capacity – the mills are stated to have a capacity of 50 tons/day and 75 tons/day respectively as stated by the owner. As daily operations were stated to be either 18 or 24 hours, the hourly capacity ranges from 2.0 to 2.7 tons/h for the 50 ton mill, and from approximately 3 to 4 tons/h for the 75 ton mill. All indications are that the 75 ton mill is currently not in operation. A feature of the monthly operational capacity was that it varied according to the availability of funds from the owner. Data from the books on

monthly capacity revealed that from April through August of 2004 they milled on average 1200 tons per month (see Table 6 below), equivalent to about 40 tons/day on a 30 day per month basis. The persons at the mill premises stated that the mill normally operates about 7 months per year and mills about 20,000 tons. For example, this year, they have milled about 9000 tons thus far for a 6 month period.

Electrical energy use – the owner stated that he spent on average about 4.0 million CFA per month on electricity. The actual data on consumption is provided below, and shows an average of 3.36 million CFA per month:

Table 6. Electricity consumption at Modibo Keita Mill, Segou city

Month		Paddy milled(tons/month)	Electric bill for the month (million CFA/month)
April	2004	1622	4.48
May	2004	1210	3.57
June	2004	1232	3.48
July	2004	1192	2.61
August	2004	985	2.68

Mill type – The above mill consists of paddy cleaners, two rubber roll shellers, two paddy separators, abrasive type polishers and rice graders (Figures 7 and 8). This configuration is capable of producing quality rice, pure bran, and pure rice hulls. The operator claimed that their final rice product contained about 25% broken rice. The bran is sold as animal feed and the rice hulls are mainly unused and left in the adjoining field (Figure 9).

Figure 7. Modibo Keita Mill, Segou City

Figure 8. Rubber Roll Shellers, Modibo Keita Mill, Segou City

Figure 9. Rice Hulls Left Unused

Paddy purchases - The availability of paddy for the larger rice mills is a concern and has a bearing on the closure of most of the larger mills in Mali as discussed earlier. At this mill, for example, paddy is obtained by purchases at the 'factory gate' from farmers, or purchased through buyers who on behalf of the mill travel to the villages to purchase/collect paddy for the mill. The furthest point of purchase was stated as 160 KM. Quality checks at the 'factory gate' or when purchased by buyers appeared to be limited to a visual inspection. Price is said to vary by 'quality', and the Gambiaka variety fetched the highest price. Purchase price data was not available.

ii) Bakore Silla Rice Mill, at Diorra

This mill, also located in the Segou area (Figure 10), was one of the large mills now closed for operations. According to the factory manager this mill was built in 1980 and ran as a government mill until 2000. Due to the absence of grid power in the area, the mill also had a low pressure steam cogeneration system run on rice hulls to produce power for the mill operations. The following are pertinent data on this mill:

Figure 10. Bakore Silla Mill, Diorra

Mill capacity – The manager stated that the mill ran at between 2 and 3 tons/h for 24 hour per day for 6 months of the year. This translates at the higher 3 tons/h rate to an annual capacity of 12,960 tons per annum. The mill also has paddy storage (rectangular silos) of 6000 tons and milled rice storage of 2000 tons. The surrounding area (within a 20 Km radius) produces sufficient paddy for the mill, and it was stated that almost 20,000 tons of paddy could be available for this mill. Since 2000 when operations at the mill were stopped, the smaller mills have taken over the milling in the area. When inquired about the quality of the rice produced at this mill versus the quality of the rice from the smaller mills, it was stated that the quality of rice produced at this mill was better than from the smaller mills. However, the mill did not command a higher sale price consistent with rice quality as the population at the present did not care about the quality and was only willing to pay the lowest price. During the time of operations, the government had used the rice for hotels and restaurant use. The manager did state that they can ask for a higher price at other locations.

Figure 11. Part of Cogeneration System

Electrical energy use – The mill, as referenced earlier is located in an area without grid power, thus it was installed with a rice cogeneration system (Figure 11) primarily of Italian manufacture. Although details of specifications were not readily available, it appears that the system had a fire tube boiler fueled by rice hulls using a gravity fed step grate system for combustion. They used straw and cotton waste for start up before switching to rice hulls after the boiler system reached steady state operation. The boiler capacity was stated to be 400 Kg/h, and husk use was stated to be between 400 and 500 Kg/h. The boiler provided steam for a single 400 KVA steam turbine generator set. This power was used for the running of the mill, lighting for the premises and for electricity use by three houses for staff at the same location. In addition to the cogeneration system, they also had installed three diesel generator sets of 400, 250 and 50 KVA respectively. Data on power use by the mill was not available. It was only stated that the diesel based operation of the mill was more expensive that the cogeneration system running on rice hulls.

Mill type - The mill was essentially of the rubber roll sheller type (Figure 12) with equipment supplied from Italy and China. The rubber roll shellers used were of Italian make with 250 mm diameter x 250 mm long rolls, the paddy separator (Figure 13) was of the "Satake" design made in China, and the polishing (bran removal) operations used a 4-stage vertical cone (1500mm diameter x 600 mm height) polishers (Figure 14) of Italian manufacture. To grade the milled rice, there were two oscillating sieve type graders and a single trieur cylinder type grader. Rice quality was estimated at about 65% total milled rice output with an estimated 50% whole kernels based on 100% paddy.

Figure 12. Rubber Roll Shellers

Figure 13. Paddy Separators

Figure 14. Vertical Cone Polishers

<u>iii) Rubber Roll Sheller/Polisher Combination Mills, Seriwala village, KM 30, Niono Area</u>

This group of villages have a village association that is stated to operate 10 of these fixed location mills (as opposed to the moveable mills found in the villages), with plans for introducing another ten units in the near future. As discussed elsewhere in this report, this group of villages and other like this group offer possibilities for organized rice husk collection and the generation of electrical power from rice hull based cogeneration systems in the near term for Mali.

The unit is a rubber roll sheller that dehulls the paddy, mounted atop a steel polishing unit to remove bran. The capacity of these units (Figure 15) are stated to be 2000Kg paddy per hour, and use an 200 mm diameter x 150mm and 250 mm long rollers. The information on motor power used to run the unit (a single motor drives the entire unit) varied, but a figure of 40 kW was taken as the average. All of these units are run by electricity produced by a 40 kW diesel engine alternator set (Figure 16) using about 5 to 6 liters per hour of diesel. Inquiries at one location revealed that these mills generally run 18 hours per day, 30 days per month, for 7 months per year. This translates to about 7560 tons of paddy per annum. For this duration, the mill requires 22,680 liters of diesel valued at 9.2 million CFA per annum (U.S. $ 18,400 at 500 CFA/$).

A variation of the unit described above was a separate rubber roll sheller and steel huller type polisher with a lower throughput capacity of about 800 kg per hour. In one village, it was estimated that about 30 such units mill paddy in comparison to at least 500 huller type mills of the fixed and moveable variety.

These mills purchase paddy at a price range of between 100 and 120 CFA/kg based on 'quality', variety, and season (or time of year – at harvest time price is low, and at other times in the year the price could be higher). The charge for milling is around 750 CFA per bag of 70 kg. The rice hulls are not utilized for any specific purpose (in some villages there is some use for brick making, as a fuel for cooking and the use of ash for horticultural production), while the pure bran (with some small rice brokens in it) is sold at 2500 CFA per bag of 70 kg. The milled rice is said to be sold at 225 CFA per kg (with approximately 50% brokens), and sold at 275 CFA per kg after grading to reduce the brokens. Information on how much brokens were present in this 'graded' rice was not available. The imported rice in Mali was said to be sold at prices close to the 225 CFA per kg level.

A discussion on willingness to participate in a cogeneration project was welcomed by the above referenced association, although the association head stated that the opinion of the association members will have to be considered. He realized that at present,

there was no value associated with rice hulls, and that once people realize that rice hulls have value, they would be willing to consider the collection and use in a cogeneration system.

iv) Small Portable and Fixed Huller Mills

As discussed elsewhere in this report, by far, these mills were most common in all villages in the rice producing area in Mali. To obtain an overview of these mills, discussions were held in one village in the Office du Niger area near Macina. The discussions held with the leaders of the town administration for Sasendang Town revealed that at least 80 mobile units and about 30 fixed units are operational in their area to handle the paddy produced from approximately 10,000 ha under rice production. Farmers are said to keep most of the rice crop as paddy stored in their homes, and mill the grain on an as needed basis. The charge for the processing at these small mills varies from 1 bag of paddy for every 12 bags or 14 bags of paddy processed. In general the villagers are said to prefer the rice quality from the fixed mills as compared to the mobile units, but that transport to and from the fixed mills was a consideration. These small mills are all of the Engleberg huller type, and produce two outputs: a) milled rice and brokens, and b) a mixture of ground hulls and bran with some small quantity of small broken rice particles.

Figure 15. Rubber Roll/Polisher Unit

One such mill visited (figures 17 and 18) in Sasendang village was powered by a small diesel engine of Chinese manufacture (Yangdang Company). This engine, model S 195 had a maximum horse power rating of 13, and ran at 1200 RPM. The diesel consumption was estimated at between 2 and 3 liters per hour. The capacity of the huller was stated to be ten 70 Kg bags of paddy or approximately 700 Kg paddy per hour. A visual examination of the milled rice output indicated that nearly 100 % of the kernels were broken.

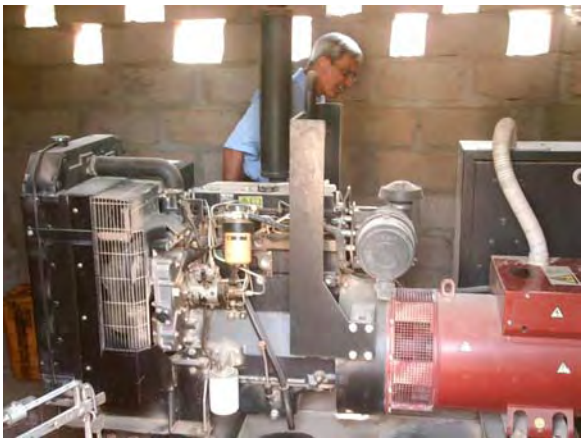

Figure 16. Diesel Generator Set

Figure 17. Portable Mill, End View

d. Rice Quality Issues

As discussed previously, rice quality appears to be a major consideration if post harvest losses are to be reduced. While it now appears that rice quality may not be a consideration for the majority of the people, inquiries revealed a price differential for milled rice (225 CFA to 300 CFA/Kg) based on quality (amount of brokens), particularly in the Bamako market. Secondly, it was found that while imported rice is available in the market (landed price approximately FOB price at sale point plus $ 100/ton transportation

plus 18% import duty versus local rice at $ 520/ton) the people generally prefer the locally produced rice. Further it was found that those who can afford will pay a slightly higher price for better quality.

Figure 18. Portable Mill, Side View

The situation described above is not unlike the situation in other rice producing countries where as one approaches self sufficiency and look to exports of any excess production, then rice quality issues become important. Mali is in fact poised to move in this direction. At the same time, Mali can seize the current opportunity of exporting to neighbors who collectively have a current estimated deficit of 1.2 million tons milled rice per annum (2). To move in this direction producing export quality rice, Malian processing facilities need to focus on improved rice quality. This has the added advantage of reduced food losses in general for the country. To absorb any increased production, increased milling capacity, particularly for export oriented businesses, it would be normal to invest in larger capacity mills that produce rice of acceptable standards. This has an implication on availability and quality of rice hulls for cogeneration purposes, in that the rice hulls of an appropriate quality (for cogeneration) will be available at the sites (of the mills), thus removing and collection and transport costs, and the cogeneration unit will provide power to run the mill and associated facilities, and based on the cogeneration system installed, produce excess power for the locality.

Given the above discussion, consideration should be given to an awareness program focusing on post harvest operations, losses (in the field, at storage, and through the milling process). This program should be oriented to general awareness for the producers, capacity building through training programs for Office du Niger and Office du Riz personnel, local NGOs and village leaders. The LSU AgCenter has conducted similar programs and has the capacity to develop and implement such programs in-country. In addition to the capacity building effort, paddy/rice quality assessment needs to be addressed. One way to accomplish this is to establish small low cost quality assessment laboratories in key locations in the main rice producing areas. The added advantage of these small laboratories is that they will be appropriate sites for conducting the training programs.

2. Electrical Energy Production and Use

a. Energy Production ~ Sources and Use

To obtain an understanding of the energy production and use in Mali, several meetings and visits were conducted during this study. Further, reports available from USAID and other sources were also consulted. Meetings with the Minister of Energy, at the offices of Energie du Mali (EDM), and Agence Malienne pou le Developpement de l'Energie Domestique et de l'Electrification Rurale (AMADER) in Bamako and Segou were conducted. Mali is stated to have one of the lowest per capita energy consumption in the world (2). At the present only 8% of the population (approximately 100,000 customers) are said to have access to electricity, with a projected additional 7% of the population having electricity by 2010. Installed power in Mali includes hydroelectric (50 MW) and thermal (64 MW) sources. Mali is also stated to possess about 1 MW of solar power sources serving about 2000 homes, and public buildings including schools and community buildings. Some solar powered water pumps are also used.

At the present time, nearly 80% of the energy consumed by the population is estimated to come from fuel wood, albeit without a plan to sustain this renewable resource. Due to the absence of any source of fossil fuel in the country, Mali currently imports 3800 bbl/day (200 million liters per year) of refined petroleum products for the purpose of power generation, transportation needs and domestic use (lighting and cooking).

It is reported that both the quality of power supply and distribution are major issues that contribute to the mismatch between supply and demand (2). There are several causes for this mismatch: a) the delay in the availability of the Manatali plant (100 MW) , b) the decommissioning of some of the thermal power plants in the urban areas without replacement, and c) the inefficiency of transmission with losses amounting to about 25% of the generated amount (an amount that Mali can ill afford). Some factors that cause this high transmission loss are long distances of power lines, low transmission voltage, and possibly low quality transmission equipment and maintenance.

Given the above situation, future development will likely emphasize distributed power generation. This notion was confirmed when discussions were held at the Ministry, AMADER and EDM offices. Distributed power generation will help provide power to rural consumers faster than currently possible with the national grid, and improve transmission efficiency by producing the electricity close to the consumers. Off-grid, independent sources of electrical power including from rice hull based systems were welcomed and encouraged by all agencies visited during the study.

Energy prices, particularly for electricity for use in the rural setting for rice mills and home use were investigated. These cost values will be important when considering rice hull powered systems. Electricity is supplied at three rates: social, normal and industrial. Both the social and normal rates are based upon the amount of use per month by the consumer. The higher the use, the greater the cost of a unit (kWh). The industrial rates are generally based upon the time of day (peak, regular and off peak). Prices also vary by region. Data from a USAID study conducted in 2001, and data obtained during this study are shown in Table 7 below:

Table 7. Electricity Prices in Mali

		August 2001 Study		November 2004 Study
Electricity	Social Rate	Use < 50 kWh/month	- 64 CFA/kWh	68 CFA/kWh
		Use 50 to 100 kWh/month	- 99 CFA/kWh	
	Industrial Rate	Off Peak (0h-6h)	- 43 CFA + 18% TVA	43 CFA/kWh w/o tax
		Regular (6h-18 h)	- 70 CFA + 18% TVA	70 CFA/kWh w/o tax
		Peak (18h-24h)	- 98 CFA + 18% TVA	98 CFA/kWh w/o tax
	Household Rate	-	-	94 CFA/kWh
Fuel Oil	Disel	344 CFA/liter		

Source: Reference (2), USAID 2001 Report; Present study data

b. Energy Use in Rice Mills

In assessing the use of rice hulls for energy, it is useful to estimate the energy consumption by the rice mills that produce the hulls. The following are pertinent data (Table 8) from a previous publication (3):

Table 8. Electric Power Use by Rice Mills

Maximum Power Demand	kW	Source
½ ton/h hullers, India	7 ½	IIT, Bombay, 1989
½ ton/h shellers, India	22	IIT, Bombay, 1989
2 ton/h mills, India	100	Assoc. Engineering, 1995
3 ½ ton/h mill, Molodo, Mali	125	German Ag. For Tech. Coop., 1987
kWh per ton of paddy	**kW**	**Source**
1 ton/h mills, Indonesia	25	ITB, Bandung, 1994
1 ton/h mills, world wide (maximum)	65	FAO, 1978
2 ton/h mills, world wide (maximum)	50	FAO, 1978
3 ½ ton/h mill, Molodo, Mali	32	German Ag. For Tech. Coop., 1987

Source: Reference (3), Velupillai et al, 1996

The above data are consistent with the data obtained from some of the mills in Mali during the study. The smaller huller type mills found most commonly in the rural settings in Mali are all driven by diesel engines and consume an estimated 7.5 to 10 KW. The diesel consumption for these ranged from 2 to 3 liters per hour. The capacity of these hullers were approximately 700 Kg/h

The next type of mill found in Mali was the rubber roll sheller with the steel polisher. These mills had a capacity of approximately 2 tons per hour and were driven by a 35 HP electric motor powered by a diesel engine/generator set. The diesel set used about 5 to 6 liters of diesel per hour. Data on the larger mills was more difficult to obtain or estimate.

It needs to be pointed out that any discussion of the power consumed by a rice mill needs to consider the quality of the rice output and the components of the mill. At the one end, paddy can be milled in a single pass, one operation mill such as the Engleberg huller which produces two outputs – milled rice and brokens, and a mixture of partially ground husk and bran. This mill is known to produce the lowest quality of milled rice as found in the case of most small mills now in operation in Mali. Given the current conditions – state of economy, buying power of the populace, availability of energy etc., this quality appears adequate for the people. Inquiries have revealed, however that those who can afford it will purchase the better quality (primarily less brokens) rice. Indeed, some mentioned the fact that there is some grading of the rice to separate brokens at some locations in Bamako, and the sale of better quality rice to the hotel/restaurant industry.

The next step in the configuration of milling systems is to step up to a separate sheller (to remove the rice husk) and a 'polisher' to remove the bran. For the sheller, there are two common types of machines, a) the under-runner disc huller (an older design, still in use in some countries), and b) the rubber roll sheller. This system generally produces three outputs, milled rice and brokens, bran, and rice hulls. In general this system produces rice of higher quality (than the Engleberg Huller type one-pass mill), produces pure bran and rice hulls as by products. This implies that the rice bran is of higher quality (hence capable of fetching a higher price) and pure rice hulls suitable for use in cogeneration systems. Additional improvements in milling systems are mainly enhancements of the rubber roll sheller/polisher combination. Improvements include the addition of a paddy pre-cleaner; a paddy separator (rubber roll shellers do not dehull 100% of the paddy, rather shell about 85% at optimum setting (a trade off between the percent shelled and the breakage of milled rice) requiring that a separator remove the unhulled grains for rehulling, and the brown rice to be sent for polishing); and rice graders to separate brokens rice from whole kernels to achieve a certain grade for the market.

As seen from Table 8 above, rice mills that have a combination of components to produce milled rice of good quality generally require increased power as the capacity (tons per hour of paddy) increases, but require less power per ton of paddy as the mill capacity increases.

3. Husk Utilization and Technologies in Use

a. Utilization of Rice Hulls and Availability

Given the present methods of rice milling in the country, the amount of rice hulls available for cogeneration is not significant. Given that only one large mill is currently operating at about 10,000 tons of paddy per annum, this translates to about 2000 tons per annum of rice hulls. In addition, there are an estimated ten 2 tons/hour mills (producing pure husk as opposed to a rice husk-bran mixture) operating 18 hours per day for 30 days per month, for seven months per year. These mills produce a total of approximately 15,000 tons of husk per annum. Discussions at the village association which owns these ten mills revealed that they are planning on adding another ten mills of the same type and capacity. When these plans are completed, it is likely that these 20 mills will be located within a 15 to 20 KM radius, permitting husk collection for any centralized cogeneration system. Rice hulls have a low bulk density, and thus transporting this by product over long distances (greater than 15 to 20 KM) is not economically viable. Thus in summary, presently a total of about 17,000 tons of rice hulls appear to be available for cogeneration for production of electrical power. Assuming that a high pressure steam turbine system is feasible in terms of cost of production of electricity (compared to the mostly diesel based systems in the rural areas of Mali), such a system producing 1.2 MW will have sufficient husk to run at 45 tons husk per day throughout the year. Since the mills only run for 7 months in the year, the cogeneration system can supply a limited excess during the seven months, and a much larger excess power to the villages for the balance 5 months in the year. Smaller systems using the low pressure steam engine configuration are also a possibility. However the low pressure systems that normally are less efficient (in converting rice hulls to electrical energy) than the high pressure systems, may not have sufficient excess power for rural use.

Given the current situation, the best option seems to be to organize groups of villages where the rubber roll type mills are in operation to collect the needed rice hulls for pilot cogeneration system. A second option would be to seek the support and participation of the larger mill owners to consider the addition of the cogeneration system to produce sufficient power to run the mills. There are two possibilities in this regard. The owner of the Segou mills, Mr. Modibo Keita showed interest in this approach, and inquired about costs for cogeneration systems. A second possibility is the new rice mill being planned by the Aiglon Group in Bamako (contact: Ms. Aissa Diallo) whose owners are currently in the cotton business. Incorporating a cogeneration system may be an option for this company.

Initiating cogeneration using locally available rice hulls has several implications for the rural population. These include the avoided cost for diesel fuel currently being used for running the mills; the possibility of locally generated off grid power for domestic use; the possibility of employment for a local organization charged with the task of collecting and delivering the rice hulls to the cogeneration plant; eliminating a disposal problem for the rice hulls; and finally, revenue from the sale of ash from the cogeneration system.

b. Gasification/Combustion Technologies Previously Used in Mali

Two of the larger rice mills now closed for nearly ten years used a cogeneration system based on the rice hulls produced by the mills. The mill at Molodo had utilized a Chinese rice hull gasifier cogeneration system. At the time of the visit to this mill the premises were closed, but the gasifier system was visible, and the data reported here are mainly drawn from the past experience of the authors from visiting and examining similar systems in China. In essence, the system uses a digester which produces the gas from the rice hulls, and in turn this gas is fed to a modified diesel engine driving the electric generators. One complete unit was seen out side the premises, and appears to have been abandoned. A newer unit Digester/diesel engine/ generator set were seen inside the premises. The following are pertinent data based on the Chinese experience, and can be considered representative of the system used at this mill:

- Capacity of generator was 160 to 200 KW
- Ash from the digester was sold as poultry litter
- Approximately 33 to 55% of rice hulls were unused
- Electric power consumed by mill and cogeneration about 50 KW/ton of paddy
- Cost of electricity generated at mill ranged from 33 to 60% of cost of grid power. This was specific to the Chinese mill based on cost of grid power and time of operation (price at night was cheaper than during the day)

While the above data are specific to the Chinese mills gathered in 1995, there are some useful inferences to be drawn for the Malian case. The mill saves on electric power costs, producing all the power needed for its operations; and makes additional income from the sale of the ash. The drawback, however is that some rice hulls are still left over at the mill premises and need to be disposed.

The second mill located at Segou and owned by Mr. Bakore Silla has utilized the low pressure steam system to generate power for running the mill. The data obtained at this mill, while incomplete, are as follows:

Boiler output:	400 Kg/h
Husk Consumption:	400 – 500 Kg/h
Turbine/generator set rated at:	400 KVA

One important inference to be drawn the above two cases is that apparently the cogeneration systems did not fail, rather the mills ceased to operate due to a variety if reasons including the lack of paddy for milling.

c. Technology Choices and Opportunities

To identify opportunities for cogeneration systems, several factors need to be considered, foremost amongst which is the availability of husk, as discussed in the previous sub sections. Capital costs of systems capable of generating electric power from rice hulls, and even the importance of avoiding the use of diesel fuel need to be considered. This latter reason may be an important consideration for Mali that currently imports diesel fuel. To enable the formulation of appropriate strategies in this regard, data and a discussion of previous research are provided below.

In a study by Twente University in the Netherlands (3), the capital costs of three types of systems capable of producing electric power from rice husk, at three sizes of mills was compared as shown in Table 9 below:

Table 9. Capital Costs of Three Types of Systems Producing Electric Power from Rice Husk

Mill size	Power	Diesel Plant	Gasifier System	Steam Engine System
1 t/h	30 kW	$ 10,500	$ 24,000	$ 42,000
2 ½ t/h	70 kW	$ 21,000	$ 42,000	$ 70,000
6 t/h	160 kW	$ 40,000	$ 72,000	$ 104,000

Source: Velupillai, et al,

Among other factors, the weight of conventional steam engines contributes to the higher capital cost of such systems. The use of more modern light weight alloys and standard parts designed for internal combustion engines can help reduce the capital costs for the steam engines. In comparing the costs as shown above, the cost of diesel fuel, the cost of rice hulls at the cogeneration site and other factors need to be considered. In the above table the cost of diesel used was $ 0.25/liter (the current cost of diesel at the rural setting in Mali is about 410 CFA/liter or at an exchange rate of 500CFA to the dollar, about $ 0.82). Another consideration in this regard is the extremely durable nature of steam engines that can normally operate for 30 to 40 years with minimal maintenance.

Despite high capital costs and low efficiency of steam engines they may still be a viable choice when the price and availability of diesel and rice hulls are taken into consideration. In like fashion, the cost of electric power produced at an off grid site needs to be examined. To enable a discussion, the following Table 10 illustrates a study conducted by Twente University in 1992:

Table 10. Comparative power costs (US cents per kWh)

Mill size	Power	Diesel Plant	Gasifier System	Steam Engine System
1 t/h	30 kW	18.4	21.9	29.9
2 ½ t/h	70 kW	13.6	11.9	19.3
6 t/h	160 kW	11.1	7.9	14.0

Source: Velupillai, et al,

The above study assumed that the mills were at off-grid locations, the cost of diesel was $ 0.25/liter. The above data illustrates that there is a considerable economy of scale for both the gasifier and steam engine systems as the size of the mill increases (or the available rice hulls increases).

It is also worth noting that in another study conducted by the International Development and Energy Associates Inc. (IDEA) in Washington, DC in 1989 to look at the commercialization of rice hull powered gasifier systems of 20 kW capacity in India. This study concluded that the capital cost of the system was less important in determining the economic viability of the system than the percentage of diesel fuel displacement, the annual number of operating hours, and the price of diesel fuel in comparison to the price of rice husk.

In summary, the above analyses are provided to support any analyses for economic viability of cogeneration systems in Mali. The status at the time of this assessment includes key issues that need to be taken into consideration:

12. There is an urgent need for off-grid power generation
13. Diesel fuel is imported at considerable cost
14. Rice production is poised to increase to take advantage of capturing an export niche
15. A focus on increased production and rice quality enhancement will mean that an appropriate quality and quantity of rice husk will become available

Part IV Conclusions

Based upon the pre-assessment research, the assessment conducted in Mali in November 2004, and post assessment discussions, the following general conclusions are presented.

1. Rice Production

- Maintain and improve controlled irrigation in the Markala dam areas of rice production.
- Seek advanced technology for rice production from the Institut D=Economie Rurale, including high yielding varieties, cultural practices and plant protection.
- Continue the development of farmer cooperatives/associations to promote better production and milling.
- Make an effort to stress higher quality in both paddy and milled rice.
- Search for means to increase production on existing land used for paddy production by the proper use of applied chemical fertilizers, and perhaps the growing of a second crop during the dry season if water is present for controlled irrigation.

2. Rice Milling/Rice Hulls Utilization for Energy

a. The Rice Post harvest System

The rice post harvest system is currently handled by a combination of manual means with very little energy use, and small scale threshers and rice mills run by diesel power. The timing of harvesting and threshing practices could be modified to reduce internal breakage of the rice kernels, and subsequent low mill yields and food losses. An awareness program mainly through training of trainers, and low cost rice quality assessment laboratories can be one solution to address past harvest losses, currently estimated to be about 38,000 tons of milled rice equivalent valued at 16 million U.S. Dollars per annum.

b. The Rice Milling Industry

Since the privatization of the processing and trade in rice in the early 1990s, most of the larger mills with an estimated total annual milling capacity of 115,000 tons have been closed for operations. This situation has been caused by a variety of factors including lack of finance for paddy purchases, competition from the smaller mills for paddy purchases, and possibly lack of management efficiency. Despite this one miller plans on continuing operations, and has even purchased another government mill, while another company is planning to establish a new large rice mill. Further, groups of villages have invested in improved rice milling systems that are capable of producing quality rice for the local markets.

As far as milled rice quality is concerned, by far the most striking observation was the amount of broken rice, overall about 50%, and in some cases even 100% brokens. Due to the low purchasing [power of the rural populations, there is no present recognition for higher quality, and hence a higher price for milled rice. However, there appears to be a growing market for quality milled rice in the major cities, and discussions have revealed that those who can afford it will purchase the higher quality rice at a higher price. Mali currently imports a small quantity of rice from Asia, and this rice is sold at a price that is slightly lower than the locally produced rice. However, it is believed that the local population prefers the Malian rice.

Through an awareness and education effort referenced in subsection (a) above, a focus on rice quality improvement will result in reduction of food loss, which in turn will reduce imports. Concurrently, the focus on improved rice quality will encourage a move away from the current milling systems that are largely the cause for the broken rice component. This move will also result in a purer bran component, and rice hulls, more suited for cogeneration systems.

c. Rice Husk Availability

Given the current status of milling systems in the country, the availability of rice hulls for cogeneration systems is limited. The only operating large mill at Segou city currently produces approximately 2000 tons of rice hulls per annum, while in a group of villages in the Niono area are currently operating ten 2 t/h mills currently producing 15,000 tons rice husk per annum. This latter group of mills is within a ten to fifteen kilometer radius making husk collection for a cogeneration unit feasible. Further, discussions with this village association revealed that they are planning to add another ten mills of similar capacity, thereby enabling a total husk availability of 30,000 tons per annum. Assuming a 1.2 MW cogeneration unit (consuming 45 tons husk per day) is viable, the present amount of rice husk of 15,000 tons per year will be sufficient to run the power plant for approximately 330 days/year. Other systems of lower capacity, particularly steam engine based systems need to be explored.

d. Potential for Cogeneration from Rice Hulls

As a backdrop to this assessment, there is considerable agreement that electrical energy availability is a serious constraint to economic development in Mali. Due to funding and maintenance issues, and the delay in the Manatali Power Unit coming on stream, grid power is limited and transmission losses are high, estimated at 25% for a country that can ill afford this loss. Thus off-grid, independent sources of electrical power are encouraged by the authorities. Secondly the country with no known fossil fuel resources is currently importing 200 million liters of refined petroleum products for power generation, transportation and domestic use. Thus not only capital costs for cogeneration systems but also the corresponding reduction of diesel fuel for power generation needs to be considered. While high pressure steam turbine systems are more efficient, smaller capacity cogeneration systems driven by steam engines should not be ruled out.

For the near -term prospects for cogeneration, there are three areas that need to be investigated, particularly for financial viability. These possibilities are based on the present availability of rice hulls and the potential interest of investors in the milling sector. The areas that need to be looked at are:

(i) The possibility for organizing husk collection and cogeneration in the group of villages in the Niono area (KM 30). This group of villages currently produce approximately 15,000 tons of husk per annum. The village association has indicated that they will invest in an additional 10 mills with the potential to double the quantity of rice hulls.

(ii) Mr. Modibo Keita who currently owns two mills in the Segou area and has recently purchased another in the Seuare/Mopti area has indicated interest in a cogeneration system. This needs to be explored.

(iii) The Aiglon Group in Bamako that is currently in the cotton business is planning to build a large rice mill in the Niono area. Discussions with this group to incorporate a cogeneration system may prove useful.

Part V References

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