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Feasibility and Impact Assessment of a Proposed Project to Briquette Municipal Solid Waste for Use as a Cooking Fuel in Rwanda

Pete Young
Smail Khennas
Intermediate Technology Consultants (ITC)

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Pete Young
Smail Khennas

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1. Executive Summary

The densification of agricultural residue and biomass waste in the form of pellets and briquetted logs is now a major source of energy in Europe and North America. Sweden, a leading country on the production of pellets, utilises in excess of 1 million tonnes per year. The spread in popularity of biomass-derived fuels is entirely due to the huge environmental and local economic benefits. These have been made possible by advances in technology and higher fossil fuel prices resulting from increasing levels of taxation on Carbon Emissions.

In contrast, the production and use of briquetted fuels in developing countries over the past 20 years have been disappointing. Many projects set up in the 1980s in Asia and Africa have failed, mostly because of poor planning, unrealistic expectations in results and failure to target production towards appropriate markets. Many of the lessons learnt now appear simple and obvious but at the time, unrealistic expectations to achieve national impacts often enticed planners to neglect the basic commercialisation parameters including Price, Performance, People, Product and Place considered as the 5 Business Planning 'Ps'.

This study aims to assess the socio-economic risks and the overall sustainability of manufacturing fuels from Municipal Solid Waste (MSW) in Rwanda and to determine the likely economic, social and environmental impacts.

1.1. Overall Conclusion

The proposed expansion in briquette production in Kigali would achieve important and substantial environmental and socio-economic benefits. Through the production and sale of 15,000 tonnes of briquettes per year it would create 450 jobs and support indirectly a further 1550 jobs. It would save 86,000 m3 of fuelwood, around 1.2 % of the currently demand. The utilisation of MSW collected from low and medium income households would save the city Mayors' office 40,000 tonnes in waste that has to be carried to the over-used dumpsite. This would save up to Frw 706 million (US$1.50m)in transport and dump site costs. Furthermore it would reduce environmental damage and reduce leachate contamination of local water supplies. The money saved could be used to strengthen the city's Administration and Management Capability or improve local facilities and infrastructure.

The strength of the proposed project lies in the successful experience and findings from a pilot Production Plant operated by ENEDOM since 2001. Over 850 tonnes have been sold and marketed successfully to large institutions with kitchens, including schools, prisons and feeding centres.

There is an estimated availability of 73,000 tonnes per year of waste suitable for briquetting, out of which 16,000 tonnes is currently economically viable. The market potential for briquettes in institutional kitchens is estimated at 7,100 tonnes per month out of which 1,250 tonnes could easily be reached in two years.

Considering the excellent availability of raw materials and high market potential there are good long-term prospects to further expand proposed production levels by introducing a

second shift as and when the business develops strong planning and implementation skills.

The briquetting process looks technically and economically sound and there is scope to lower briquette prices and/or increase raw material prices as production levels rises.

The real risk to the overall success of the project is the lack of experience and implementation skills necessary to expand production in a pilot operation producing 0.75 tonnes per hour to 7.5 tonnes per hour – a tenfold increase in production, marketing and management issues. It is essential that both ENEDOM and TTT, partners in the joint company, take onboard the necessary skills either through training or partnership with other technical agencies to plan, design and operating a large briquetting business.

1.2. Overall Recommendations

It is recommended that this project be considered for funding on the following basis:

- There will be significant economic, social and environmental benefits resulting from expanded production and sales of manufactured fuels from MSW and agricultural residues.
- The pilot plant has adequately demonstrated that the process is technically feasible, there is market acceptance and huge sales potential, and the supply of raw material is robust and diverse thus minimising the dependency on any one source.
- The Waste Collection Associations vaccinate all their staff and issue protective clothing to the waste pickers to minimise the health risks.
- There are significant setup costs during the first 2 years resulting in negative cash flows and financial assistance would be essential to maintain a positive balance over the first 3 years.
- Medium and long-term financial support is currently not available at competitive rates for business development in Rwanda.

Considering the importance of the design, and development of the proposed expansion phase of the Briquetting Project it is recommended that financial assistance be linked to a series of project mile stones outlined in a Project Implementation Plan and Budget as follows:

1) Provision of Technical Assistance, either through an agreement with a third party or via the joint agreement with TTT.

2) Submission of a capability statement from ENEDOM and TTT together with the last 3 years accounts.

3) Development of a Business Plan and Marketing Strategy taking into account past successes and failures in Briquetting Projects and based on verifiable research covering:

i) Comparative laboratory and field trials on the utilisation of MSW briquettes and wood in institutional stoves, to independently assess actual fuels savings and acceptance.

ii) Market survey of institutional energy needs and cooking practices to develop a long-term marketing strategy that would meet users' needs.

iii) Continued operation of the Pilot Plant on MSW to verify long-term effects of the high ash content in MSW on the wear rates and press maintenance.

iv) Outline of investment plan and clarification of contributions and role of the partners in the joint company.

2. Specific Conclusions & Recommendations

2.1. Socio-Economic Benefits

A pilot factory producing 7 tonnes per day of briquettes has successfully demonstrated that there are good prospects for expanded briquette production in Kigali. Fuel wood is increasingly difficult to get, particular in large volumes as required by schools and prisons. Although wood fuel prices remain low, briquettes appear to offer 15% cost savings because their moisture content is low and they require very little handling unlike wood that requires splitting and drying.

A proposed new briquette production unit producing 15,000 tonnes per year would provide by 2004 the following annual economic benefits at current prices:

- Create over 2000 jobs mostly for women collecting and sorting MSW. Total income is valued at Frw 350 million (US$0.74m)per year.
- Generate Frw126 million (US$0.27m) in profits for waste collection associations for distribution to its members, mostly women.
- Provide an additional income to coffee millers and carpenters valued at Frw 3.6 million (US$7,700) for the supply of agriculture residues.
- Create 38 skilled jobs at the briquette factory with a total income of Frw 42 million US$89,000).
- Clients such as schools and other users of Briquettes would save 15% on their current fuel expenditure valued at Frw 121 million (US$ 260,000).
- The Office of the Mayor and Communes would save Frw706 million (US$1.5m) in transport fees and Landfill site fees.
- The value of recycled products such as plastic and tins is valued at Frw 192 million (US$409,000) and would contribute to saving foreign exchange required to import the same raw materials.

2.2. Raw Material Supply

There is a large regular supply of dry MSW suitable for producing briquettes. Waste collections services are being set up by NGOs to collect and sort MSW. Recyclable materials such as plastic and tins are sold and the organic matter is chopped and dried then sold to the Briquetting factory. Currently 1000 tonnes/year of dry MSW is being produced for briquetting. Waste services are being expanded to eventually cover the entire City. This is likely to generate 15,000 tonnes per year of briquetting material. Over the next 2 years a total of 10,000 tonnes is economically viable to collect. The remaining 5,000 Tonnes would become available as and when Waste Collection Associations improve their efficiency and become cost effective at reaching more decentralised areas of the City.

The waste collection services appear financially viable. They receive incomes from a number of sources. Fees of Frw300/mth are collected from households which are enforced by the Local Mayors and the Commune offices. Recycled materials are sold at Frw 5,370 per tonne to industries and dry MSW is sold at Frw 8000 per tonne to the briquette factory. At the 'start up' of Recycling Centres the organic matter was intended for composting. However, at Frw2per kg there was no demand. The Briquetting factory pays Frw8per kg which is considerably more profitable than making compost.

Vast quantities of agriculture residues are available for briquetting. 12,000 tonnes of sawdust is produced in Kigali by a large number of sawmills and carpenters. Sawdust is used by some sugar factories but most of it, is un-utilised. In the short-term at least 2,000 tonnes is available at one

site adjacent to 200 small carpenter businesses. Other sources could provide further sawdust but at high cost involving more labour and transport.

Larger quantities of coffee husks are available for briquetting. It is estimated that from 26,000 tonnes of coffee produced each year there is 6000 tonnes of coffee husks. A brick factory utilises in the region of 1,500 tonnes leaving a balance of 4,500 tonnes. About 2,500 tonnes of this would be available in Kigali for briquetting.

Other residues include papyrus (38,400 tonnes) but it would require harvesting and would be more expensive than either sawdust or coffee husks. Maize cobs are available during two seasons each year. No estimates of the quantities are available but it is mostly likely there are several thousands of tonnes per year. Maize cobs could be briquetted, but would require chopping and pulverising to reduce their particle size and would add considerable cost to the raw material.

Out of a foreseeable supply of 73,000 tonnes of briquetting material the briquetting factory could easily secure a regular supply 16,500 tonnes per year at affordable prices. If any source was to become unavailable or uneconomic other sources could easily provide the balance. In this regard the supply of briquetting material looks robust and reliable and there is considerable scope for expansion as the market grows.

2.3. Viability of the Briquetting Process

The pilot plant experience shows that briquette production can be highly profitable because the briquette quality offers considerable benefits compared to wood fuel. On the production of 850 tonnes the average cost of producing 1Kg was Frw20.44. At a selling price of Frw35/kg this provides a gross margin of Frw14.56/kg and a mark up of 42%. This level of profitability could accommodate considerable fluctuations either in the selling price or raw material prices.

Out of the 850 tonnes of briquettes already produced only 2 tons have been produced from MSW. The bulk of briquettes were made from sawdust and coffee husks, therefore the long-term effects of utilising mostly MSW are not fully understood. Trials with MSW indicate that up to 10% of either sawdust or coffee husks are necessary to produce a good briquette. In this regard, there is ample sawdust and coffee husks to meet the 10% requirement. However, combustion trials show that MSW briquettes contain 10% ash compared to sawdust briquettes that only contain 2%. It is therefore likely that using mostly MSW will increase wear on the piston and dies. This will seriously affect maintenance costs and machine operating times.

Piston presses as used throughout the trials are renowned for their reliability and are robust. They are also easy to maintain and repair. Workshops in Kigali are well equipped to re-face and re-surface the piston and dies. In the event of a serious failure of the briquetting machine most spare parts could be replaced or fabricated in Kigali.

The original plan proposes a pellet press. These machines are highly regarding in Europe and North America because they require the least amount of input power per Kg of briquette output. They have high capacity and can producing up to 8 tonnes per hour. These machines have highly engineered ring dies and rollers that require specialised machines for re-surfacing when they have worn out. The briquette diameters are smaller than for the piston press which would change the way the briquettes burn. Although, pellet presses do offer significant advantages over the piston press, further investigations and trials using MSW would be necessary with actual pellet samples to verify briquette quality and combustion performance in Institutional Stoves.

The briquette quality is highly dependent upon the quality of the raw material. The moisture content should be 12% prior to briquetting and the particle size no greater than 10 to 15mm. Given that Kigali has nearly 100cm of rain during two seasons there is particular need to build

secure storage facilities to keep the raw materials dry. Any new briquetting facility should include dryers to provide the factory with some control over the moisture contents.

The briquette factory should also set quality control standards for the supply of raw material - for example moisture contents should not be greater than 15% and particle size no larger than 15mm.

A proposed briquetting factory with a capacity of 1,250 tonnes per month producing briquettes with a diameter of 60mm and consistent quality (same as the present quality) would be technically and financially viable. The Financial and Economic Analysis of the operation of the plant shows the internal rate of return (IRR) is 34 % and NPV valued at $2.28 million US per annum.

2.4. Viability of Markets

The markets for briquettes have been well established in large institutions such as schools, feeding centres and prisons. The briquettes are used to directly replace wood as used in large enclosed stoves with chimneys.

Although no reliable market research has been carried out users report that:

- Briquettes are a good substitute for wood
- They burn with a small flame and with less smoke
- They are clean and easy to handle
- Do not require chopping
- Cook with an even heat and are longer lasting
- More suitable for slow cooking
- Difficult to ignite

No performance testing has been carried out to verify how much briquettes can replace wood. On a theoretical basis using calorific values it is estimated that 0.7kg of briquettes @ 9% moisture can replace 1kg of wood @ 30% moisture and on a cost saving basis briquettes can achieve a 15% saving in fuel expenditure compared to wood.

Whilst it is expected and generally recognised and accepted that briquettes can lead to significant savings it is essential that properly conducted trials be carried out to measure actual savings under controlled conditions, and that actual use be monitored in kitchens over a period of one month.

Briquettes cannot substitute charcoal in households without the introduction of specially designed stoves to remove smoke. Based on combustion trials in Brussels and observations in Kigali it is established that briquettes have combustion characteristic similar to wood. Unlike charcoal, briquettes have a high volatile content which requires adequate excess air well position in the combustion zone to promote clean burning.

The briquettes currently produced have a density of around 650Kg/m3 with a diameter of 60mm. These characters have proved highly acceptable to institutional kitchens and can burn directly in existing stoves. Changes to the briquette quality and size would affect the combustion properties. Switching to smaller briquettes (as proposed) would make them burn faster but with a tendency to block the grates and they may even fall through the bars. High densities would make them even more difficult to ignite. Before committing to a massive change in briquette quality it is essential to test market the new briquettes.

The natural market for briquettes is a direct replacement for wood in institutional stoves. The current demand for wood is estimated at 7,100 tonnes per month from schools, prisons, feeding centres and restaurants. ENEDOM's existing clients have a consumption estimated at 2,200

tonnes per month. ENEDOM's current production is just 140 tonnes per month. There is considerable scope to expand production to 1,250 tonnes per month from a new briquetting factory and supply the existing client base.

Further expansion by introducing an additional production shift would also be possible to meet new customer demands. However it would require a new and more vibrant marketing campaign to reach new customers particularly the huge potential marketing in restaurants.

Industries such as brick kilns, tea estates and sugar factories are unlikely markets for briquettes since they bulk purchase freshly cut trees and use them directly. This is a particularly wasteful way of using wood because the moisture contents would lower the calorific fuel values significantly but it still works out cheaper than using briquettes. Bakeries are another large consumer of wood and could become a market in the future.

2.5. Environmental Impacts

Fuel Wood savings

The Government considers that the forestry statistics and data are currently out of data as a result of the massive upheaval of large numbers of people during the war in 1994. Many displaced persons have taken advantage through opportunity and necessity to move into formally protected and well forested land. The rate of damage and destruction is currently out of control as displaced persons attempt to resettle and restart their lives once again.

Based upon revised data in 1999 the estimated forestry deficit is 4,400,000 m3. This represents a deforestation equivalent to 7% of current forestry reserves. In reality this deforestation probably represents a slow but important decapitalisation of the farmers own tree resources rather than a consistent clearing of forests.

The production of 15,000 briquettes per year could lead to the replacement of 86,667m3 of fuel wood which represents 1.15% of the total fuel wood demand.

Carbon Emissions

The use of wood is highly regarded as a fuel because it has the potential to be environmentally neutral, in that if wood is replaced at the same rate it is used then the amount of carbon released would be negated by the new trees. Where the consumption is greater than the supply as in most cases, there is an overall increase in carbon emissions.

The savings in fuel wood demand would therefore have a similar impact on reducing carbon emissions. The reduction in actual carbon released would not change significantly because the combustion of wood and briquettes would release similar quantities into the atmosphere. However, a reduction would occur because more trees are left standing to absorb more carbon. Based upon the quantities of trees saved by substitution with briquettes the carbon emissions would be lowered by tC 14,461 according to IPCC / OECD methodology.

Increased efficiency of MSW collected

According to recent reports, out of the 95,000 tonnes/year of MSW generated in Kigali 40% is not being collected. It is therefore assumed this is allowed to accumulate on the streets, eventually to be washed away by heavy rains into nearby rivers and streams.

It is estimated that Waste Collection Associations set up by NGO's will collect and process 40,000 tonnes of MSW per year to supply the briquetting factory. This represents 36% of the total waste generated nearly equal to the quantity of MSW that is not collected. This will have an important

impact on the cleanliness of the local environment, reduce blockage of drains and reduce the accumulation of rubbish in river and streams.

Household Benefits

For a number of years households have complained about the un-healthy state of neighbourhoods. A survey of 1,182 residents in 1998 highlighted that the irregular garbage collections and accumulating mountains of rotting MSW caused a significant number of problems:

- Frequent sickness
- Increased presence of mosquito's and flies
- General uncleanliness and bad smells

The general conclusion was that many households were willing to pay for the collection services to be improved and have the will to form local societies to pre-garbage collection.

Five years after the initial idea was proposed a number of associations are beginning to make an impact. With the viability of selling the dry organic matter to the briquetting factory many of the residents problems will finally be addressed.

Leachate and Landfill gas

Leachate is the runoff from landfill sites. It is particular dangerous because it contains high concentrations of heavy metals and residues and organisms from decaying matter. The leachate from the current open dumpsite is un-controlled and is left to pollute local groundwater supplies. In 1998 a report was carried out by Carl Bro Ltd that proposed that the old site be closed and a new sealed site opened which would allow the leachate to be controlled and decompose in ponds and aerated lagoons. To date the new site has not been implemented.

For the new site it was estimated that the leachate would be 16,808 m3 per year. It is assumed that a similar amount is produced at the old site. It is therefore likely that if the amount of MSW delivered to the dump is reduced by 34% this will have the effect of reducing the concentrations by a similar amount. If the new site is given the go ahead a briquetting factory diverting MSW means that it can be reduced in size, thereby reducing the management and maintenance costs.

The organic part of MSW in a landfill site decomposes in the presence of oxygen, to form carbon dioxide. Large quantities of methane and carbon monoxide are also produced, in the absence of enough oxygen. These gases have carbon emissions equivalents of 4 and 21 times that of carbon dioxide in the short-term and are harmful to human and environment health.

The proposed project can be expected to reduce the amount of organic material delivered to the dumpsite and thereby result in a similar reduction in landfill gas. It is estimated that this will save 1,400,000 m^3 of landfill gas from being released into the atmosphere.

2.6. Health Impacts

Household MSW is generally considered as being non-hazardous but it can be a breeding ground for many infectious diseases. The collection and sorting of MSW is therefore high risk and given that as many as 2000 workers will be engaged in this activity there is every chance that accidents will happen and infections will be caught.

The Waste Collection Associations have taken many precautions to reduce their workers exposure and each member of staff is provided with:

- Vaccinations against tetanus and TB

- Protective clothing including boots, overalls and gloves
- Respiratory Masks

Staff working the briquetting factory could be exposed to toxic fumes and smoke coming from the hot briquettes as they leave the presses.

The combustion of briquettes will lower emission in the kitchen and exposure by kitchen staff will be lower. Wood is nearly always used as long sticks. This prevents the stove doors from being fully closed during cooking and allows smoke to enter in the room. briquettes are small and can be placed entirely in the firebox. The stove doors can be fully closed thereby preventing smoke leaking into the room.

Briquettes have another advantage in that they do not require chopping and splitting with an axe, unlike wood, which can lead to a large number of accidents. Briquetting alleviates this potential problem.

2.7. Implementation Capabilities

ENEDOM is a young company and has limited experience of business planning including staff management, planning projects and accounting. In particularly the reporting skills of ENEDOM require strengthening. Many of the problems associated with the development of this project and its feasibility has been the complete absence of written performance data on the briquetting process and of sales and market research on institutional kitchens. In this regard TTT has a major responsibility in providing the joint venture with business implementing skills.

TTT has an impressive portfolio of projects (un-verified by the consult) and appears to be particularly strong in business structuring and finance. In TTT's Executive Memorandum there is no indicative evidence that TTT has good in-house practical (hands on) capability to provide technical assistance to ENEDOM.

The proposed project represents a massive increase in the production capability of ENEDOM. A step up from 7 tonnes per day to 75 tonnes would require specialised technical assistance to design and plan the project from conception, and supervise commissioning trials to adapt the presses to local material conditions.

There are no substantiated market trials carried out with users either households or institutions to indicate levels of acceptance or the comparative advantage of briquettes. Whilst this study has been able to meet only a few customers who report very favorably on the briquettes there is an essential need for more market data. Such a study should independently verify the comparative performance between briquettes and wood, assess market needs and user acceptance.

2.8. **Recommendations** (to improve project design, planning & economic analysis)

A study should be carried out by Kigali Institute for Science and Technology (KIST) to independently verify the comparative performance between briquettes and wood. Such a study would comprise controlled laboratory tests and monitor kitchen trials over the duration of at least one month. The results would generate reliable data on how much wood can be replaced by briquettes and the actual costs savings.

A market survey of at least 100 institutions should be carried out to collect energy use data including fuel wood consumption, types of stoves used and types cooking practices. This data would be used to plan marketing campaigns and assess impacts and establish market networks with new customers.

The pilot briquetting plant should be run full time on MSW to verify the long-term briquetting problems associated with high ash content residues.

The pilot plant should be run with a material pre-heater to monitor the increase in performance and reduction in wear rates.

ENEDOM and TTT should seek additional technical assistance to help scale up the production process, design and plan from concept the briquetting plant and write a Business Plan and Marketing Strategy.

3. Rwanda General Situation

3.1. Socio-Economic Background

The Republic of Rwanda is situated in the Central African Region and borders with Uganda, Tanzania, Burundi and the Democratic Republic of Congo. The country covers an area of 26,340sq km and with an estimated population of 7.98 million in 2000 Rwanda has one of the highest population densities in Africa. With only 10% of the population living in urban areas Rwanda is considered as having a rural agricultural economy. Coffee and tea production normally make up 80% to 90% of the total exports whilst other exports include minerals, pyrethrum and vegetables to neighbouring countries. Industrial output is low and nearly all finished consumer goods and building materials are imported at very high cost. Rwanda's landlocked position is a constraint to doing business with the major trading nations. Commodities either exported or exported have to be trucked enormous distances via Tanzania or Uganda and Kenya before reaching the internationally renowned trading Ports of Dar Es Salaam or Mombassa.

Agriculture in Rwanda has prospered because of the temperate climate, good rainfall and fertile soils which has contributed to the expanding economy and burgeoning population growth rates. During this expansion phase, economic reforms lagged behind the expansion in agriculture and when the international coffee price fell the country suffered a massive trading loss. As a result the per capita income fell sharply during the 1980s and early 1990s. Correspondingly, agricultural inputs such as investment in terracing and the use of fertilisers also fell. To partly compensate against falling agricultural productivity and growing population there was increasing encroachment onto marginal farm land and protected forests. The rampant deforestation which continues today is very much rooted in the causes of the economic failures in the late 1980s.

The country's economy was again severely disrupted by the political violence that swept the country during 1994. Since then, the economy has rebounded by growing 5% per year, largely assisted by loans from other countries and organisations. Much of this growth has benefited the urban community and the Kigali population may have grown by as much as 10%, although most reports forecast a growth in the region of 7%. The accelerating imbalance between rich and poor households, and rural and urban areas is very much a legacy of the war in 1994.

Today, much of the rural infrastructure has not been restored or is lacking altogether in areas where large groups of people moved into areas that were (previously sparsely populated). Poor households have not been able to replace lost livestock. Rural households have severely recapitalised their farms. Social and business links and networks have been disrupted because of personnel conflicts and displaced persons. Today there still remains large numbers of orphaned children, 85,000 child headed households and 107,000 people in prison awaiting trial.

The unprecedented movement towards towns and cities in Rwanda is now a major socio-economic problem and has major implications for many service sectors. Living in towns and cities

brings new opportunities and demands new resources often supplied from rural areas. This can have positive and detrimental effects on rural economies. If managed correctly, urbanisation can stimulate rural incomes because of the increased trading between rural and urban households. However, if managed incorrectly urbanisation can lead to severe deforestation and long-term environmental problems, as appears to be happening in Rwanda.

3.2. Forestry Situation

Since 1994 the Forestry Sector, like many other sectors, has been severely neglected. From 1975 to 1998 forestry in Rwanda appears to have been particularly well supported and forestry plantations grew from 25,500 Ha to 247,500 Ha an increase of 870% over a period of 14 years. Even up to 1994 forestry continued to grow at a modest pace. (MINAGIR, 1999). Since 1994, reports and statistics have been thrown into complete confusion and the forestry data is now very unreliable due to the planned resettlement of returning Rwandese on forested land and un-planned encroachment into protected areas and forest plantations. According to estimates from MINAGRI 1999 15,000Ha of forested plantations have been destroyed, 35,000 Ha seriously damaged and more than 180,000Ha of forested land have been down graded to farming land. 8,800 Ha of Gishwati forested has also been encroached upon and many farmers have taken advantage of wavering authorities and cleared some public forests. By all accounts the Forestry Development has been severely set back. Without a clear audit of the current forestry situation it is left to speculation as to what exactly the level of current deforestation is.

Table 1: Fuel Wood Demand, Supply and Deficit

Category	Fuel	Pop	Wood m3	%
Rural HH	Wood	7,200,000	6,480,000	86
Urban HH	Charcoal	720,000	849,000	11
Urban HH	Elec/gas	80,000	0	
Institutions		n/a	146,000	2
Industry			87,231	1
		Total Wood Demand	7,562,231	100
		Extraction Potential	3,186,700	
		Annual Deficit	4,375,531	
		Equivalent Ha Forest lost	16,829	
		Total Forest Ha	247,500	
		Annual Percent Forests lost	7	
Ref: Data complied from various reports				

From available data (Table 1) the demand and consumption of fuelwood is 7,562,231m3 and the estimated annual extraction potential is 3,186,700m3 which indicates there is a deficit of 4,375,531m3. At modest rates of forest cover this represents a decline in forests at the rate of 7%. In reality, the actual situation would be very different because the fuelwood used by 90% of the population (rural) would be extracted locally from their own farms and from nearby sources. This figure of 7% deforestation would more likely represent a slow decapitalisation of the farmer's fuel wood resources.

Given that the population growth is at 2.5% and urbanisation is growing at 7% this has major implications for the forestry and energy sectors and the impact upon the environment. Accelerating urbanisation is causing an increase in demand for shelter and buildings which is stimulating a rampant expansion in brick making and supply of construction poles. Both these industries can lead to increased deforestation as trees are cut down to supply poles and firewood. By far the biggest concern to deforestation is the demand for charcoal for cooking. Whilst, people are content to use firewood in rural areas, charcoal is by far the most accepted fuel in urban areas. Wood is used less in towns and cities because it causes smoke that can annoy neighbours and it is detrimental to users health when used in confined spaces which is often the case in urban areas. In comparison, charcoal is clean and convenient to use because it is virtually smoke free. Charcoal has a much high energy density than wood, which makes it cheaper and easier to transport. The negative effects of charcoal on deforestation are however quite severe. It requires on average 10Kgs of wood to make 1 kg of charcoal in a traditional charcoal kiln. The cooking efficiency for charcoal is better than for wood which helps to compensate for some of the

wood, but overall, using charcoal requires 4 to 5 times more wood than when wood is used directly for cooking.

However accurate the figures for forestry and wood stocks may be it is very evident that the demand for wood resources is outstripping a depleted supply and the situation will continue to deteriorate if the demand and supply is not brought back into line. This can be achieved by tackling the problem from both ends. Reforestation can help to restore supply and fuel substitution such as briquettes and energy conservation can reduce demand.

3.3. Energy Consumption and Trends

The energy situation in Rwanda is characterised by the country's poor economic performance hindering the development of the potential sources of energy within the country. Low household incomes and poor purchasing power of consumers also prevent the trading of commercial forms of energy. As a consequence households and medium to small-scale businesses are forced to utilise charcoal, fuel wood and residues because it is the cheapest and most easy form of energy to access. However, the long-term impact of hillsides and farmland being denuded of tree cover, is accelerated soil erosion and reduced agricultural productivity. The energy balance (Table 2) shows that the country is highly dependent upon biomass for cooking and that petroleum products are used wholly by the transport sector. Small amounts of LPG are imported but at 44US$ per 15Kg cylinder its cost is prohibitively expensive and is very much a luxury product. Electricity consumption remains very low at barely 1% of the total energy demand and there are only 25,000 registered households officially connected to the grid. Although Rwanda has an installed electricity generating capacity of around 27Mw, it still has to import 46% of its electricity from Uganda and DR Congo.

Table 2: Importance of Energy Sources

Energy Source	Quantity (TOE)	Percent
Firewood	1,745,645	88.03
Agri-Residues	183,216	9.24
Charcoal	42,293	2.13
Petroleum Products	609	0.03
Electricity	11,345	0.57

Ref: KIST Oct 2001

Rwanda is in fact very well resourced with potential energy source (Table 3). It has been known for 50 years that the methane deposits, which lie in the deep waters of Lake Kivu, amount to 70 billion cubic meters, representing 55 million tons of petroleum energy. Geologists believe that the gas, which is of biological origin, has a regeneration capacity of 250 million cubic meters every year, and is therefore a potentially very good source of renewable energy. This could not only power the economy of Rwanda but much of the neighbouring region also. To date, only a brewery uses a small amount of the methane for process heating. Plans to exploit these resources are currently being considered but it will be quite some time before impacts are felt. Due to the cost of transporting gas and or electricity it is doubtful if utilizing the methane will have any impact whatsoever on the need for wood fuel in rural areas unless the disposable income of rural households rise significantly.

Table 3|: Alternative Energy Sources and their potential

Energy Source	Installed Capacity	Potential Capacity
Hydro Power		
Ntaruka	11.25Mw	
Mukungwa	12.45Mw	
Gihira	1.8Mw	
Gisenyi	1.2Mw	
15 Micro Hydro		2Mw
Methane		
Lake Kivu	1.4Mm3	70Bm3
Biogas	886m3	unknown
Solar		
Country Wide	6323panels	Vast
Wind		
Turbine	n/a	Some

Ref: Kist Oct 2001

Rwanda has a good history of utilising Solar PV systems and over 6000 units have been installed. Given that the country is very mountainous rural electricification via a national grid is unlikely to be economic and solar home PV systems would be a very cost-effective way of providing light and power for entertainment to rural households. Rwanda has also a good history of exploiting Biogas and over 886m3 of biogas digesters have already been installed. It is not clear how much

potential still remains to be exploited, but without continued subsidies biogas will likely be affordable only by the wealthy farmers.

The Ministry of Energy has good wind data that indicate there are potential sites for wind farms. However, without rising incomes and greater disposable incomes it will be some time before electricity will be affordable by the communities within the vicinity of the wind farms. Transmission costs for small amounts of electricity over larger distances will remain a barrier to connecting wind turbines to the grid system.

4. Pilot Briquetting Plant Experience

4.1. Start up

In response to the growing mountain of saw dust and coffee husks residues in Kigali, ENEDOM, purchased a briquetting machine (in 2000) with ancillary equipment from Dev-Tech in India with Funds from UNDP and the Swiss Embassy. The equipment was installed by Indian engineers in April 2001 in a workshop provided by ENEDOM. Dev-Tech India provided 15 days of training and it took a further 1 month to adapt the machine to utilise coffee husks. In June 2001 production of briquettes finally started. To date 850 tonnes of briquettes have been successfully produced from sawdust and coffee husks. In 2002 an EU officer contacted ENEDOM to run some briquetting trials with dried municipal solid waste - a by-product from an EU project to setup community recycling centres to collect and sort out the burgeoning mountains of household garbage accumulating in the streets of Kigali. Tests were carried out on 2 tonnes of MSW which proved very successful when mixed with 10% to 15% of either sawdust or coffee husks. On the basis of these trials ENEDOM looked for partners to expand the business and in July 2002 formed a joint partnership with TTT in the US.

Pilot Machine Specification

Manufacturer: Dev-tech India
Output: 750Kgs/hr (actual 650Kgs/hr)
Category: Mechanical Piston Press
Briquette Size: Dia 60mm

Ancillary Equipment: Hammer Mill for material preparation, auger transfer to hopper, auger transfer to Briquetting m/c. Briquette Cooling track.

4.2. Pilot Marketing

The marketing of briquettes has been highly successful (Table 4) and demand is outstripping current supply. One of the problems for ENEDOM has been maintaining a consistent supply and customers have had to frequently switch between wood and briquettes depending upon the availability of briquettes. Although, this is a problem for the planning and purchasing departments of the institutions involved, it is an important strength, that the briquettes can be a simple substitute for wood without stove modifications. Out of a total of 12 months operating experience briquettes have been consistently produced for 6 months at 10hrs a day. The briquette quality is very sensitive to the raw material moisture content. The ideal moisture has been found to be 12% and no greater than 15%. With the existing facilities and equipment ENEDOM has found it difficult to maintain accurately the moisture content throughout the season. Kigali has an average rainfall of 100cm over two main seasons Mar-May and Oct-Dec each year. With only 6 months of consistent dry weather per year it is very difficult to keep raw materials dry. Therefore ENEDOM's experience to date is very seasonal. This is a very important consideration to be borne in mind when designing any new briquetting facility.

Table 4: Briquette Sales (Tonnes)

Prisons Department	650
Kigali Institute of Education	50
UNHCR	100
Gitagata Rehab centre for Army Children	50
Total Sales	**850**

4.3. User Acceptance

The high demand and continued sales of briquettes with the existing customers is an important but limited testament for the acceptance of the briquettes. Based upon direct discussions with users of the briquettes at KIE and College Du Christ Roi, there are specific advantages and disadvantages over wood. Although overall briquettes are considered to be a cheaper alternative to wood there is no data or independent reports to verify these

User feedback on Briquettes

1 Briquettes are a good substitute for wood
2 They burn with a small flame and with less smoke
3 Clean and convenient to handle
4 Do not require chopping
5 Fit entirely inside cooking stoves so that doors can be closed.
6 Cook slower and last longer than wood
7 Produce less heat than wood and are not suitable for high power operations such as frying chips.
8 Difficult to ignite

findings. No marketing of briquettes has been carried out directly with households although ENEDOMs workers have been given briquettes to use at home.

4.4. Production and Operational

The production trials over 6 months have generated good data on the maintenance needs and operational costs (Annex 1). Although it should be borne in mind that the raw materials have mostly been sawdust and coffee husks and some papyrus which all briquette very successfully. In comparison only a very limited number of briquettes have been made with MSW and the output and wear characteristic could indeed be very different when using MSW long-term. However the pilot plant does appear highly profitable based on operating costs and the profit margin is Frw12 per kg (Table 5) representing 35% of the ex factory selling price. Important features of the process include quite high maintenance costs. ENEDOM report that the piston needs resurfacing every 160 hours and the dies must be replaced every 2 months. According to worldwide experience wear in briquetting machines is normally excessive and pistons and dies may need re-fabrication every 20 to 30 hrs for very abrasive materials or as long as 500hrs for soft materials such as sawdust.

Table 5: Pilot Production Costs (average over 6mths)

	Frw/mth	Frw/kg
Raw Matls Dry MSW	1,320,000	8.80
Packaging	370,000	2.47
Salaries	1,027,000	6.85
Utilities	360,000	2.40
Maintenance	184,334	1.23
Transport MSW	175,000	1.17
Totals	**3,436,334**	**22.91**
Production Cost/kg		**22.91**
Ex Factory Price/kg		**35.00**
Margin/kg		**12.09**
Ref: Details Annex 1		

Packaging is also a large cost. Briquettes are left to cool before packaging in new 50 kgs sacks. The sharp edges of the briquettes easily cut through the sacks during transportation and renders the sacks useless after being only used once. In this regard supplying customers in bulk would provide large cash savings that could be shared with or passed onto the customer.

4.5. Combustion Characteristics

To date the pilot production briquettes have been used in large institutional kitchens with enclosed cooking stoves and have directly substituted for wood. Observations indicate the briquettes are very similar to wood although they do burn slower and with less intensity. They are also difficult to ignite on account of their much higher density and hard outer skin compared to wood. In enclosed cooking stoves with well insulted combustion chambers these problems are unlikely to be significant. If briquettes were to be used in an open fire, difficulties with ignition and combustion would become more evident as was seen during combustion trials at the pilot factory.

It is also very clear that briquettes are a substitute for wood because the similar combustion characteristics are unlikely to become an alternative to charcoal which has a much lower volatile content and correspondingly produces less smoke (Table 6). It is widely reported that in Gambia, Niger, India and Ethiopia briquettes have been commercial failures when marketed in competition with charcoal. The only documented evidence of commercial success is in Refugee Camps in Thailand. Where briquettes have been converted to charcoal there are a number of reported successes in Thailand, Sudan and Malaysia. Again it is important to stress that the bulk of the sales of briquettes by ENEDOM are made from sawdust or coffee husks which have different combustion characteristics to MSW. According to tests commissioned by the EU (Annex 5) on the ENEDOM

Table 6: Combustion Charteristics

Parameter	Units	MSW Bri ISeP Belgium	Saw Dust Bri ECN Holland	Charcoal B&B12 (97)
Moisture	%	8.3	7.0	0
Ash	%	10.7	0.2	2.2
Volatiles	%	n/a	82.2	55
CV Upper	MJ/kg	15.4	18.0	33

Briquettes there are some small but noticeable differences when compared with sawdust briquettes. The Calorific Fuel Value is 14.4% lower and the ash content is 10.7% compared to just 0.2%. This means for the same moisture content 14.4% more MSW briquettes are required to provide the same amount of heat as sawdust briquettes. Although the ash content will not significantly affect combustion it will lead to greater clogging on the fire grate. However, the higher ash content will seriously affect the briquetting equipment performance and costs. A very low ash content will result in low wear rates on the dies which at present is 160 hrs. With continuous briquetting of MSW with ash contents as high as 10.7% the wear rates could very well deteriorate and decrease the operating time due to repairs and re-fabrication of the piston & dies.

4.6. Comparative Costs of Briquettes with other Fuels

The cost of cooking or utilisation of fuels is a key factor in determining who uses a particular fuel but it is not the only determining factor. With regards to cooking, the goal of every user is to cook in the cleanest and most convenient way. In nearly every household with a limited disposable income the decision to use a particular fuel is therefore a process of deciding what level of benefits they can afford. For most households in Kigali the option of using LPG is just not affordable although it is quick, clean and easy to use. Wood on the other hand is very cheap but it blackens the pots and in urban areas the smoke can cause a lot of annoyance to the cooks and neighbours. Charcoal is by far the obvious choice and offers a level of convenience and cleanliness at a reasonable price. Although wood and briquettes are more than half the cost of charcoal they do not provide the same level of benefits as charcoal and are perceived as fuels for the countryside.

Table 7: Comparative Energy Costs

	Prices Frw/kg	CV MJ/kg	Stove Efficiency	Useful Frw/MJ
Charcoal/bag	51.43	27	25%	7.62
Charcoal/Tin	80.00	27	25%	11.85
Restaurant: Wood Bulk	6.00	6.3	45%	2.12
Restaurant: Wood Pieces	29.09	12	45%	5.36
Kiln wood	5.00	6.3	45%	1.76
Briquettes	35.00	15.39	50%	4.55
Kerosene	270.2703	44	55%	11.17
LPG	1466.667	49	60%	49.89

A major oversight of the pilot project is the absence of testing and monitoring of the performance of the briquettes. Without such data that details how much of a given fuel is required to cook food or last for X days or weeks there is no accurate way of comparing the comparative costs. Whilst theoretical calculations do give an indication of the relative differences this process is not a substitute for practical tests and long term monitoring.

Note on the calculation of fuel costs (Table 7): To be able to directly compare different fuels a 'useful energy cost has been calculated for each fuel. This calculation takes into account, the fuel cost, its Calorific Fuel value and its use efficiency. For traditional charcoal stoves the efficiency has been assumed to be 25% as tested in many other African countries. The wood stoves used in most Kigali kitchens are well engineered and such stoves have been tested at 45% in Tanzania. The briquettes although used in the same stoves allow the stoves to be fully closed and therefore encourage even greater efficiency. A nominal increase in 5% has been estimated but in reality this could be higher. Kerosene and LPG stoves have efficiencies respectively of 55% and 60%.

Table 8: Illustrations of Savings Briquettes versus wood purchased for institution cooking

Fuel	Actual Energy (MJ)	Fuel CV (MJ/kg)	KG	Fuel Saved %	Fuel Cost Frw	Actual Cost	Cost Saved %
Wood	22	12.05	1.8	0	29.09	53	0
Briquettes	20	15.4	1.3	30	35.00	45	15.3

Based upon a cooking task requirement of 10MJ of heat

From estimates based upon the heat requirements of 10MJ (Table 8) briquettes do indicate a potential saving of 30% by weight and a cost saving of 15.3% as compared to wood typically bought for use in restaurants and institutional kitchens. However, the bulk purchase of wood for use in bakeries and kilns is very much cheaper and less than half the cost of briquettes. Although bulk purchased wood for use in kilns is green and has moisture contents of 60% to 70% it does not require chopping and splitting which would add considerable cost to the wood. Therefore the natural market for briquettes are situations where wood has to be prepared and dried. These include restaurants and institutional kitchens.

The two schools that use briquettes did say in interviews that briquettes are cheaper than wood but their main reason for buying briquettes is that wood is increasing difficult to get. In theory anyone wanting to cut down a tree should first get permission from the local authorities. It is not clear how much this practice is observed but there is a definite concern that wood is increasingly difficult to get in some areas. The project therefore has the advantage of public perception of scarcity and therefore of the need for change.

4.7. Lessons learnt from the pilot plant

1. Briquetted sawdust, coffee husks and papyrus produces a fuel with combustion properties comparative with fuelwood.

2. Briquettes can directly substitute for wood in enclosed combustion chambers such as cooking stoves or furnaces for process heat. Briquettes cannot directly substitute for charcoal on account of their higher volatile content.

3. The natural market for briquettes includes institutional kitchens such as schools, prisons and restaurants with enclosed cooking stoves.

4. In comparison with wood, briquettes are clean and easy to use because they do not require chopping or splitting unlike wood. They are also easy to store and keep dry.

5. The current size and shape of the briquette is ideal for institutional kitchens. It is <u>not advisable</u> to switch production to the smaller pellets that are designed for automatic furnaces. The small pellets will burn much more quickly, block the grate of stoves and reduce the circulation of primary air. The pellets would also require more handling and frequent feeding to the fire.

6. With production costs at 23Frw/kg and a selling price of 35Frw/kg the pilot briquetting process is highly profitable.

7. With further innovation and increased productivity there is plenty of scope to reduce production costs leading to greater profit margins and/or lower selling prices.

8. At current retail prices the energy cost of briquettes is around 15% cheaper than for wood, Users also report that there are significant savings because wood requires special labour for cutting, splitting and drying.

9. The production of briquettes from MSW is more successful with the addition of 10% either sawdust or coffee husks.

10. The combustion analysis of MSW indicates there is a very high presence of ash (10.67%) compared to wood (1%). These minerals will increase wear on the piston and dies and, for the continuous production of MSW briquettes, will lead to higher maintenance costs and higher production costs. Given that only small amounts of MSW have been briquetted the long term effects of MSW are not yet fully determined. This requires further investigation.

11. The quality of briquettes and successful operation of the machine is highly sensitive to the material preparation and moisture content which ideally should be around 12%. The current production process has no specific means to control moisture. The moisture content at

present is controlled by drying the material in the sun. A larger operation would require such a facility. Future briquetting plants should include dryers to maintain moisture contents at 15%.

12. Pre-heaters should be used to heat the material as it enters the press. This will reduce wear on the dies and piston and increase production rates.

5. Technical and Economic Feasibility of Briquetting MSW

5.1. Original Proposed Plan by ENEDOM and TTT

ENEDOM and TTT plan to manufacture 75 tons of fuel pellets per day which would be marketed as a replacement for firewood and charcoal. The raw material would be dried organic Municipal Solid Waste. This material would be collected from households in Kigali, separated and then dried by NGO Assisted Associations and Community Organisations.

Two types of fuel pellets would be produced comprising small pellets for households with diameter 30mm and large logs with a diameter 60mm for institutional kitchens. The fuel pellets would have a moisture content not exceeding 1% and a calorific fuel value of 16.8MJ/kg.

Current Machine specifications:	Log pellets	750kg/hr at Diameter 60mm Estimated costs $60,000
Proposed machine specification:	Pellet Press	8,000kg/hr at Diameter 6mm Estimated costs $600,000

5.2. Municipal Solid Waste (MSW) Supply

The raw material for briquetting and pelletising is expected to come from dried organic Municipal Solid Waste collected and processed by various NGO's and communitiy organisations. Agriculture residues such as sawdust and coffee husk also exist in large quantities and are available for processing into fuels.

In 1998 the annual production of municipal and non-hazardous waste was estimated at 83,000 tonnes from 84,000 households with a population of 350,000. At this time, less than 60% of the waste was being collected and transported to the existing open dump site. The problem however was expected to get worse, given that the population growth in Kigali was around 7%. On this basis the production of municipal waste would grow from 95,000 tonnes in 2000 to 238,000 tonnes in 2014.

As part of a long-term strategy to improve the waste collection services a number of measures were carried out. The waste collection services were decentralised to the comumunes in Kigali and in 1998 6 new trucks and 200 containers arrived as part of an upgrading process of the collection equipment in Kigali. However, despite these measures, collection services continued to decline mostly as a result of the trucks breaking down and no spare parts or money being available to repair them. Although at that time each household in Kigali was paying 400Frw tax per month to cover the city's general activity costs.

The issue of waste management has become so critical that it has now got to the point where NGO's are assisting with the burden of waste collection. Two NGO's have set up three recycling centers to collect and sort MSW from medium and low income households for a

Table 9: Average MSW collected and dried Ton/mth

NGO	Location	No HH	MSW	Dry MSW	Staff	Income Group
FDC	Rugenge	3,200	128	21	76	Medium
FDC	Muhima	7,000	161	39	128	Medium
ISUKU	N'banda	8,000	100	24	117	Poor
	Totals	18,200	389	84	321	

fee of 300Frw per month per household. Private contractors collect waste from the high income households and transport it to the open dump site at Nyanza.

The two NGOs have been operating only a few months and they curretly collect from 18,200 households each month (about 389 Tons of MSW) using 321 staff (Table 9). After sorting to remove items that can be recycled such as plastic and tin cans the organic matter is dried which yields about 84Ton/mth. This is then sold to ENEDOM for briquetting at 8000FRw/ton.

The analysis of the peformance to date for FDC and ISUKU show that there is a large difference in the amounts of MSW collected between medium and low income households (Table 10) . This may be partly to do with FDC and ISUKU having different processing proceedures but more likely due to the difference in purchasing power between medium amd low income household. However, the analysis is important for making furture predictions on the amount of total 'collectable' MSW available across the whole of Kigali City.

Table 10: Average MSW collected kg/hh/mth

NGO	MSW	Org Matl	%	Dry MSW	%	HH
FDC	31	20	65	6	30	Medium
ISUKU	12.5	10	80	3	30	Poor

Another source of MSW are 8 large markets across Kigali mostly selling vegetables. Nearly all of the waste material is organic and it is estimated that on average each market produces 8 tons of waste 6 days per week. NGO's do not at present collect market waste but they are currently negotiating fees for doing this with the commune authorities. If market waste is included in the sorting and drying process it could provide up to 4,700 Tons of dry MSW per year.

Table 11: Estimates of Collectable MSW in Tons/year for 2002

MSW Source	HH / markets	MSW	Dry MSW
Poor HH	56,102	8,415	2,020
Medium HH	49,089	16,671	3,487
Rich HH	12,623	0	0
Total HH	117,814		
Industries (Ref 1998)			
Markets (est:8TPD)	8	18,432	4,700
Shops etc.	10400	-	-
Enterprises	110	-	-
Available MSW Tons	95000	43,518	10,207
*ENEDOM estimates 97,200Tons*70% *25%*			*17,010*

The total amount of dry MSW available is estimated at 10,207Tons per year (Table 11). This takes into accounting the collecting performance of FDC and ISUKU and the 8 markets. Earlier estimates by ENEDOM suggest that up to 17,000tons are available. Although, this figure probably represents the thoretical maximum in practice there are likely to be losses to collection efficiency. Rich households are likely to have large amounts of MSW but the proportion of organic material will be very much less than for low or medium income househlds. In this case it may not be very econcomic to sort out proportionally small amounts of organic matter in rich households MSW. Furthermore, private companies currently collect waste from rich households for a fee and transport it to the dump.

The total amount of dry MSW probably lies between 10,000 tons and 17,000 tons per year and will likely grow slightly faster than 7% population growth.

5.3. Agriculture Residues

The briquetting experince from the pilot plant suggested that the briquetting of MSW is improved with the addition of at least 10% of coffee or sawdust. The figures for the availability of sawdust and coffee husks (Tables 12) are not easily obtainable because the sources are widely distributed throughout the country. Sawdust has been estimated at 12,000 tonnes per year, half of which is available in Kigali. A visit to the centre where as many as 200 small businesses produce furniture is by far the largest concentrated source of sawdust. According to the accumulating mountains of

sawdust adjacent to the businesses, there is probably at least a daily supply of 10 tons. A few other industries collect sawdust but at least half probably remains un-utilised. This remaining half, probably has a dry weight of at least 4 tons amounting to 1000 tonnes per year which would be useful for supplementing MSW for briquetting. Several other sources of sawdust in Kigali could probably provide a further 1000 tonnes but at a higher cost compared to the central furniture market.

The largest source of agriculture residues is coffee husks. Coffee production was 15,000 tons in 1996 which is low compared to a pre-civil war variation between 35,000 and 40,000 tons. The Government is presently trying to expand coffee production again to around 26,000 tons (Ref: WB PRSP 2001). The residues from coffee production are probably around 6,000 tons per year. The only known user of coffee husks is the brick factory which was built in 1996 and is totally dependant upon coffee husks as the heat source. Figures were not available on the quantities of coffee husks used but based on estimates of 20tonnes of bricks fired per day the consumption of husks is in the region of 1,500 tonnes per year at the rate of 4 tonnes per day. This would leave a maximum of 4,500 tonnes per year. Asumming about half of these would be available in Kigali that would leave about 2,500 tonnes available for briquetting.

Table 12: Analysis of MSW and residues available for Briquetting in Tonnes per year

	Actual	Conservative Estimates Available	
Raw Material	**Quantities**	**2002**	**2008**
MSW growth @8%growth	17,000	10,200	15,869
Sawdust @7%growth	12,000	2,000	3001
Coffee Husks @2%growth	6,000	2500	2815
Papyrus	38,400	n/a	n/a
Rice Husks	42	n/a	n/a
Total raw Materials	73,442	14,700	23,693
Briquettes Less 10% dust	66,070	13,230	21,324

Vast quanties of papyrus (estimated at 38,400 tomes) are available for briquetting in theory. In the early 1980's a briquetting project was set up to utilise papyrus and it operated successfully for a large number of years. It is not known whether the project failed as a result of poor economic performance or mismanagement. Papyrus grows in swampy regions and can only be harvested during the dry season. To make it suitable for briquetting it would require cutting, drying and transporting large distances to Kigali. For this project, papyrus is not considered economic and its future use would needed further investigation to check the economic viability.

There is a considerable supply of suitable material for briquetting however it is probably not all available for briquetting either because of other uses and because the source is too small to economically collect. However, when briquetting does take off in 4 to 5 years other sources of residues will more than likely become economic. Therefore the project does offer considerable scope to expand into new areas. Furthermore, in the short-term if one source of material is disrupted the project will have alternative residues available. In this regard, the supply of raw material at the rate of 15,000 tonnes per year could be considered as quite robust. Further more, the supply of MSW will easily grow at 7%. By the time the production plant will have been built and operating the supply of MSW will be at least 16,000 tonnes. In the long-term it would also imply that there is considerable scope to expand production either by purchasing more machines or by operating longer hours such as introducing another shift. The economic and financial analysis of the production plant is therefore based upon a residue supply of 16,500 tonnes producing 15,000 tonnes of briquettes per year.

5.4. Sustainability of MSW collection and supply of dry material

The availability of MSW and agriculture residues is certainly assured. However, the collection, sorting and drying by NGO's and other independent companies will probably and ultimately determine the scale of the briquetting process. The long-term sustainability of the current two NGO's and other companies who enter into the waste collection business will be highly dependant upon the profitability of collection sorting and drying. Both FDC and ISUKU have only

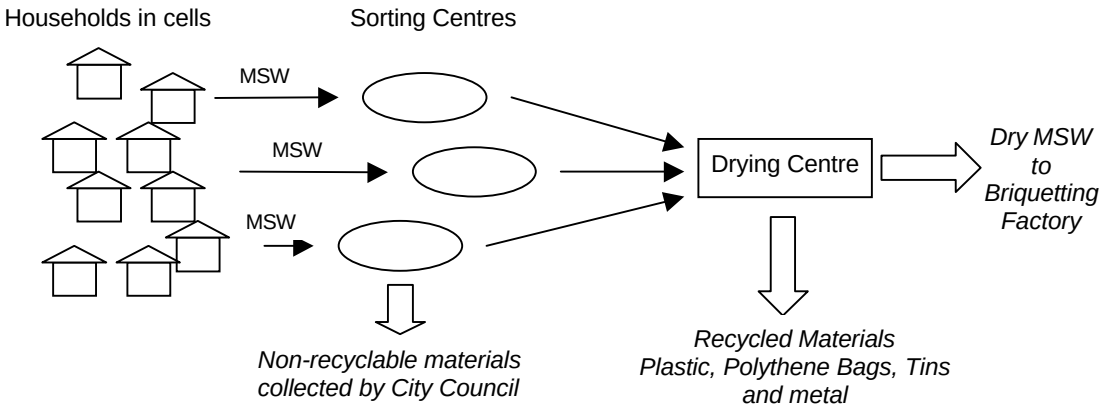
a few months experience operating 3 drying centres and have varying degrees of success although the collection, sorting and drying processes are similar.

ISUKU

ISUKU was set up in 1991 as an NGO to promote a sustainable environment. Isuku in Rwandese means clean. Work started by recycling waste from markets and composting waster hyacinths and tree planting in open urban areas in Kigali. The work was severely disrupted during the war and composting never proved to be economically viable because its cost was too high. After the war ISUKU re-established itself and by 2000 it had a staff of 228 comprising an executive secretary, 4 heads of departments, 2 agronomists and 1 waste treatment engineer, 20 trainers / promoters and 200 manual labourers, mostly women. In 2001 the annual budget was Frw 30million rising to Frw40 million in 2002. Funds are mostly raised through collection fees from households and project funding provided by Ministry of Environment, PPLM and EU.

ISUKU has established one recycling centre in a catchment area of about 8000 households. It plans to launch 4 more centres as soon as possible. The sites and location have been agreed with the communes, but no further funding has yet been arranged with donors to pay for land preparation and buildings.

Recycling Business Model



Formation-Cooperation-Developement

FCD is a Belgium NGO with a local annual budget of Euro1 million. Projects include Micro-Finance for Agriculture Associations and Recycling MSW. The recycling project started in June 2002 with a budget of Frw43 million to set up 4 recycling centres. Two centres are up and running and a further 2 centres will start working in February. Each centre costs in the region of Frw4 to 6million to setup with land preparation, buildings for storage, sorting bins and drying facilities. Each recycling centre is run solely by an Association, mainly by women.

FCD has a good business monitoring strategy and is able to provide monthly performance data on MSW collected, materials recycled and costs and income. Initially, the organic mater was composted but, like ISUKU it was found to be un-economic.

5.5. Economics of recycling

Both ISUKU and FCD provide funding to the recycling Associations to cover setup costs and running costs to cover the initially trials. Each centre is designed and managed to be self-sufficient in 3 months. The following review (Table 13 and 14) of the revenue therefore only applies to the running and operating costs.

Table 13: FDC Rugenge Costs and Income from recycling

	Costs	Income					
Basis	**Salary**	**Fees**	**Dry MSW**	**Plastic**	**Cans**	**Total**	**Profit**
Actual 20%Fees	912,000	247,000	168,982	382,784	255,189	1,053,956	141,956
Target 80% Fees	912,000	900,000	168,982	382,784	255,189	1,706,956	794,956

Notes: 72 workers collecting MSW from 3200HH medium income;
4 workers sort and dry MSW;
Workers salary Frw400/day but should rise to Frw600;
Collection Fees Frw300/hh and Frw1000/Rest.

Table 14: FDC Muhima Costs and Income from recycling

	Costs	Income					
Basis	**Salary**	**Fees**	**Dry MSW**	**Plastic**	**Cans**	**Tot Inc**	**Profit**
Actual 20%Fees	1,536,000	500,000	313,740	483,240	322,160	1,619,140	83,140
Target 80% Fees	1,536,000	1,680,000	313,740	483,240	322,160	2,799,140	1,263,140

Notes: 116 workers collecting MSW from 7000hh medium income;
12 workers sorting and drying MSW;
Workers salary Frw400/day but should rise to Frw600;
Collection Fees Frw300/hh and Frw1000/Rest.

The economics of collecting and recycling MSW do appear very profitable. The fees (Frw300) collected from each household for the waste collection service has been set at a level that should enable each association to breakeven if 80% of the fees are collected. The income from the sale of the recycled materials (Table 15) was only intended to be a bonus. In practice only ISUKU is achieving 80% collection of fees. FCD is at present only achieving 20 to 30% collection of fees. Even so, with the incomes from the recycled materials FCD is probably at breakeven point with 20% of the fees collected.

ISUKU has considerable political support in the areas where it is intending to set up the recycling centres. The Mayors and administrative officers working with ISUKU have been particularly active and forceful in ensuring that each household contributes to the collection services although these areas are often the poorest in Kigali.

On the other hand FCD has focused more on middle income areas but lacks political support compared to ISUKU and has had to resort to their own efforts to promote collection services. The low fee collection rates are an important issue amongst the local residents because of the friction between those households that pay and those that do not. Given that all Mayors in Kigali are very concerned with the current waste collection services it's mostly likely that FCD will also get more support from the Mayors and administrative offices in the communes where it works.

Whilst, the recycling associations should be able to make a small profit with the original concept of selling MSW compost at Frw2/kg, the emerging market for MSW as a briquetted fuel at Frw8/kg is much more attractive.

Overall, the profitability of waste collection and recycling looks very encouraging for NGO's and small businesses. Each association with 120 employees providing collection services to 7000 Households should be able to make easily, a gross profit of Frw1.2 million per month, less miscellaneous expenses for plastic sheeting and tools etc.

Table 15: Price of recycled materials

Recycled Material	Prices Paid	Unit
Plastic Bags (used for sheeting)	50	kg
Tomato Paste cans	1000	kg
Tins	10	each
Plastic / Bottles	?	each
Compost	2	kg
MSW Briquetting	8	kg

A cautionary note: The quality of the supply of raw material can also play an important role on the economics of production. If the moisture content of the raw material were to significantly rise above 15% ENEDOM would have to spend more time and money reducing it to around 12%. Similarly if the particle size was to increase beyond 2cm it would require more time and effort at the factory to crush it. In this regard ENEDOM and the partners supplying the raw material should agree upon the standards and quality of the material. Standards for example should specify moisture contents, size and shape.

5.6. Briquetting Process

The project design calls for an 8 ton/hr Pellet Press producing small diameter pellets. Whilst the size of machine is broadly in line with the available supply there are a number of problems associated with this choice of machine.

1. Although Pellet Presses have been around for a very long time it is only recently they have been used extensively, mostly in Europe and North America. The popularity of the pelleting machines has risen primarily because they use the least amount of energy and can achieve very high rates of output. The pellet press could be considered the current state of the art in briquetting. The dies and rings which form the pellets are highly engineered but like all briquetting machines are susceptible to wear. It would require the services of a very well equipped workshop to support and maintain the running and smooth operating of a pellet press.

2. All briquetting presses are subject to wear and breakdowns. It is not advisable for a large business to rely solely upon one machine. In the event of a break down all production would stop and the delays could be extensive if parts have to be ordered from overseas. It is therefore advisable to have up to 4 machines working in parallel. This would reduce the business vulnerability to break downs and ensure a more consistent supply of briquettes to customers.

3. Pellet presses can produce small briquettes from 6mm up to 30mm depending upon the choice of rollers and dies. The trials in institutional kitchens are with 60mm logs, which are a very good substitute for split wood. It is not advisable to switch to smaller briquettes without extensive market trials with established customers. Small diameter briquettes will alter the combustion characteristics and for example they would burn more rapidly than the existing 60mm logs. The small briquettes would also fall through grates with large openings. Compared to the current briquettes it is likely that switching to pellets would require modifications to existing appliances.

5.7. Alternative Briquetting Machines

There are three alternative briquetting machines:

Screw Presses: Briquettes are extruded through a longitudinal die by means of a specially designed screw. These machines use a lot of energy but are highly regarded because they produce the best quality briquettes. India has recently carried out extensive research on the design of screw presses in order to help minimise some of the design limitations. The main conclusions were that, at best wear, rates could be reduced by hard facing the screw and pre-heating the raw material. Screw press output range from 250kg/hr to 750kg/hr. Given the continual problems with screw presses and the limited output range they are not considered appropriate for this project.

Hydraulic press: These machines operate by hydraulic pressure acting upon a piston that extrudes the material through a longitudinal die. The machines operate rather slowly which minimises the wear rates. However, they operate at much lower pressures and the briquette quality is of lower density. They are typically used for low outputs of 40Kgs/hr but can be made to achieve up to 800kg/hr. They are not considered appropriate for this project.

Piston Presses: A reciprocating piston attached to a large flywheel pushes the material out through a longitudinal die. These machines are very robust and have a reputation for having a long working life. They are easily maintained and although the piston and dies wear out they are easy to repair. Energy consumption is high but less than for screw presses. Piston presses are by far the most commonly used briquetting machines and are the cheapest of all the presses to purchase and install. Outputs range from 450kg/hr up to 2200kg/hr. ***The piston press is recommended for this project because of its superior strength and it produces a briquette quality best suited for use by ENEDOM's customers.***

5.8. Ancillary Equipment

The Pilot Plant installed by ENEDOM with a processing capacity of 750Kg/hr, with integrated hammer mill and holding hopper is a good example of a small-scale briquetting plant set-up. For a larger output the basic arrangement should be retained but it is advisable to consider a few other additional features that will improve the quality control of the briquettes and reduce the running costs, as follows:

1. Moisture Control
2. Piston and Die Wear
3. Removal of Smoke Fumes

1. Moisture Control

It is essential that the raw material moisture content is maintained closely at 12%. Given that it rains 6 months out of 12 in Kigali it would be impossible to keep stocks of raw material dry throughout the year. Even with good storage and shelters the moisture content of the residue will go up and down depending upon the humidity and temperature. For these very reasons, the pilot plant has only operated 6 months out of the past 18 months. Any new plant installed should therefore be fitted with dryers. These are standard appliances typically used for drying grains and cereals.

2. Piston and Die wear

It is now almost standard practice in briquetting plants to pre-heat the raw material prior to briquetting. This provides a number of important advantages. By heating the material to 200^{o}C it helps release the lignum, a glue type substance from within the cellulose cells of the biomass. During briquetting the lignum is normally released because of the pressure and the frictional heat in the die. By pre-releasing the lignum this glue type substance acts more like a lubricant and reduces the power requirement and wear on the metal surfaces. The overall effect (Table 16) of pre-heating improves production and increases profitability because production rates are increased and maintenance costs on the piston and die are lower.

Pre-heaters work from small furnaces heating oil which is pumped through a pipe that surrounds the incoming material as it is fed into the compaction chamber. The furnaces are usually fired from a small amount of waste briquettes.

Table 16: Increases in production rate of briquettes with preheating (90C) on machines with a standard capacity of 400kg/hr

Raw material	*(kg/hr)	% increase
Rice husk (ground)	480-540	35
Groundnut shells (ground)	480	20
Coffee husk (ground)	600-700	75
Note also: For sawdust, the screw life increased from 17 to 44 hours		

3. Removal of Smoke Fumes

When the briquettes exit the machines they have temperatures that can be well over 300^{o}C. The outer skin can even by partially charred and the briquettes are always accompanied with smoke. It is therefore important that hoods with extractor fans are fitted over the cooling racks to remove the smoke for the safety of the workers and to improve their general working environment.

5.9. Recommended Plant Setup

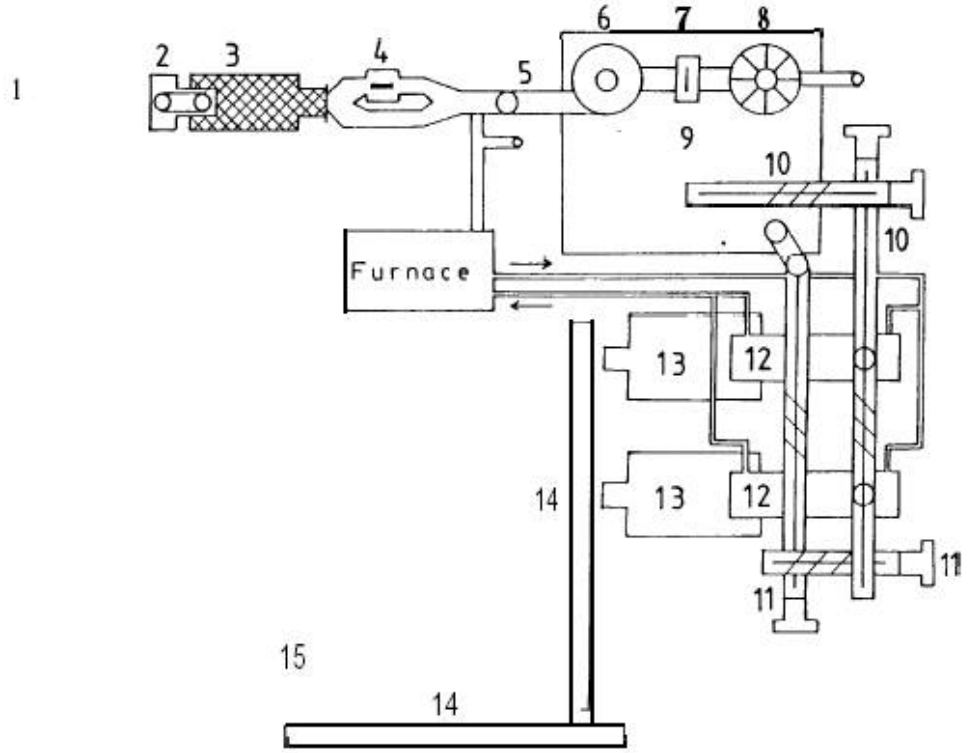


Fig.4.1 Process flow sheet

Description of Components

1 - Raw material supply: The residues for briquetting should be kept in storage bins or in bays under shelters that are fully protected from the rain and the run off. The shelters should be well ventilated to allow any moisture in the raw material to evaporate. The residues can either be delivered to the start of the Briquetting process manually or by automatic feeders typically used in the grain and cereal industry.

2 - Inclined screw or elevator: The residues can either be lifted automatically or manually into the hammer mill.

3 - Vibrating Screen: A screen or simple mesh should be fitted over the hammer mill to trap any foreign matter such as over size residues, stones or metals.

4 - Hammer mill: Reduce the particle size to 6 to 8 mm.

5 to 8 - Dryer Set-up: To assist the control of the moisture content of the raw material a dryer is essential.

9 - Intermediate Storage Bin: The residues can be held in a storage bin after leaving the dryer. At least 4 hours of production capacity should be held in storage in case of a short break down.

10 - Main feed screw: This screw distributes the material in the storage bin to the machines. The supply should be at least 15% greater than production to ensure that none of the machines are starved of material.

11 - Return feed: The excess material not required by the machines is returned to the Intermediate Storage bin.

12 - Pre-heater and Furnace: The residues are dropped into a chamber that pre-heats the material. The temperature should be adjustable from 90 to 200 C depending upon the type and moisture content of the material.

13 - Briquetting Machines: The auxiliary equipment can be sized and matched to supply any number of machines. Although more than 4 machines may mean that the feed screws become un-necessarily complicated.

14 - Cooling racks: The briquettes are hot after they leave the presses. A system of conveyors need to be arranged so that the briquettes get time to cool down prior to storage and packing.

15 - Ventilation Hoods. The smoke and fumes coming off the hot briquettes should be extracted to the outside of the plant buildings via ducts and hoods closely fitted over the cooling racks.

5.10. Briquette Markets

The original project intended to focus on the household fuel market because the substitution of charcoal the principal household fuel with briquettes could have brought a significant number of environmental benefits and that the price advantage would give higher operating profits. However, the experience today shows that the briquettes are best suited to the institutional markets, because they can directly substitute wood without modification to the stoves. ENEDOM has also received an overwhelming number of orders from large wood fuel consumers (Table 17). The potential market amongst other consumers is also very high (Table 18).

Other potential markets

Schools

Rwanda has had a very active Institutional Stove Programme over the past 10 years and large numbers of stoves have been sold throughout the country. The main promoter has been KIST and at present they have a very large workshop dedicated to the production of Institutional stoves. KIST estimated that they have installed 2500 stoves in prisons, schools and orphanages since 1994. A further 2000 stoves were installed prior to the war. The stoves are very well made and based upon a proven design from Tanzania they have a life of 10 years, KIST also provides a maintenance and replacement service and it is likely that at least 4000 stoves are still being used.

Table 17: Enquires received from existing Clients

Markets	Consumption ton/mth
Army	1,000
UNHCR	400
Prisons	700
Schools (KIE)	50
KIST	50
Total	**2,200**

Depending upon the numbers of students each school may require up to 6 stoves on average. If we assumed that there are 5 stoves per school this suggest that they may be as many as 800 schools using improved stoves that could easily substitute wood fuel with briquettes. On average schools require 0.5 kgs of wood per day to cook a standard meal. This means in total that schools with stoves could be consuming as much as 3,200 tons per month of wood to cook food. The market for briquettes in schools that cook food is therefore enormous because a higher proportion of schools in Kigali are boarding. Due to the shortage of fuel wood and the difficulty to purchase it the Chris Roi School in Nyanza with 508 students is happy to transport briquettes 100km from Kigali. Although this is an exception, it does indicate that although wood may still be cheap it is not always easy to obtain it.

Restaurants

In 1993 it was estimated that there were 124 restaurants and 210 Rest-Hotels in Kigali and half were using wood that total 1000 tons per month. These premises have increased enormously in the past 10 years and at a modest growth rate of 5% the consumption could easily be 1700 tons per month.

Industries

The demand for energy in industries has also mushroomed since 1993. However, a survey of current prices paid for wood suggest that briquettes cannot compete with the bulk purchase of wood. Unlike schools and restaurants that require wood that has been split and dried, industries use large logs that do not require very much preparation and the costs remain very low. At present industries are not likely markets but remains a future opportunity, especially if the Government and local authorities decide to further enforce the restriction on cutting down trees. In which case, wood could be very difficult to obtain.

Overall there is good potential to substitute wood with briquettes. At present ENEDOM has large customers to satisfy and the current demand is of the order 2,200 tons per month. A further 700 ton/mth could easily be sold to new customers such as schools and restaurants. If a promotional campaign in partnership with KIST the Stove Maker was implemented a new market in the region of 1,700 tons/mth of briquettes could be generated.

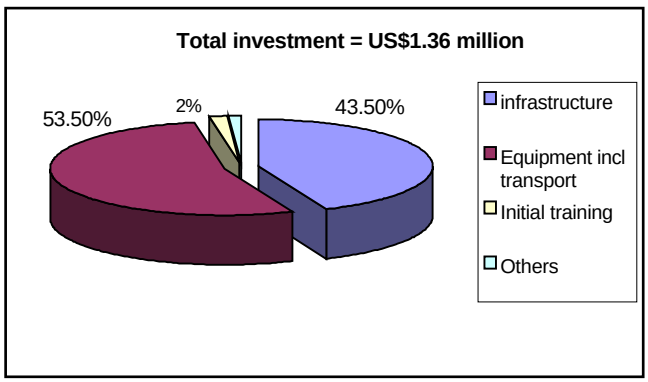
Table 18: Summary of Markets in tons per month that could be reached in 2 years

Sectors	Total Wood Consumption	Potential for Substitution	Comments
Army	1,000	1,000	Exist client
UNHCR	400	400	Exist client
Prisons	700	700	Exist client
Schools (KIE)	50	50	Exist client
KIST	50	50	Exist client
Other Schools	3,200	500	Requires Contact
Kigali Restaurants	1,700	200	Requires New stoves
Totals	**7,100**	**2,900**	

6. Economic and Financial Analysis (Refer to Annex 2)

The financial and economic analysis is based on the data collected from ENEDOM. The credibility of the data had been checked by the consultant and adjusted where the data diverged significantly from previous briquetting experience. The financial analysis focuses upon the viability of the production unit only. The project as a whole does have many other direct and indirect benefits and these are discussed separately in the section Socio-Economic Benefits

The main assumptions considered under this scenario are as follows:



1. All figures are in US Dollars. Based upon exchange rate 1US$ = Frw470 (Dec 2002)
2. Production 1500 t/month spread over 10 months as a precautionary measure e.g. on average 1250 t/month
3. Calculation based on 1250 tonnes sold per month on average
4. Production will start after one year (time to build the unit)
5. Replacement cost: one third of Briquetting plant every 6 years, salvage value = nil .Cost of Briquetting plant = US$ 483,520. Prices being expressed in US$, we are assuming that the replacement cost will remain the same across the lifetime of the project.
6. Plant life expectancy = 19 years after completion date
7. Raw material cost per tonne US$ 17.02
8. Selling price: $74/tonnes
9. Bank fees from initial investment = US$ 3,120

The investment was comprehensively costed and includes all the costs such as licences, land, connection to utilities, initial training etc. Infrastructure and utilities account for 44% of the total investment, which was evaluated at $1.36 million. The assumption is that the initial investment cost is covered from own funds or partner. According to the data**,** collected bank fees are limited to US$ 3,120, which is relatively low if the capital was borrowed and commercial rates used.

Results

Under these assumptions the internal rate of return (IRR) is 34% and the NPV is $2.28. (Annex 3) The analysis also shows that during the first three years there will be a need for a loan to cope with the negative cash flow as shown by the figures on retained cash flow. This is of course due to the high capital costs that occur before any positive cash flow can be expected.

Over the life time of the project more than $2 million US of salaries will be distributed to the employees and US$ 315,000 will be paid in taxes. Such an amount, although modest, over the lifetime of the project could be used to improve the environment in the city of Kigali.

7. Socio-Economic Benefits

The project appears particularly strong in terms of the economic benefits (Table 19) that are distributed amongst five key sectors as follows:

- The Waste Collection Associations will employ large numbers of women to collect and sort the MSW, and these workers will receive salaries.
- The employees of the production unit, although mostly men, will also receive salaries. The clients and users who purchase the briquettes, such as schools, will likely save up to 15% on their normal fuel bill.
- Clients and users of the briquettes will save upto 15% of fuel expenditure.
- Finally the Major's Office and councils who are currently responsible for the collection services will make huge savings resulting from less transport costs and lower waste dump management costs.
- To a small extent the produces of residues such as sawdust and coffee will have an additional income.

Assumption for the supply of raw materials is 16,500 tonnes in year 2004 comprising:

- Dry MSW: 12,000 tonnes
- Residues: 4,500 tonnes

7.1 Waste Collection Associations

By the end of 2004 there will be over 12 Waste Collection Associations employing 2,036 people, mostly women. Providing the Associations can achieve 60% fee collection rates from households they are likely to benefit Frw 126 million (US$270,000) per year profits for their members. The collection workers will receive directly Frw 350 million (US$0.74m) in salaries by 2004 - an average of Frw 172,000 (US$366) per person per year. Although not all of the jobs can be directly contributed to the Briquetting project because primarily the associations are being set up

to provide a MSW removal service. The revenue from MSW sold to the Briquetting plant by 2004 will be worth Frw 85,888,000 representing 500 jobs for manual workers.

Table 19: Estimates of annual Benefits (current prices) accruing by year 2004 (Frw)

	2002		2004	
1. Waste Collection Associations		**US$**		**US$**
Dry MSW sorted (tons)	1,012		10,736	
Jobs at Associations	321		2,036	
Employment Income @Frw670/day	55,229,976	117,510	350,346,326	745,417
Association Profits@60% collection efficiency	19,980,444		126,744,130	
2. Residue Producers				
Coffee Husks and Sawdust Producers	800,000	1702	3,600,000	7,660
3. Briquette Production Plant				
Briquette Production (tonnes)	1,012		15,236	
Briquetting Jobs (persons)	28		38	
Employment Income (Frw)	12,324,000	26,221	42,179,400	89,743
4. Clients and Users				
Schools (15% Savings on fuel costs in Frw))	8,096,669		121,891,001	
5. Mayors Office and Councils				
Council Savings: Transport (Frw)	20,822,608	44,303	313,473,181	666,964
Councils Savings: Dump Management(Frw)	26,066,820	55,461	392,421,983	834,940

7.2. Briquetting Plant

Up to 38 jobs will be created at the pilot plant including 8 skilled positions and 30 manual jobs. Total salaries will be in the region of Frw 42million (US$89,000) per year.

7.3. Clients and Briquette Users

Based upon the economic analysis comparing the cost of wood used in institutional kitchens with the cost of briquettes it appears that their will be a financial saving of 15%, this represents a saving of Frw 8000 per tonne. By 2004 the total annual savings accruing from the sale of briquettes will be worth Frw 122million.

7.4. Mayor's Office and Councils

According to the study on the MSW Landfill site and cost recovery system in 1998 by Carl Bro Ltd the unit costs of managing a new landfill site would be US$13.5/ton for transport cost and US$16.9/ton dump management cost. No current data exists on the costs of operating the current dump but it is fair to assume that the proposed costs do reflect the real value for improving the current situation, consider that the old dump is full and in desperate need to be replaced. The amount of MSW that is being collected recycled and sent for briquetting will not have to be transported to the dump. Therefore this is a huge saving for the Mayor's office and the councils responsible for the transport of MSW. By 2004 the total annual savings will be Frw 706 million (US$1.5m) comprising Frw 313 million (US$0.667m) transport cost and Frw 392 million (US$0.835m) dump management costs.

7.5. Recycled Materials

Out of the raw MSW collected, the Waste Collection Associations sort out for resale polythene bags, plastic, cans, tomato paste tins and metal. Companies collect the materials from the recycling centres whenever there is sufficient quantity to make it worthwhile to visit with a pickup. The information identifying how much of these materials can be collected has been provided by FCD. Although the monitoring period is only a few months the revenue from the resale of the recycled materials appears to make an important contribution to the profits of the association. The analysis of the FCD reports (Table 20) suggests that as much as Frw 5,370 can be earned from each tonne of MSW collected and sorted. By year 2004 this would total Frw 192 million (US$0.41m) per year.

Table 20: Revenues from the sale of recycled materials

Recycled Matl	Prices Frw/ton	Percentage of MSW	2002	2004
Plastic	30,000	0.90%	910,875	9,662,738
Polythene bags	50,000	6.00%	10,120,836	107,363,751
Tomato Tins	100,000	0.21%	7,084,585	75,154,626
		Totals	**18,116,296**	**192,181,114**
		Frw/ton MSW	5,370	

The revenue from the sale of the recycled materials would also represent a saving in foreign exchange. The net effect of recycling materials that would otherwise have to be imported in their raw form will be a reduction on the import costs. It is therefore assumed that the revenue earned on the sale of the recycled materials would be similar to the amount of foreign currency saved.

7.6. Negative Benefits

- **Landfill Site Scavengers**

At present there are an estimated 150 to 200 scavengers visiting the Nyanaza Waste Dump. Although at any one time during the day there are probably no more than 50 persons comprising children, women and men. They sort through the incoming waste for scrapes of food, charcoal, complete plastic bottles, beer or coke bottles, cans and metal. On a good day scavengers can earn Frw 400 to 500 per day although on average this is very much less. The scavengers live at the waste site in makeshift shelters created from the waste. They consider themselves either from the North or the South of the Country.

There will be a negative impact on the scavengers although this may not be particularly large. The Waste Collection Associations will focus mostly on the low to medium income areas because these households have the highest concentrations of organic matter and all the houses are easily accessible by the collectors. The rich households are already serviced by commercial waste collection companies who truck the waste directly to the dump site. The amount of rich household waste in the short to medium term is therefore unlikely to change. It is this waste that probably has more value to the scavengers than waste from low-income household, so conflict is likely to be minimal.

7.7. Reduction in Farmers' Incomes

The MSW briquettes will directly replace wood. Whilst this has important environmental impacts the reduction in the demand for fuel wood will adversely affect farmer's incomes. Farmers often rely upon tree cutting to supplement incomes particularly at occasions when additional monies are required to pay school fees, medical costs weddings and funerals. The loss in farming

income is estimated at Frw 107million (US$228,000). Based upon 21,400 tonnes of wood at Frw 5000/ton, although the retail price of wood is much higher at around Frw 29,000/ton because of transport and labour costs. Briquettes will still require transporting so the impacts on the transport sector are not likely to be significant and therefore can be ignored.

8. Environmental Impacts

8.1. Impact of Briquettes Replacing Wood

In a straight forward comparison between briquettes and wood on a useful energy basis 30% less briquettes are required to replace the wood. In practice this saving could be very much higher but since no verifiable data exist it is assumed therefore that 0.70kg of briquettes (@9% moisture) can replace 1kg of wood (@35% moisture).

By year 2004 when the plant is fully operational and producing 15,000 tonnes of briquettes per year the quantity of wood replaced will be in the region of 86,667m3 representing 1.15% of the total demand (Table 21).

Table 21: Expected reduction in fuel wood m3 in year 2004

Year of operation	**2004**
Hr/day	10
Days/year	200
Total Tonnes	15,000
Wood Replaced	19,500
Volume m3	86,667
Total demand m3	7,562,231
% reduction	1.15%

Note:
1. *1m3 wood at 70% moisture is equivalent 0.225kg*
2. *Production Capacity: 6.75Tonnes /hr*
3. *Replacement value 30%*

8.2. Impact of Reduced Consumption of Fuel on Carbon Emissions

The combustion of wood releases carbon emissions into the atmosphere and contributes to global warming. Wood has the benefit that if it is replaced by reforestation it reabsorbs a similar amount of carbon emissions as were released during combustion. Wood therefore is highly regarded as a fuel for being neutral or nearly neutral in terms of the overall effect on global warming. However, this ideal situation breaks down when the consumption of wood is greater than the regeneration. Such a scenario is equivalent to mining of coal, or to oil extraction. This is the situation that currently exists. According to the National Forestry statistics the demand for fuel wood is 7,562,231m3 and the extraction is 3,186,700m3 which indicates a deficit of 4,375,531m3 which is directly contributing to the overall carbon emission of the country. To bring the supply and demand into line it is necessary to increase tree planting and cut demand.

Table 22: Estimates of Carbon Emissions based upon IPCC/OECD methodology

	m3	t C
Fuel wood Demand	7,562,231	1,433,194
Extraction Potential	3,186,700	603,943
Deficit	4,375,531	829,251
Fuel wood Saved	86,667	16,068

The effect of replacing fuel wood would result in a net reduction of tC16,068 emissions (Table 22) released into the atmosphere which represents about 1.7% of the current tC emission contribution.

(Annex 4: IPCC/OECD Conversion and Emission Factors)

8.3. Impact of Increasing Efficiency of MSW Collected

Local Environment

According to recent reports 60% out of the 95,000 tonnes of MSW generated in Kigali is being collected. There is no analysis to suggest what happens to the other 40%. At is therefore assumed that as much as 38,000 tonnes is left to accumulate on the streets eventually to be washed away by heavy rains into nearby rivers and streams and finally end up polluting local water sources. Increasing the efficiency and the effectiveness of removing household waste would provide significant benefits to local communities and the city of Kigali.

It is expected that within 2 years the total amount of MSW collected and sorted by community organisations will be at least be equal to the amount that is presently not collected by the City Council. With the current planned expansion the total MSW collected and processed should be in the region of 36% of the total amount of MSW generated (Table 23). With further involvement and improved management by the Collection Association it would be possible to recycle nearly 76% of the entire production of MSW. The time frame for achieving this would very much depend upon the support from the City Council and commitment from the Commune Mayors.

Table 23: Projections for collected and sorted MSW

	Years	
Description	**2002**	**2004**
MSW projections	95,000	108,765
Raw MSW processed	3,054	35,788
Other material recycled	305	3,579
Totals	3,354	39,367
% Collected & Sorted	3.5%	36%

Household Benefits

In 1998 Africare carried out a survey amongst 1,182 households to establish knowledge, attitudes and practices in Kigali towards MSW. Given that by 2004 the amount of collected and sorted MSW will be equal to that which currently remains on the streets there is a strong likelihood that many of the following household concerns will finally be addressed:

- Sickness or illness (565 households) - improved hygiene was suggested by 43% of households, immediate collection by 11%, dumping away from homes and community work by 3% and others by 32% of households. 14% of households did not respond;

- On bad smells (304 households) - getting rid of garbage immediately was suggested by 33%, covering the garbage by 6%, well identified dumps by 4%, education of the population 3%, others 26%. 16% of the households did not respond;

- General dirt/uncleanliness (272 households) - availability of bins suggested by 15% of households, availability of vehicles by 11%, well identified dumps by 10%, quick disposal by 9%, community work by 9%, education of the population 8%, covering bins 5%, utilisation of sacks/bags by 4%, others by 40%. 6% of the households did not respond;

- Mosquitoes (276 households)- 21% of the households proposed improved hygiene as the means of getting rid of mosquitoes, cutting bushes was proposed by 16% of households (not directly related to SWM), immediate collection by 15%, dumping away from homes by 4%, covering the garbage by 3%, others by 29%. 15% of households did not respond;

- Flies (258 households) - improved hygiene as a means of preventing flies was suggested by 26% of the households, immediate collection by 17%, covering garbage by 15%, and dumping garbage away from home by 4%. 17% of the households did not respond;

- Irregular garbage collection (106 households) - immediate collection was proposed by 20% of the households, enough vehicles by 10%, hygiene by 4%, enough bags and system of collection each by 1%, others by 4%. 51% of the households did not respond.

- 74% of the households are willing to pay for garbage collection. 58% of those willing to pay say they can pay between 100-200 Frw per month (0.3 to 0.7 USD)

- 810 households (69%) made suggestions as to systems for garbage collection. Of these 20% suggested use of societies, 17% cell heads, 17% zone heads, 9% councillors (43% using the administrative structure of cells/zones/councils), 16% users committees, 12% Nyumba kumi (groups of 10 houses) and 8% others.

- 65% of the households were in favour of forming beneficiary societies for garbage pre-collection. Of the households interested in joining societies 70% were in favour of contributing funds for running the cooperatives.

Leachate

Leachate is generated from landfill sites when water (predominantly rainfall) enters the waste. The quantity of leachate depends primarily on the amount of precipitation and the evaporation from the surface. The composition of leachate is related to the waste types and the degradation taking place in the waste. (Table 24: Typical concentrations)

For more than 70 years, disposal of waste from Kigali City has mainly been concentrated within the Nyanza area, located approximately 12 km to the southeast of the centre of the city. The disposal has been and still is uncontrolled. Up to the end of the 70's, waste has been dumped at various sites within the area, by gravel quarries being filled up or simply by waste being dumped downhill along the main road through the area. This practice resulted in complaints from the local residents, as the wild waste dumps caused pollution of drinking water springs within the area. Thus, at the end of the 70's, the government recognised that the dumping practice used so far was unsuitable and the wild dumping was no longer allowed.

Therefore, dumping of waste was concentrated on one of the sites within the area. This site has been used for waste disposal since 1927 to the present. The site is located on a steep hillside. No exact data on the size of the dumpsite are available, but during the consultant's inspection it was estimated to cover an area of approximately 7-10 ha.

No measures as to environmental protection have been introduced, either constructive nor operational. A bulldozer is supposed to be at the site to move the waste although it was not present when the project team visited the site. The waste is simply dumped on the ground and is not being covered. Although there is a good access gravel road to the site, the trucks have a hard time going up to the site during the wet season and therefore often dump the waste on the side of the road.

All kinds of solid and liquid waste is brought to the dumpsite as it is the only official disposal option within the Prefecture of the City of Kigali. Apart from the dominating amounts of municipal solid waste, smaller amounts of waste from the few industries within the prefecture are dumped at the site. Furthermore, a relatively large but unknown amount of liquid waste from septic tanks is dumped in open lagoons within the site.

As the dumpsite is completely open and uncontrolled and as waste is being dumped wherever it suits the truck drivers, wind-borne waste lies about within the surrounding areas. Furthermore, an unknown amount of leachate infiltrates through the subsoil and causes pollution of the groundwater.

The dumpsite is unfenced and unguarded. The waste picking carried out by a large number of scavengers (150 to 200) at the site seems to be the only kind of management executed. The scavengers have formed their own society at the dumpsite, literally living on and from the waste brought to the site. The children jump on the trucks as soon as they enter the site and start searching for food and recyclables. The adults dig through the waste using hoes or simply their bare hands. The scavengers walk bare-footed directly on the waste causing a high risk of injuries and infections from broken glass, metal, hospital waste etc. They wash themselves at the open surface water puddles and even use the same water as drinking water.

Under the present conditions there is no means of control on the amount of leachate runoff. In a recent proposal for a new landfill site the dump would be sealed and the leachate would be channelled into a series of anaerobic ponds and aerated lagoons. The leachate quantity is estimated at 16,808m3 per year. With the introduction of MSW collection and briquettes this would reduce the amount of concentrations of pollutants in the leachate and runoff. If the new landfill site was to go ahead the size and management of the lagoons would be reduced. Under current open management conditions the concentrations in the leachate could be reduced by as much as 36% into year 2 and further in the future by as much 76% if all the MSW waste was recycled

Table 24: Typical Concentrations expected in Leachate

Components	Concentration
PH	6 – 8
COD (mg/l)	2,500
BOD_5 (mg/l)	1,500
Total N (mg/l)	1,200
Ammonia-N (mg/l)	1,000
Chloride (mg/l)	2,000
Sulphate (mg/l)	300
Iron (mg/l)	15
Manganese (mg/l)	1
Zinc (mg/l)	1
Copper (mg/l)	0.3
Nickel (mg/l)	0.2
Chromium (mg/l)	0.1
Lead (mg/l)	0.1
Cadmium (mg/1)	0.2
Ref: Study on MSW Landfill site and cost recovery system 1998 Carl Bro Ltd	

Landfill Gas

The organic part of the waste to be landfilled will decompose forming a natural gas. Within the initial period after the landfilling of waste, oxygen will still be available and the produced gas will mainly consist of carbon dioxide. When the oxygen has been used up, which happens very quickly, the decomposition normally goes into the methane fermentation phase through a transition phase. In the fermentation phase methane, carbon dioxide and small amounts of other gases will be generated.

The total amount of gas from the landfill, which mainly will contain municipal solid waste, can in theory exceed 400 litres per kg wet waste. Practical investigations have shown that the total gas amount will hardly exceed 200 litres per kg waste.

The distribution of gas production over time is even more uncertain than the total amount of gas, as it depends on the distribution of easily and hardly degradable compounds within the waste as well as the actual conditions for the decomposition process at the landfill.

It can be estimated, however, that the gas production can be as much as 35 litres per kg waste per year; that the production will not reach its maximum until after the closure of the landfill and that it will continue for a long period of at least 30-40 years after land filling has stopped.

It is particularly important to avoid the production of Methane and its release into the atmosphere because its short-term effect on the Greenhouse Gas contributions is in the order of 21 times the index for Carbon Dioxide. Based upon the projections for collected and briquetted MSW the amount of landfill gas prevented from release into the atmosphere is in the order of 1,400,000m3 by year 2004.

Overall, the benefits of lower gas emissions would be lower GHG contributions, less likelihood of waste dump fires and less smell and the lower release of more toxic emissions.

9. Health Impacts

There are important considerations regarding health impacts on the workers responsible for sorting through the MSW, exposure to emission pollutants during briquette manufacture and during combustion by the users.

9.1. Waste Collectors and Sorters

MSW is considered to be non-hazardous and comprises of waste from households, commercial establishments, institutions and markets. Nevertheless, the nature of waste as it decomposes can cause toxic, allergenic and infection responses amongst those persons exposed and in contact with it. Health studies in developing countries indicate that waste picking is high-risk work. Some of the results are highlighted below.

- Tuberculosis, bronchitis, asthma, pneumonia, dysentery, parasites, and malnutrition are the most commonly experienced diseases among waste pickers based on health studies of waste pickers conducted in Bangalore, Manohar, and New Delhi in India
- At Metro Manila's main open dump in 1981of 750 waste pickers studied 40% had shin disease and 70% had upper respiratory ailments.
- 180 waste pickers at the Calcutta open dumps in India were studied in 1995. During the course of one year 40% had chronic coughs and 37% had jaundice. The average quarterly incidence of diarrhea was 85%, fever was 72%, coughs and colds were 63%. Eye soreness or redness occurred quarterly in 15% and skin ulcers in 29%, with nearly all rates higher at the largest dumpsite than these averages.
- A comparative study of waste pickers working at Calcutta's Dhapa dump in the 1980's and nearby farmers who use organic solid waste as fertiliser showed that pickers reported higher prevalence of respiratory diseases (pickers: 71% vs. farmers: 34%), diarrhea (pickers: 55% vs. farmers: 28%) and protozoal and helminthic infestation (32% vs. 12%).
- At the Bombay open dumpsites 95 solid waste workers were surveyed and examined. Of all landfill workers surveyed 80% had eye problems, 73% had respiratory ailments, 51% had

gastrointestinal ailments, 40% had skin infections or allergies, and 22% had orthopedic ailments. Based on clinical examination, 90% had decreased visual acuity. Most workers complained of eye burning, diminished vision, redness, itching, watering. Clinical examination showed 27% had skin lesions, of which 30% were determined to be directly related to their occupation.

The Waste Collection Associations do take precautions to minimise the risks:

- All staff are vaccinated against tetanus
- Workers are provided with protective clothing including boots, overalls and gloves
- Respiratory masks

It is also advised that the associations set up a medical fund to help provide medical assistance. Training is provided on the dangers of handling waste and the precaution that should be taken to avoid injury and infections. The recycling centres should be equipped with washing facilitities, so workers can fully clean themselves before returning home after work.

9.2. Briquette Manufacturing

Once the MSW is dry and sorted it becomes less hazardous. However, the particle size is very much reduced and the likelihood of inhaling the dust in the form of minute particles increases. This could lead to increased risk of respiratory diseases particularly in the staff responsible for bulk handling and moving the MSW from one place to another. Those persons most at risk should be provided with respiratory masks. The MSW is subjected to temperatures of 250^{o}c and higher in some areas during the briquetting process. When the briquettes exit the machines they will continue to smoke and smoulder until they cool down. This smoke is particularly dangerous and comprises organic volatiles that can be carcinogenic if inhaled. The risk of infection would be greatly increased depending upon the dosage and the duration and frequency of exposure. Furthermore, the volatiles could lead to a fire if exposed to a flame or additional heat.

The briquetting plant should therefore be housed in a well-ventilated room with smoke removal hoods fitted over the cooling tracks to extract the fumes coming from the hot briquettes.

There is no increased risk of handling and sorting MSW after briquetting compared to wood.

9.3. Exposure to products of combustion

The complete combustion of biomass produces carbon dioxide and water, however, complete combustion is never actually achieved and incomplete combustion will produce toxic gases such as carbon monoxide, methane and thousands of other products that can be carcinogenic. The combustion temperature, turbulence factors and time spent in the combustion zone are the determining factors that lead to more complete combustion and lower toxic emissions. In this regard briquettes do have a slight advantage over wood. Briquettes have moisture contents much lower than can normally be achieved in wood, typically 10% compared to 30% or even as high as 70% if the wood if fresh. The presence of moisture will retard the temperature thereby tending to increase smoke production and toxic emissions.

The intended market for briquettes is institutions with wood stoves that have chimneys to remove smoke to the outside. Nevertheless, it is common that some smoke will remain in the kitchen area because smoke leaks out of the stove doors. Briquettes have two advantages over wood. The emissions will be lower because the moisture content is lower and the stove doors can be fully closed during cooking because long sticks of wood are often left protruding out of the doors which encourage the leaking of smoke into the kitchen.

10. Project Implementation and Management Skills

ENEDOM and TTT is a new joint venture that still has to be legally registered in Rwanda. The development, formulation and agreement of the new company constitution, regarding the functioning and ownership of the joint venture is currently in progress. In 2001, Mr Jean Marie Vianney Kayonga the owner and manager director of ENEDOM contacted GTN (Global Technology Network) seeking technical and financial assistance to further develop the Briquetting Business. GTN carried out a partner search and identified TTT. In September, 2001 ENEDOM completed a TTT application to become a partner and paid US$2,500. During, 2002 ENEDOM and TTT jointly developed the briquetting project and application for BLCF funding.

10.1. ENEDOM

The company was established by its sole owner Mr Jean Marie Vianney Kayonga. Its sole business is the manufacture and marketing of briquette biomass residues. It currently employs 25 persons mostly on a part-time basis.

Jean Marie started in 1996 researching opportunities and markets for briquette fuels. In 2000 he created the company ENEDOM and secured funding from UNDP (US$40,000) and Swiss Embassy (US$20,000) to setup a Briquetting Plant. Jean Marie provided US$60,000 of his own capital to secure the land and erect the current factory buildings and facilities. In April 2001 the pilot machine arrived from DeV-Tech in India. The Briquetting press was later installed by DeV-Tec engineers who provided 15 days training to ENEDOM workers. Jean Marie conducted a further 1 month of development work on the machine to adjust the process to coffee husks. Full scale operation of the briquetting process started in June 2001. To date 850 tonnes of briquettes have been manufactured using sawdust, and coffee husks and small quantities of papyrus. In 2002, trials were carried out on 2.5 tonnes of MSW.

10.2. TTT (Tucson Transatlantic Trading)

The company is a privately owed US corporation with 15 years experience in structuring joint ventures between technology based firms in the USA and Europe (Annex 6 TTT Executive Memorandum). According to Alex Dely the Executive Director, TTT Inc Holding Group has the following main operating units:

TTT Development Projects, with 5 Divisions:

1) TTT Europe Development Company
2) TTT Africa Development Company
3) TTT Asia Pacific Development Company
4) TTT Energy Development Company
5) TTT Food Processing Development Company
   -TTT Services
   -TTT Scientific R/D

The 2002 Board of Directors consists of:

- Alex Dely (USA)
- Marni Patterson (USA)
- Franz Schreiber (Germany)
- Charles Mulagwe (Uganda)
- Terri Lee (Taiwan)

all with major corporate expertise.

TTT has presently an active US OPIC (Overseas Private Investment Corporation) Credit Facility, validating its financial capability.

Previous experience in pelletising/briquetting involves 2 major projects:

- city of Tucson/Arizona municipal waste processing via patented Burkett Mill into
- both pellets and waste/composite mixtures for housing materials
- coal mining ash reprocessing with resins into briquettes

TTT has **NO previous experience of marketing biomass fuels to poor/middle income households in developing countries** and their activities in the energy sector involve industrial cogeneration, boiler/chiller/etc type projects. A lists of previous/current projects is available on the updated TTT website (http://www.ttthg.com/).

It has not been possible to hold joint meetings with TTT and much of the experience and capabilities of TTT therefore remain unverified. Their annual turnover and accounts are currently not available and it is advised that these are requested as soon as possible.

10.3. Project Swot Analysis

Strengths	**Weaknesses**
18 months hands on experience Skilled staff Strong relationship with small client base Demand greater than supply Proven acceptance of products Good local knowledge on the supply of raw materials	No Business Plan No company profile or publicity brochure Market research lacking No monitoring of comparative advantages of briquettes Poor reporting and follow up with donors TTT role and experience
Opportunities	**Threats**
There are no briquetting competitors. Setup costs and extensive learning curve will likely deter other producers Can easily expand as the only producer of Briquettes. Promotion and distribution of appliances Wood fuel supply diminishing	Staff may leave to setup rival factory Supply of residues may decline or prices increase. Demand for residues for use in other industries may emerge. Current factory too small and supply of briquettes to irregular to client base. Financial support is available at least for the first 3 years

11. Annexes

1. **Pilot Factory Set-up and Operating Costs**
2. **Proposed Briquette Factory Set-up and Operating Costs**
3. **Briquette Production Economic Analysis**
4. **Conversion and Emission Factor (IPCC /OECD Methodology)**
5. **Combustion trials: Institute Scientifique de Service Public**
6. **TTT Executive Memorandum**
7. **Picture Gallery**
8. **References**
9. **Contacts**

Annex 1 – Pilot Factory Set-up and Operating Costs

1. Pilot Plant Costs Frw							
Items		Costs Frw					
Land:provided free by City Council							
Buildings		25,000,000					
Services: Installation Costs		0					
Electricity		30,000					
Water		75,000					
Tel		45,000					
Equipment:US$600000 Grant		30,000,000	UNDP: 40,000 Swiss 20,000				
	Total	55,150,000	4mth	8mth		**Cost/kg**	
2. Operating Costs Frw			Op	Non-op	Op	NonOp	Tot
Services							
Electricity: Operating RF42 /Kwh		300,000	1,200,000				
Electricity: Non operating		5,000		40,000			
Water		10,000	40,000	80,000			
Telephone		50,000	200,000	400,000			
Vehicle per month		175,000	700,000				
		Total	2,140,000	520,000	3.57	0.87	4.43
Raw Materials							
MSW from NGOs	RF/kg	8	5,280,000				
Coffee Husks: 4-5Kms		5					
Saw Dust: 1Kms		4.5 to 6					
Papyrus: 20Kms		12 to 14					
Sheet for drying per month		40,000	160,000				
Packaging: Bag per 50Kgs		110	1,320,000				
		Total	6,760,000	0	11.27	0.00	11.27
Staff							
Labourers RF /day	20	700	1,428,000				
Hammer Mill Operator RF/mth	1	60,000	240,000				
Press Operator	1	100,000	400,000				
Cleaner	1	30,000	120,000	240,000			
Marketing	1	80,000	320,000				
Manager	1	300,000	1,200,000				
Accountant	1	100,000	400,000				
Askari Non-operating days	2	700		368,200			
		Total	**4,108,000**	608,200	6.85	1.01	7.86
Maintenance							
Piston: every 160hrs resurfacing		25,000	159,375				
Die: every 2 months repairs		35,000	70,000				
Crank every 700 hrs replacement		200,000	291,429				
Oil Change every 15days		16,000	108,800				
Grease every 15days		8,000	54,400				
Hammer Mill every 6mth		80,000	53,333				
			737,337	0	1.23	0.00	1.23
Total production Costs			13,745,337	1,128,200	22.91	1.88	24.79
3. Income Frw							
Briquettes: total sales over 18mths	900	35,000	21,000,000		35.00		
Delivery costs 740/10tons/km							
		Profit	**7,254,663**				

Annex 2 – Proposed Briquette Factory Set-up Costs

			Exch Rate Dec2002	**470**	**Total**	
1	**Land and Infrastructure**	**Units**	**US$**	**Frw**	**US$**	
1.1	Land preparation			4,000,000		
1.2	Buildings					
1.2.1	Plant Building	1,400	100	65,799,328	140,000	
1.2.2	Office building	600	150	42,299,568	90,000	
1.2.3	Warehouse	1,000	100	46,999,520	100,000	
1.2.4	Drying Concrete Slab	600	100	28,199,712	60,000	
1.2.5	Road construction	450	300	63,449,352	135,000	
1.2.6	Sanitation & Storm Drainage	294	100	13,817,859	29,400	
1.2.7	Perimeter Fence	800	50	18,799,808	40,000	
	Sub-total 1				**594,400**	
2	**Water, Electricity & Comms**					
2.1	Water connection			500,000	1,064	
2.2	Elec Lines and connections			1,000,000	2,128	
2.3	Telecommunications			400,000	851	
	Sub-total 2				**4,043**	
3	**Equipment**					
3.1	Briquetting Plant		483520	227,252,079	483,520	
3.2	Forwarding, Frieght to Kigali		66176	31,102,402	66,176	
3.3	Installation & commissioning		48350	22,724,268	48,350	
3.4	Wkshop Facilities & equipment			2,800,000	5,958	
3.5	Wieghing Scales	3	2000000	6,000,000	12,766	
3.6	Office Equipment			14,312,000	30,451	
3.7	Vehicles:			14,000,000	29,788	
3.8	Vehicles:			17,000,000	36,171	
3.9	Vehicles				0	
3.1	Installlation IT services & Coms			8,052,000	17,132	
	Sub-total 3				**730,311**	
4	**Training**					
4.1	Technical & Management			10,000,000	21,277	
4.2	Manual Preparation			2,219,875	4,723	
	Sub-total 4				**26,000**	
5	**Legal and Professional Fees**					
5.1	Lawyer & Solicitor Fees			300,000	638	
5.2	Licenses and permits			620,000	1,319	
	Sub-total 5				**1,957**	
6	**Insurance**					
	Buildings and Equipment			437,667	931	
	Vehicles			509,552	1,084	
	Sub-total 6				**2,015**	
7	**Bank Fees**			1,466,493	3,120	
8	**Advertising and Promotion**			1,000,000	2,128	
			Sub-total 7-8		**5,248**	
			Total Set Up	**645,061,483**	**1,363,975**	1,372,485

Annex 2 cont..

Briquette Production Setup Costs Operational

9	**Operating Costs (monthly)**				**Sales**		
		Units	**Costs**	**Costs Frw**	**Kg**	**Income**	
	Raw Materials Dry MSW	1375	8000	11,000,000	1250	43,750,000	
	Packaging			3,712,999			
	Raw Materials		1900800				
	Metals		12199				
	Briquettes		1800000			**US$**	
	Salaries			3,285,000		6,989	83,873
	Utilities	76000	42	3,192,000		6,792	81,499
	Communications			291,125		619	7,433
	Advertising & Promotion			200,000		426	5,106
	Travel Costs			469,995		1,000	12,000
	Training			300,000		638	7,660
	Fuel	3000	400	150,000		319	3,830
	Office supplies			130,000		277	3,319
	Maintenance			2,176,892		4,632	55,581
	Spares			461,854		983	11,792
	Insurance			30,000		64	766
	Transport MSW & Briquettes	1375	2000	2,750,000		5,851	70,213
	Financial Fees			30,000		64	766
	Taxes	12	6500000	541,667		1,152	13,830
	Miscellaneous			500,000		1,064	12,766
			Total	29,221,532		62,174	370,434
			Cost/Kg	**23.38**			
		Selling Price /kg		**35**			
	Basis for Costs						
	Target Daily Production	75	Tons/day				
	Assumed Days Production	200	days/year				
	Annual Production	15000	Tons/year				
	Raw Material (10%+Briquettes)	16500					

Annex 3 – Briquette Production Economic Analysis

Briquette Cashflow Analysis

Financial Year Ending:		1	2	3	5	8	11	14	17	20	Total
Income											
Monthly production (1250 t)	t		15,000	15,000	15,000	15,000	15,000	15,000	15,000	15,000	
selling price ex factory per tonne	US$/t		74	75	79	83	88	94	100	106	
Sales Revenues	US$/t	0	1,110,000	1,132,200	1,177,941	1,250,040	1,326,553	1,407,748	1,493,914	1,585,353	
Other Income (avoided cost)	CUs										
Waste dumped (per year)	t										
process+dump (cost /ton											
Total Income	CUs	0	1,110,000	1,132,200	1,177,941	1,250,040	1,326,553	1,407,748	1,493,914	1,585,353	
Expenditure											
Capital Costs (breakdown local curreny and US$)											
Infrastructure plus utility (total 1 +2)	CUs	-598,443									
Equipment (total 3)	CUs	-730,311									
tranining	CUs	-26,000									
Other (licences, bank fees etc..)	CUs	-13,263								0	
replacement cost	CUs										
Sub-Total	CUs	-1,368,017	0	0	0	0	0	0	0	0	
Operating Costs (2% +/year)	US$										
a- Salaries	unit		-83,873	-85,551	-89,007	-94,455	-100,236	-106,371	-112,882	-119,792	-1,915,711
b-Raw material (1375 tx US$17.02)*12			-280830	-286,446	-298,019	-316,260	-335,617	-356,160	-377,960	-401,094	-6,414,314
c- Utilities	US$		-81,499	-83,129	-86,487	-91,781	-97,398	-103,360	-109,687	-116,400	
d- transport	unit		-70,213	-71,618	-74,511	-79,072	-83,912	-89,048	-94,498	-100,282	
e- Maintenance			-55,581	-56,692	-58,983	-62,593	-66,424	-70,490	-74,804	-79,383	
f- Other costs											
f- Other costs			-64,672	-65,966	-68,631	-72,832	-77,289	-82,020	-87,040	-92,368	
Sub-Total	CUs	0	-636,669	-649,402	-675,638	-716,992	-760,878	-807,450	-856,872	-909,319	
Total Expenditure	CUs	-1,368,017	-636,669	-649,402	-675,638	-716,992	-760,878	-807,450	-856,872	-909,319	
Net Cashflow Before Fin&taxes	CUs	-1,368,017	473,331	482,798	502,303	533,048	565,675	600,299	637,042	676,034	
Financing Charges and taxes											
Taxes	CUs		-13,830	-14,107	-14,676	-15,575	-16,528	-17,540	-18,613	-19,753	-315,883
Financing Charges	CUs		-766	-781	-813	-863	-915	-971	-1,031	-1,094	-17,495
	CUs										
Net Cashflow for Year	CUs	-1,368,017	458,736	467,910	486,814	516,611	548,232	581,788	617,398	655,187	
Retained cash flow		-1,368,017	-909,281	-441,371	522,712	1,881,180	3,493,837	5,044,034	6,860,147	8,626,254	

Returns on Project		
IRR (pre-tax nominal)		34%
NPV @ 12.0%	CUs	2,282,149

Annex 4 – Conversion and Emission Factor (IPCC/OECD Methodology)

Conversion and Emission Factors

Fuelwood

		1000 Kg/TJ
13.8 MJ/kg	PCI wood	1000 Kg/32,47MT
13.8 GJ/MT	PCI wood	
13.8 TJ/1000 MT	PCI wood	32.47 MT/TJ
29.9 t C/TJ	(IPCC/OECD default Factor)	
412.6 t C/1000 MT	(emission factor for consumption)	

Charcoal

30.8 MJ/kg	PCI charcoal
30.8 GJ/MT	PCI charcoal
30.8 TJ/1000MT	PCI charcoal
22.7 t C/TJ	(derived from IPCC/OECD assumption of 0,7 Carbon fraction of the charcoal)
700.0 t C/1000 MT	(emission factor for consumption derived from IPCC/OECD assumption above)

Emission factors for Woodfuels use (1000 MT GHG/1000 MT)

Conversion from Carbon to CO2: **3.667**

	CO2	CH4	N2O	NOx	CO	NMVOC
Fuelwood	1.513	0.00414	0.0000552	0.00138	0.069	0.00828
Charcoal (per unit of charcoal produced and consumed)						
Consumption process	2.567	0.00616	0.0000308	0.00308	0.2156	0.00308
*Production process**	6.511	0.0308		0.000308	0.2156	0.05236
Total Charcoal	9.078	0.037	0.0000308	0.0034	0.431	0.055

Specific CO2 emission due to charcoal production was not provided by IPCC/OECD methodology.

For the pupose of the current study, an emission factor was derived by considering the difference between the carbon content of the Fuelwood units used as inputs in the production process, and the resulting carbon content of the charcoal output. This difference is considered as the carbon that was emitted to the atmosphere.

Annex 5 – Combustion Trials: Institute Scientific de Service Public

Annex 6 – TTT Executive Memorandum

TUCSON TRANSATLANTIC TRADE INC HOLDING GROUP (USA)
8522 E. Helen Place, Tucson, Arizona 85715, USA
Phone: Intl + 520-721-4336 Fax: Intl + 520-886-7234 E-mail: Dely@ttthg.com

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TTT 2002-2004 ENERGY AND ENVIRONMENT PROJECTS EXECUTIVE MEMORANDUM

SUMMARY: Upon execution of a Partnership Agreement between TTT and a suitable local Partner Group, TTT proposes to implement via its USA daughter companies a LONGTERM TWO-WAY RELATIONSHIP, with following INTEGRATED set of components:

1) **1000 MEGAWATTS OF ELECTRICITY/STEAM/HOT WATER GENERATION AND DISTRIBUTION USING WORDCLASS PROPRIETARY TECHNOLOGIES AND SHARED ENERGY SAVINGS FINANCING:**

   - **High Energy Efficiency Steam/Hot Water Boilers (Oil/Gas/Coal/Biomass Fired)**
   - **High Energy Efficiency Coal Burners**
   - **Advanced 4 Function Commercial/Industrial HVAC Systems**
   - **(Micro) Turbines (possibly coupled to Fuel Cells)**
   - **Integrated Biomass Systems**
   - **Stirling Engines**
   - **Advanced Motor Systems**
   - **Small Scale Hydro/Dams**
   - **Advanced Solar Technologies**
   - **Advanced Water, Wastewater, Air and Land Pollution Control and Recycling Technologies**

2) **DEVELOPMENT OF A NETWORK OF SMALL/MEDIUM SIZE FIRMS FROM THE AMERICAS, EUROPE, ASIA AND AFRICA TO PARTICIPATE IN LARGE SCALE ENERGY SECTOR PROJECTS GLOBALLY, AND TO MARKET THE CAPABILITIES OF ALL OUR PARTNERS GLOBALLY.**

BACKGROUND:

Tucson Transatlantic Trade, Inc is a privately-held US corporation with majority ownership by the Dely family in the USA and Belgium. In the past 15 years TTT has concentrated in structuring joint ventures between technology based firms in the USA and Europe, and **TTT presently has active Private/Public sector STRATEGIC and INDUSTRIAL SECTOR PARTNER relations with more than 20 Firms/Agencies in North America, the European Union, Central Europe, Asia and Africa. TTT has corporate subsidiaries in many of these countries as well.**

In the early 1990's TTT began taking increasingly large equity positions in several Joint Venture companies TTT co-founded with European partners, each specializing in a TTT Sector of specialization.

The TTT Inc Holding Group has ZERO debts/liabilities, and 50% or greater shareholding stakes in TTT Industry Sector and Global Regional Subsidiaries focused on 4 High Growth Global Industry Sectors:

- **Energy and Environment**
- **Factory Automation and Construction**
- **Food Processing**
- **IT/Telecommunications**
- **Medical**

Other key TTT assets include select state-of-the-art technologies and intellectual property rights, a substantial US and international Customer Base, and the ability to offer Shared Energy Savings/Shared Operational Efficiency Improvement Financing to selected global customers.

For more than a decade **TTT has actively assisted the Boeing Aerospace Group and its Tier I/II/III Supplier Base** in arranging commercial transactions as part of their Military/Civilian Offset Contract obligations, and we have solid access to many of their US/international facilities.

A detailed overview of TTT's Structure, Mission, Vision, Customers, Subsidiaries, Technologies, Financing. Partnership Options, etc can be found at our corporate Website at www.ttthg.com

TTT's Energy Program activities began in 1985 with the systematical international expansion of the 4 Function DISCO Industrial/Commercial HVAC technology in cooperation with Disco Engineering Inc. These activities expanded to Boiler technology in 1996 with initial funding from Tucson Electric Power, a subsidiary of Unisource Holding, a New York Stock Exchange-listed utility holding group headquartered in Tucson. Since then TTT has expanded into projects involving cogeneration, advanced engine systems and alternative energy technologies.

TTT ENERGY DEVELOPMENT COMPANY (TEDC) "SHARED ENERGY SAVINGS" FINANCIAL/MARKETING METHODOLOGY:

TEDC will typically employ one of the following FINANCING methods for Energy Projects:

1) **TEDC becomes THE FULL PARTNER in the project by offering a Customer our technologies on a "Shared Energy Savings" basis. TEDC obtains the financing for the project, handles project engineering/procurement, and offers "turnkey equipment" at NO/LOW UPFRONT COST in return for a 5-10 year contract in which TEDC shares the financial value of the energy savings/benefit generated by our equipment with the Customer on a 50%-50% basis. The basis for energy savings/benefit comparison is determined on case-by-case basis in the project Due Diligence stage.**

2) **TEDC joins the project as ONE of TWO/MORE CO-PARTNERS in the project. As in option 1), TTT offers its "Shared Energy Savings" program, but in recognition of its reduced financial risk, TEDC will share with the other CO-PARTNER(s) the 5-10 year value of TEDC's 50% split of the energy savings/benefit generated by the project. The exact formula for the division of this value between TEDC and its CO-PARTNER(s) will be determined on case-by-case basis.**

3) **TEDC generates third-party financing (buyer credit) for a project, but is not otherwise asked to be involved in the implementation/operation of the project/ plant. In this case TEDC will receive a percentage commission on the loan transaction value.**

TTT ENERGY DEVELOPMENT COMPANY CUSTOMER SELECTION AND PROJECT EVALUATION PROCESS:

TEDC's technology and financial/marketing programs are sufficiently unique that it can afford to be very discriminating in its selection of Partners/Customers.

The IDEAL CUSTOMER for a TEDC ESCO/"Shared Energy Savings project is a firm that not only has an "energy generation and/or environment and/or process inefficiency challenge", but also operates in an industrial sector in which TTT is operational so TTT can also help the Partner/Customer with USA/International market penetration, technology transfer, management training, quality certifications, etc (with TTT target customer concentrated in the Aerospace, Automotive, Factory Automation, Oil/Gas and Petrochemical, Advanced Materials, and Food Processing sectors).

Typical INDIVIDUAL PROJECTS will fall in the 1 to 25 MW capacity range, with larger projects requiring a separate IPP (Independent Power Producer) approach.

The KEY PROJECT ANALYSIS PHASES are:

1) **Agreement in principle from the Customer's Senior Management that TEDC may deliver at low/no cost a system of hardware/software to be jointly agreed upon, in return for a 5-10 year contract in which TEDC and the Customer will share the resulting energy savings/benefit on a 50-50 basis.**

2) **An intensive Audit by TEDC of the Customer's facilities/processes to establish in writing all the feasible methods by which energy/operational savings may be accomplished, including a mathematical determination of the "baseline energy efficiency" level of the overall facility and all key subsystems. Some of this analysis may be done via a protected section on the TTT Internet Website.**

3) **Determination by TEDC of the optimum suggested new hardware/software configuration to be implemented and its "target energy efficiency" level. While TEDC proprietary technologies will be used to the optimum extent, TEDC will use best available technology whenever feasible. The percentage energy efficiency improvement or energy benefit generated, serves as the basis for the contractual 50-50 energy savings value split.**

4) **Upon delivery by TEDC to the Customer of the agreed upon hardware/software solution, the Customer agrees to maintain/operate the plant/energy systems in such a way as to maximize the energy efficiency improvement for both TEDC and the Customer. TEDC will continue to monitor the the operations both electronically and physically, offer additional training, and other activities to maximize mutual gain. Energy savings payments will be calculated and disbursed to TEDC on a quarterly basis. The ownership status of the equipment is a negotiable item pending legal/tax/etc considerations.**

TYPICAL COOPERATION MECHANISM BETWEEN TTT AND NEW INDUSTRIAL SECTOR PARTNER GROUP:

Upon activation with the NEW PARTNER of a TTT Industrial Sector Partnership Agreement, TEDC suggests the joint implementation of the following activities:

1) **IMPLEMENTATION OF UP TO 1000 MEGAWATTS OF NEW GENERATION/ DISTRIBUTION CAPACITY IN 2002-2004, THROUGH THE INSTALLATION OF 10-20 MW TEDC ENERGY SYSTEMS AT UP TO 50 PRIORITY LOCATIONS IN THE NEW PARTNER'S COUNTRY.**

   The New Partner and TTT will jointly select the project locations based on local need

and economic viability, but TTT envisions there will be a balance between commercial/ industrial sites and high priority public service sites (such as schools, hospitals).

As the Payback Period for TEDC equipment is 1-2 years, while the "Shared Energy Savings" contract will run 5-10 years (and the equipment will have a useful life of 20-30 years), TEDC will only need BRIDGE FINANCING. A "typical" project is estimated to cost TEDC between $ 250,000 and $ 1 million in upfront costs. The $ 20-30 Million US financing for the initial 3 year program is suggested to be obtained from a Credit facility TEDC and the local Partner will seek with a consortium of financial institutions/industrial groups, including but not limited to:

- Bank of America - Boeing Aerospace Group Offset Program
- General Electric Capital - US EXIM Bank - US OPIC
- EBRD - EIB - ING -
- ABN-AMRO

subject to each Project meeting the requirements of the TTT Project Investment Guidelines document.

2A) DEVELOPMENT OF A NETWORK OF AMERICAN/EUROPEAN/ASIAN/AFRICAN SMALL/MEDIUM SIZE FIRMS TO COMPETE GLOBALLY ON LARGE SCALE ENERGY PROJECTS.

Significant new energy project opportunities present themselves throughout the world:

*** within each country: due to Utility restructuring/privatization and infrastructure upgrades**
*** in certain focus regions such as the Caspian/Black Sea with development of new oil/gas fields**

The economy and job creation in each country will only truly blossom if a significant number of private small/medium size technical firms are able to participate in the large scale proposed projects (pipelines, power plants, etc) with resulting technology transfer.

TTT is forming a CONSORTIUM of AMERICAN/EUROPEAN/ASIAN/AFRICAN Small/Medium size Engineering/Technical firms to jointly bid for participation in Large Scale Energy Projects and their associated Environmental Controls. This TTT CONSORTIUM will cover all phases/aspects of Energy Development/Hardware/Services, including but not limited to:

ENERGY SYSTEMS:

- **Boiler/HVAC Installation/Maintenance**
- **Oil Field Equipment (Rods/Pumps/Compressors/Tanks/Well Services/ Tools, Pipes/Drilling, ….)**
- **Chemicals/Coatings**
- **Bearings**
- **Control Systems/Regulators**
- **Cooling Towers**
- **Corrosion Control**
- **Electrical/Mechanical Equipment Rental/Service/Repair**
- **Measuring Systems/Gauges**
- **Geologists/Geophysicists/Laboratories**
- **Machine Shop Services**
- **Oil/Gas Marketers**

ENVIRONMENTAL SYSTEMS

- **Water and Wastewater Treatment**

- **Air Pollution Control and Monitoring Systems/Services**
- **Soil Pollution Control and Monitoring Systems/Services**
- **Hazardous Waste Control Systems/Services**
- **Waste Reuse Systems/Services**

2B) INDUSTRIAL PARK DEVELOPMENT:

In each country TTT with suitable local industrial/engineering groups may have the necessary critical mass in Energy/Environment projects to establish a "Technology Incubator Industrial Park" focused on Energy/Environment/ Factory Automation and using TEDC technologies as the nucleus. Such industrial park(s) would ideally be located in a Free Trade Zone, in coordination with a University/Polytechnic/Technical Institute.

2C) PROMOTION OF NON-USA PARTNER'S INDUSTRIAL CAPABILITIES TO:

- **TTT's USA and rapidly developing European/Asian/African Customer Base (6,000 plus firms) for Distribution/Joint Ventures**
- **Boeing Aerospace Group Offset program Contacts**

TTT IS OF COURSE OPEN TO SUGGESTIONS FROM OUR PARTNERS REGARDING OTHER PROJECTS OF POSSIBLE REGIONAL/NATIONAL AND/OR INTERNATIONAL MUTUAL INTEREST!

COMMITMENT REQUIRED BY TTT FROM NEW PARTNER: Execution of a TTT Partnership Agreement (including one-time Partnership Fee of 5,000 US Dollars/Euro).

Respectfully Submitted. Alex Dely, President

Annex 7 - Picture Gallery

Annex 8 - Reference Materials

1. The Government of Rwanda Poverty Reduction Strategy paper. Ministry of Finance and Economic Planning June 2002
2. Country Profile Table: The World Bank Group December 2002
3. Bulletin de Statistiques Energetiques du Rwanda Edition GTZ 1992
4. National Forestry Situation and Forestry Statistics. MINAGRI Sept 1999
5. Occupational and Environmental Health Issues of Solid Waste Management: Sandra Cointreau. August 2000
6. The Briquetting of Agricultural Waste for Fuel. FAO
7. Rwanda: Energy Data. Augustin Hategeka October 2001
8. Biomass Briquetting: Technology and Practices FAO Bangkok 1996
9. Training on Efficient methods of Production Charcoal and Improved CookStoves. Albert Butare 1997
10. Proceedings on the International Workshop on Biomass Briquetting FAO Bangkok 1996
11. Revised 1996 IPC Guidelines for National Greenhouse gas Inventories

Annex 9 – Contacts and Site Visits

KIST- Kigali Institute of Science and Technology Albert Butare Vice Rector Avenue de l'Armee BP 3900 Kigali	GTN Global Technology Network Representative William Rutaremara
EC Franck de Saint Simon Cellule de Securite Alimentaire BP515 Kigali	USAID Embassy of the USA Djenaba Kendrick Economic/Consular Boulevard de la Révolution. Kigali
Federation Rwandaise du Secteur Prive Kalisa John Bosco Charge du Departement des Affaires Economiques et Fiscales BP 319 Kigali	City Council Innocent Gashugi. Incharge Sanitation and Environment protection
UNDP Laurent Rudasingwa Environment and Energy Focal Point	FCD Mukakarigeya Scholastique Bureau a Kigali BP 1529 Kigali
	College du Christ Roi BP 61 Nyanza

Field Visits

- Gisozi Market
- Ruyenzi Brick Kilns
- Nyanza Land Fill Site
- ISUKU Recycling Centre & Sorting Centre
- FCD Recycling Centres
- Kinyinya Brick Kilns
- ENEDOM Pilot Plant and Work Shops
- Nyakabanda Sorting Centre
- KIE-Kigali Institute of Education
- KIST Work Shop