Production of fuel briquettes from charcoal waste in Diego, Madagascar

Viability Assessment

for ECO-Consulting Group

by Matthew Owen

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Acknowledgements

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Table of Contents

1. Introduction

1.1 Programme background

With funding from the German Agency for International Cooperation (GIZ), and in collaboration with the government of Madagascar, the *Programme Germano-Malgache pour l'Environnement* (PGM-E) is addressing natural resource management and wood energy supply issues in Madagascar. One of the project's focal areas is the city and environs of Antsiranana (also known as Diego Suarez), capital of Diana Region in the far north.

PGM-E is being implemented by ECO-Consulting Group, a German firm with a long-established presence in Madagascar and significant expertise in the development of economically and environmentally sustainable approaches to woodfuel supply, conversion and utilisation.

As part of a package of initiatives designed to improve natural resource management and modernise energy supply to Diego, the ECO-Consult/PGM-E team (building on the work of its precursor programme *Gestion Rationnelle de l'Energie et de l'Environnement* - GREEN-Mad) have introduced measures to increase the sustainability of the charcoal value chain. These include the production of wood in managed eucalyptus plantations, the introduction of more efficient kilns and the promotion of fuel-saving stoves. The project has also noted that dust and fines are discarded by both rural and urban charcoal traders, and might present an opportunity for salvage and densification to produce marketable fuel. Initial efforts were made in 2012 to briquette the dust from one PGM-E "Green Wood Energy"(GWE) marketing group, but there was little consumer interest in the product due to friability and high ash content. A project staff member visited Senegal in June 2012 to learn from the briquetting experiences of another GIZ-funded project, PERACOD[1], and returned with various additional ideas for briquetting upon which the project hopes to build.

1.2 Briquetting feasibility study

Chardust Ltd. (www.chardust.com) is a Kenyan company specialising in the production of fuel briquettes from charcoal waste, salvaged from wholesalers in the city of Nairobi. The discarded dust and fines are collected by lorry, delivered to Chardust's factory, sieved into different grades, milled to a powder, combined with binders, densified using different types of machinery and then sun-dried before being packaged and sold. The company's lower grade (higher ash) briquettes are used mainly for space heating and water heating in poultry farms, hotels, tourist camps and restaurants, while higher grade briquettes are used mainly for domestic barbecues and commercial meat roasting. Chardust employs around 80 people and briquettes sales average 220 t. per month. Spin-off operations established with Chardust technical assistance now exist in Tanga (Tanzania), Mbarara (Uganda) and Goma (DR Congo).

In order to advance the briquetting initiative within PGM-E, ECO-Consult invited one of Chardust's Directors[2] - who is based in the UK and works also as an independent biomass energy consultant -to

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[1] *Programme pour la promotion des energies renouvelables, de l'électrification rurale et de l'approvisionnement durable en combustible domestiques*.

[2] Matthew Owen.

carry out a viability assessment in Diego. As per the Terms of Reference in Annex A, the objectives of the assessment were to analyse the feasibility (technical, economic, social and operational) of charcoal waste recovery and conversion to briquettes, and to determine the potential of such briquettes to serve as a charcoal equivalent. In the event of a positive conclusion, proposals were to be elaborated for the development and local production of appropriate equipment.

1.3 Methodology

The consultant travelled to Madagascar for four days in September 2012, passing through Kenya en route for discussions with Chardust colleagues on technical options. His itinerary is in Annex B.

The feasibility assessment was based upon:

- visits to rural wood energy groups supplying Diego with charcoal to determine the nature and scale of raw material availability and processing potential;
- visits within the town to charcoal traders, restaurants, households, supermarkets, bakeries and rice millers to establish potential briquette demand and the availability and pricing of the necessary inputs;
- visits to engineering workshops in Diego and Antananarivo to gain an impression of local manufacturing and maintenance capacity;
- consultation with PGM-E staff to gather data (on charcoal supply and demand, energy prices and demographics) and to ascertain their objectives and expectations; and
- lessons learned from the project's past briquetting initiative, the experiences of Chardust in Kenya and the consultant's wider knowledge of commercial briquetting in Africa.

The report is divided into three parts:

- Chapter 2: Technical viability – are suitable materials and equipment available?
- Chapter 3: Commercial viability – would a briquetting operation make business sense?
- Chapter 4: Operational viability – will people buy the fuel, and do the right players exist to make such a business work?

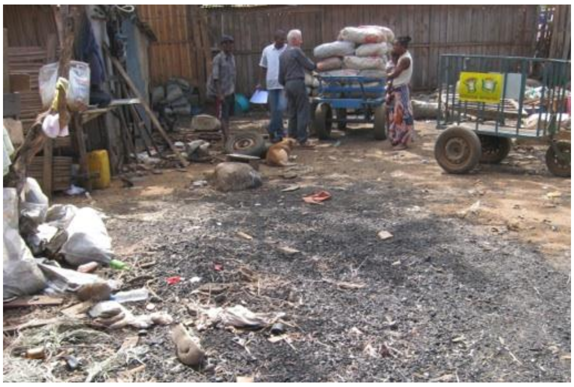
Chapter 5 draws conclusions and proposes a way forward.

2. Technical Viability

2.1 Dust availability

It is self-evident that a charcoal waste briquetting operation depends principally upon the availability of salvageable charcoal waste. In the Madagascan context this means charcoal pieces that are too small for a standard domestic stove and fall through the holes in the grate, i.e. sub-1 cm diameter. At the PGM-E-supported GWE centres, such fines are separated by manual sieving using a 25 mm wire mesh, followed by raking and manual sorting[3]. Measurements by the consultant determined that this sub-1 cm dust and fines comprises 9% of the charcoal by weight. At urban charcoal trading sites the waste percentage is thought to be approximately the same, based on a 10% average that Chardust has recorded on the East African mainland. A key difference between Diego and the GWE centres is that waste in the city is not generally separated until it reaches the final customer, except in the minority of cases where retailers break down the sacks into smaller plastic bags (*sachets*).

Stored dust at AnkitsakaGWE centre



Discarded dust at charcoal dealer in Diego

PGM-E supports three GWE marketing groups, with an average of 33 members each. They are at Ankitsaka, Saharenana and Madirobe, situated 32, 50 and 62 km, respectively, from Diego. The first two are on the main tarmac road to Tana, while Madirobe is on a feeder road that branches off beyond Saharenana.

Based on charcoal sales data provided by PGM-E, the consultant estimated the quantity of dust discarded at the GWE centres and potentially available for briquetting. A similar estimate was made for the city of Diego, based on project data on urban charcoal consumption. These estimates are summarised in Table 1.

Table 1: Estimated availability of charcoal waste at Green Wood Energy centres and in Diego

Location	Ave. charcoal sales (t/mth)	% waste	% of waste deemed salvageable	Salvageable waste (t/mth)
Green Wood Energy centres	14	9%	95%	1.2
City of Diego	1,180	9%	30%	32

Source: PGM-E M&E database and consultant's research. See Annex C for raw data and assumptions.

[3] A finer (10 mm) mesh would make this a more efficient (one-step) process.

As the table illustrates, there is conservatively 32 t/month of dust available in Diego, compared with 1.2 t/month from the rural GWE centres. This equates to just 40 kg per day spread across three locations and is well below the level required to establish a commercially viable briquetting operation. Even at the largest GWE centre (in Ankitsaka) there is currently only 22 kg of dust generated per day. This rules out the possibility of commercial production at the rural centres based on current sales volumes, particularly given that an average of over 30 members per group would be looking to benefit from such a venture in a direct or indirect way.

At full commercial scale when the project-supported groups will be producing 3,600 t/yr of charcoal[4], the available dust may eventually increase to 26 t/mth. However, this will be scattered at 20 sites across a wide areas, with just 40 kg of dust accumulated per group per day and no way of achieving economies of scale.

In contrast, dust availability of around 32 t/month in Diego presents the interesting possibility of a single production facility with daily output of over 1 t.

2.2 Dust quality


Clean charcoal waste at Ankitsaka

The manufacture of briquettes requires high quality charcoal waste with minimal soil contamination, as this ends up as residual ash in the finished product. Fortunately, it appears that the dust potentially salvageable in Diego or at the GWE centres would be of a high standard. Charcoal is sold locally in small bags, averaging just 10.0 kg and 9.4 kg[5] for Diego and GWE charcoal respectively. In Diego this makes it possible to hand-sort without necessarily tipping the entire contents on the ground. Indeed, traders delivering charcoal to their customers often tip out the best charcoal from the top of the sack and retain the value-less dust in the sack, which is then discarded. The material often never leaves the bag and remains in good condition. Similarly at the GWE centres, the dust is hand-sieved onto a plastic sheet or sack, and stored cleanly in bags. In contrast with Chardust's Nairobi operation, this would mean that even the finest material could be used for briquetting without significantly impairing the quality of the end product.

2.3 Access to dust

The bagged waste from the GWE centres is readily available at point sources (the charcoal marketing sheds), from where it is periodically removed and thrown away or burned.

Most of the urban charcoal waste, meanwhile, is scattered across the city as it moves out from wholesaling points inside bags of charcoal. Only at the point of consumption does the user remove the chunks and separate the fines, often returning them to the sack and back to the charcoal dealer. The dealer is motivated by a desire to recover his bags, which are worth Ar. 150[6] each, but in doing

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[4] Of a total plantation area of 6,000 ha, 900 ha are to be harvested each year under a five year rotation, producing 4 t/ha. Assuming 9% dust and 5% losses, 25.7 t of dust will be generated per month.
[5] PGM-E data for Diego and consultant measurements for GWE centre.
[6] 2,810 Malagasy Ariary (Ar.) to the euro and Ar. 2,170 to the US$ in Sep 2012..

so is often handed back the dust. He discards it in the street or in a municipal solid waste bin. Retailers likewise separate the fines, store them temporarily in charcoal bags alongside their stalls, and periodically throw them away.

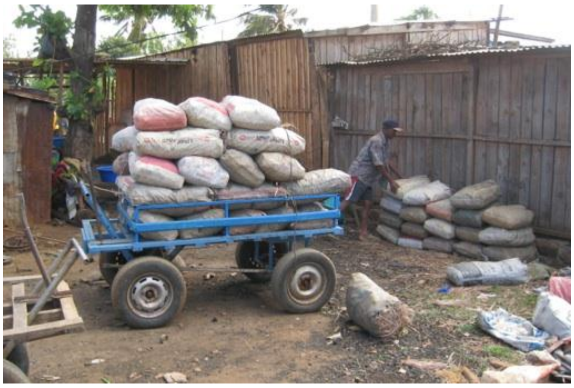
The important point in both the rural and urban cases is that there is already a habit of manually grading charcoal: the largest and best pieces (>3 cm) are sold for cooking; the smaller pieces (1-3 cm) are given away or sold cheaply to small-scale bakers (of *galettes*), blacksmiths or other artisans; the balance (sub-1 cm) is set aside and has no value, but is potentially recoverable via charcoal dealers.

1-3 cm particles (low value) are routinely separated from sub-1 cm fines (no value)

The dealers could no doubt be enticed to consolidate these fines at their depots or points of sale by a small financial offering. They could then deliver the waste to a briquetting facility, or freelance transporters could buy it from them and take up this opportunity. At the GWE centres the dust is already positioned in large heaps ready to use, if required.

Cheap transport within Diego is afforded by the ubiquitous 2-wheeled hand cart (*pousse-pousse*) and by 4-wheeled wagons (*chariots*). The former can carry 26-30 sacks (260-300 kg) of charcoal while the latter can carry 40 sacks (400 kg) with one operator or 60 sacks (600 kg) with two. Dust carrying capacity might be even higher than this, given that dust is denser than charcoal and not fragile.

Pousse-pousse



Chariot

Making use of these local means of transport for dust delivery would not only be cheap, but would also channel income to a low income group of young men within the city by providing them with a new enterprise opportunity.

Producing briquettes on location at the rural centres is one option reviewed below. But from a technical point of view it would not be sensible to convert dust - a durable, dense, bulk product that is cheap to transport - into briquettes - a fragile, packaged product of low density that is sensitive to handling and moisture. Hauling dust by road from the GWE markets is equally unappealing, as it would make little sense to bring raw material 30-60 km to an urban production facility when the same material exists within the town, unless that material was available at no cost (which it would not be). The only advantage would be the centralisation of the dust at the rural centres ready for transfer to Diego, but this is an advantage that would disappear once the urban charcoal traders saw the value in retaining the dust that they currently discard.

2.4 Sorting and milling options

Charcoal waste must be sorted and milled prior to densification, in order to remove contaminants (stones, wood and lumps of soil) and to reduce the material to a fine powder that can be bonded with locally available binders. Poorly milled material will result in weak briquettes, as PGM-E has already found with its experimental product.

Sorting can be accomplished by manual sieving using a 1 mm mesh, with a vibrating (electric) sieve, or by feeding the material into a blower that separates by density. None of these are complex operations and can be learned with appropriate training. Manual sieving would be appropriate for rural production and the other two methods for an urban operation.

Milling of the larger (1-10 mm) chunks of discarded charcoal would be best carried out using machinery already locally available and well understood by local operators. In Diego this probably means a 3-5 kW electric rice mill, as these are already in widespread use. While it would be technically possible to power such a rice mill in the rural setting using a diesel generator, for briquette production at village level it would be better to use a hand-operated grinder. Time did not permit investigation of the technological options that exist for grinding in Madagascar, but there is likely to be a suitable machine already available for some sort of agricultural processing. A manual system would be slower and more laborious than mechanised milling, however, and would not produce dust of comparable quality. Urban milling using electric equipment would be simpler and more efficient, and would generate higher grade material for briquetting.

Rice mill, locally available and adaptable for charcoal milling

2.5 Binding material

A natural, starch-based binder is the most economical and appropriate option for briquetting in Madagascar. The optimum product is cassava flour (which contains 95% starch), but rice flour (86% starch) or white bread flour (74% starch) are also technically suitable[7].

However, while cassava may be the most appropriate binder, it is eaten locally in whole or sliced form, and milled cassava can only be found in Diego in small supermarket retail packs priced at Ar. 5,000/kg. It is supplied by *Produits TAF* in Tana but they work only through agents and would not divulge their bulk prices. Still, it could perhaps be obtained for Ar. 4,000/kg or less for bulk orders.

It would be preferable to use a material readily available locally, and rice flour is therefore deemed more suitable than cassava flour in the Diego case. Rice is widely available, being a local staple, and there are numerous contract millers in the city. With a price for low grade rice of Ar. 1,350/ kg and a

[7] For starch content see: http://www.kickas.org/ubbthreads/ubbthreads.php?ubb=showflat&Number=143543

milling cost of Ar. 200/kg, rice flour could be sourced for a maximum of Ar. 1,550/kg, and no doubt less for bulk purchase.

Discarded bread (wheat) flour is available from local bakers who throw it away or give it to owners of ducks and chickens. It would be harder to source than either cassava or rice flour, and with its lower starch content is not an ideal choice.

Molasses is potentially a useful co-binder, blended with a starch, but the SIRAMA sugar factory at Ambilobe, 150 km from Diego, uses all of its molasses for rum production and there is none available for purchase.

Clay is an inferior binder that adds ash to the briquette and reduces quality, and is not recommended.

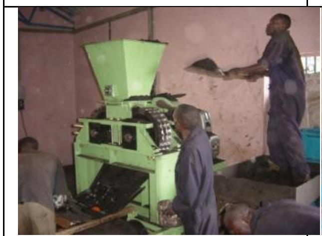
2.6 Densification options

Sorted and milled charcoal waste can be briquetted in several ways. Chardust, for example, has produced the following four types of briquette for the Kenyan market over the last 13 years, in declining order of cost and complexity:

1. a pillow-shaped briquette made using heavy-duty roller equipment;
2. a cylindrical briquette made using a locally-made screw extruder or modified meat mincer;
3. a spherical briquette produced with an electric agglomerator; and
4. a cylindrical briquette made using a hand-operated piston press.

Refer to Table 2 for a pictorial summary of these options.

Table 2: Technological options for charcoal dust briquetting

Option 1 *Roller briquettor*	**Option 2** *Screw extruder*	**Option 3** *Agglomerator*	**Option 4** *Hand press*
			
			

Option 1 (roller briquetting) was discounted for Madagascar as the necessary equipment (from India or China) costs at least USD 20,000 and is not suitable for a small-scale, start-up operation. Adding the costs of importation and ancillary switchgear, conveyors and hopper feeder, the capital cost of a single roller briquettor would exceed USD 30,000.

Option 2 (extrusion) was also discounted, as the continual re-facing of screws required when using this approach incurs significant cost and production down-time, and renders the technology non-viable in the African context where low price is key to commercial success.

The assessment therefore considered the cheaper and more technologically appropriate options of agglomeration and manual pressing. Agglomeration produces a spherical briquette and is best achieved using electrical power. Manual pressing produces a cylindrical briquette (with the option of a central hole) and can be accomplished using simple machinery based on metal piping and piston-assisted leverage. The main drawback of these low pressure densification approaches is the need for more binder, which increases production costs.

Briquette production at the rural energy centres could be accomplished using a manual system, given that producing electricity with a generator would not be a sensible commercial strategy when grid power is available in Diego. Output using a hand press would be about 25 kg/hr of cylindrical briquettes of 2-3 cm diameter.

Production in Diego, on the other hand, would be based on a 5 HP (3.7 kW) electric agglomerator. Using this system, the milled powder is poured slowly into the rotating bowl of the agglomerator, which produces spherical briquettes in a batch process through the alternate addition of powder and liquefied binder, leading to gradual build-up of the dust into granules, small balls, and eventually into briquettes of 3 cm diameter. An agglomerator can produce 100 kg of briquettes per hour with two operators. The exact specifications and operational parameters such as RPM, tilt angle and feed rate are commercially sensitive.

A sample agglomerator could be imported from Kenya and copied by a workshop in Diego. The most sophisticated of these workshops is the naval engineering facility (SECREN[8]), which is well equipped and actively seeking external contract work[9]. Other workshops exist at the University of Antsiranana campus and at a private firms. There are also many qualified companies in Tana - including Solcon, which currently fabricates solar cookers for GIZ – but local production in Diego would be easier to oversee and would permit the equipment to be repaired or modified on site.

2.7 Drying system

Drying of the briquettes would take place on outdoor mesh racks for 3-4 days. Diego receives 1,200 mm of rain per year, 83% of which falls between December and March[10]. During this season it would be necessary to cover the racks with plastic sheeting when its rains and at night, and uncover whenever possible. Drying times are approximately doubled during rainy periods, so significant storage would be required to augment reduced wet season production.

Maximum daily temperatures average 30°C in Diego and vary less than 5% from this level year-round, while average daily minima fall within a 10% range from 21.5°C. These high temperatures, together with the strong winds experienced for much of the year, would help counteract the high humidity and aid in drying.

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[8] *Société d' Etudes, de Construction et de Réparation Navales*.
[9] See http://www.secren.mg/Diversification,33.html
[10] http://www.climate-charts.com/Locations/m/MG67009.php

2.8 Conclusion

From a technical point of view, the production of briquettes in Diego shows promise. There are at least 30 t of salvageable charcoal dust available per month, a system already exists for charcoal grading within the city that could be built up into a more organised dust recovery system using low-cost local transport, electricity is available to power a mill and briquetting machine, there are high-starch binders available in powder form and capacity exists to build and maintain the necessary mill and agglomeration equipment.

Meanwhile the production of briquettes at the Green Wood Energy centres would be hampered by limited charcoal dust availability, the need to establish multiple operations instead of one to achieve commercial scale, the absence of electricity (which would necessitate manual milling of fines and hand-pressing of briquettes at lower efficiency and quality), the difficulty in sourcing a binder (or producing one *in situ* by hand pounding, with quality control risks) and the logistical challenges in maintaining equipment in a rural setting.

It would be technically complex to produce briquettes at village level and would require significant R&D to trial different processing options, whereas the urban operation could more or less replicate the experiences of Chardust and other East African producers and would have accelerated start-up.

3. Commercial Viability

3.1 Market options

There are likely to be three potential markets for charcoal dust briquettes in Diego, each with their own price and quality preferences:

1. There may be high income consumers who shop in **supermarkets** and would buy briquettes as barbecue fuel for meat roasting. They might also be interested in the product's environmental credentials, and would be looking for clean and attractive packaging (e.g. a printed paper sack). In Diego there is one large supermarket (Score) and three smaller ones run by Chinese and Pakistani families which could offer a useful outlet for barbecue fuel in small (e.g. 4 kg) bags.
2. There may be **hotels and restaurants i**nterested in a more eco-friendly fuel option for some of their operations (in addition to gas), particularly those catering for environmentally-aware international visitors.
3. The largest market for the product would be for mass **domestic cooking**. This is a conservative consumer segment into which new products with different performance characteristics would need to be introduced with care. But the fact that charcoal users are already reported to use balls of clay to slow down the rate of burn during cooking is an encouraging indication that a fuel with more ash and a longer burn may be deemed attractive for some tasks, when mixed with wood charcoal.

The primary concern for the second and third groups of customer will be price. It is vital that charcoal briquettes can be produced and sold (at profit) for appreciably less than locally available wood charcoal, given that they have a number of comparative drawbacks, e.g. they must be stored under cover to avoid rain damage; they must be handled carefully as they are more fragile than charcoal; they are slightly more difficult to light due to higher ash content; they cannot be extinguished with water after cooking for re-use; and they cannot be continually topped up in the stove as ash will build up and hamper ventilation. On the other hand, they will burn for longer and give a more controllable heat output with no sparks or smoke, as they are made from the very most brittle - hence most fully carbonised - pieces of the original wood charcoal.

Fortunately, charcoal in Diego is relatively expensive, averaging Ar. 430/kg[11]. This gives some room to manoeuvre on briquette pricing. A target price to the customer of less than Ar. 400/kg would be ideal. If this is not achievable, an alternative may be to sell briquettes in slightly lighter sacks than charcoal for a similar price (e.g. 8 kg of briquettes instead of 10 kg of charcoal, priced below Ar. 4,300 per sack).

3.2 Costings

Provisional costings have been developed for a briquetting operation in Diego and an alternative in Antiksaka, the closest of the GWE centres. It is assumed in both cases that the venture should only

[11] Average of Ar. 4,300 per 10.0 kg bag, in latest PGM-E market survey. This is similar to Nairobi, Addis Ababa and Kigali, and around 50% more than the cost of charcoal by the sack in Maputo, Lusaka or Dar es Salaam.

proceed if it can cover recurring costs and generate a profit to sustain operations. Therefore, while it has been assumed for costing purposes that the start-up investments will be externally funded, the assessment is based on realistic costs of production and includes an allowance for maintenance and depreciation so that aging equipment can be replaced from sales revenue. In other words, the analysis pre-supposes that donor funds would be available for setting up the plant and financing technical assistance, but that it should thereafter be self-sustaining thereafter from briquette sales. In fact once briquetting equipment was locally installed it would probably be copied by independent commercial producers. This has been the case in Kenya, with Chardust Ltd. having unintentionally spawned more than a dozen copy-cat operations in Nairobi alone.

In both cases it is assumed that the briquettes would be sold in a specially-printed bag of equivalent dimensions to the usual sugar, rice and cement sacks used for charcoal. Such a bag is likely to hold around 8 kg of briquettes. There might also be direct factory or kerb-side sales of smaller and larger volumes, with different packaging, but for costing purposes the standard bagged product is assumed.

3.2.1 Production in Diego

Table 3 presents estimated costs of briquette production in Diego.

Table 3: Briquette cost estimates - Diego

Production cost item	**Ar./kg**	**Assumptions**
Raw Material	50	Ar. 250/10 kg dust + Ar. 250/10 kg hand cartage to facility
Binder	47	3.5% rice flour @ Ar. 1,350/kg (Ar. 1,150 + Ar. 200 milling)
Labour - sorting, milling mixing	11	100 kg/hr; 2 workers @ Ar. 4,500/8 hr shift
Labour - agglomerator	11	100 kg/hr; 2 workers @ Ar. 4,500/8 hr shift
Labour - drying	6	800 kg/worker/day, salary Ar. 4,500
Labour - packing, weighing	6	800 kg/worker/day, salary Ar. 4,500
Labour - supervisor	13	Ar. 10,000/day, 0.8 t./day output
Electricity - mill	10	250 kg/hr, ave. load 3 kW, Ar. 800 per kWh
Electricity - agglomerator	30	100 kg/hr, ave. load 3.7 kW, Ar. 800 per kWh
Other elec & water	25	50% of above
Maintenance, fees, taxes	50	Ar. 40,000/day, for 800 kg of briquettes
Miscellaneous costs	40	fuel to heat water, tools, buckets, water, comms, mgmt, admin
Depreciation	26	Eqpt. value Ar. 20 mill, 4 yr life, 800 kg/day, 20 working days/mth
Losses (5%)	16	
Contingency (10%)	36	
Cost of production:	**366**	per kg
Packaging & delivery	**Ar./bag**	
Bag	50	8 kg polypropylene bag @ Ar. 2,000, re-used 5 times
Delivery to customer	200	Using hand cart
Cost of bag + delivery	**250**	per bag
Total cost per 8 kg bag:	***3,180***	

Based on these provisional estimates, it looks like briquettes could be produced for less than Ar. 400/kg, with a break-even delivered price of just under Ar. 3,200 per 8 kg bag. If such a bag were sold for Ar. 3,900 then the business could generate a modest profit, and the retail price would still be 9-10% lower than that of wood charcoal.

3.2.2 Production in Antiksaka

Table 4 presents estimated costs if production were to take place at Ankitsaka, the closest GWE centre to Diego.

Table 4: Briquette cost estimates - Ankitsaka

Production cost item	Ar./kg	Assumptions
Raw Material	-	Group does not charge for dust
Binder	51	3.5% rice flour @ Ar. 1,450/kg (Ar. 1,150 + Ar. 300 milling + transport)
Labour - sorting, pounding, mixing	22	20 kg/hr; 1 worker @ Ar. 3,500/8 hr day
Labour - hand press	35	25 kg/hr; 2 workers @ Ar. 3,500/8 hr day
Labour - drying	18	200 kg/worker/day, salary Ar. 3,500
Labour - packing, weighing	18	200 kg/worker/day, salary Ar. 3,500
Labour - supervisor	-	n/a
Electricity - mill	-	n/a
Electricity - agglomerator	-	n/a
Other elec & water	-	n/a
Maintenance, fees, taxes	50	Ar. 10,000/day, for 200 kg of briquettes
Miscellaneous costs	20	fuel to heat water, tools, buckets, water, comms, mgmt, admin
Depreciation	52	Eqpt. value Ar. 5 mill, 2 yr life, 200 kg/day, 20 working days/mth
Losses (10%)	22	More fragile than agglomerated type
Contingency (10%)	29	
Cost of production:	**315**	per kg
Packaging & delivery	**Ar./bag**	
Bag	50	8 kg polypropylene bag @ Ar. 2,000, re-used 5 times
Delivery to customer	800	200 bags in lorry @ Ar. 160,000
Cost of bag + delivery	**850**	per bag
Total cost per 8 kg bag:	***3,367***	

Production costs for a manual briquetting operation in Ankitsaka may be a little lower than in Diego (Ar. 315 vs. Ar. 366/kg), even with lower output, because the hand-operated equipment is cheaper to maintain and replace, electricity is not needed and rural labour costs are lower. The transport cost would meanwhile be far higher, giving an estimated break-even price at the point of delivery similar to that for the briquettes produced in the city. Crucially, however, there would be a much greater support and supervisory burden on PGM-E staff for a rural operation, which is not costed here. An urban operation would be easier and cheaper to support from the project office, and indeed an urban operator with appropriate commercial and manufacturing experience would probably need far less support in any case.

3.3 Market acceptability

The likely energy content of charcoal dust briquettes bound with rice or cassava flour would be 21-23 MJ/kg, with an ash content of 17-23%. This compares with 29-31 MJ/kg for charcoal, with ash content of 3% or less. Clearly the two fuels will have different performance characteristics and this will be relevant when it comes to branding, placement and marketing. The most noticeable feature of the charcoal dust briquette is its long, steady burn, which makes it well suited to space heating, water heating, slow cooking and meat roasting. In contrast charcoal - used at full power, especially at sea level - is capable of bringing water to a boil very quickly, which briquettes are not.

In the Diego climate, space heating is not likely to be in demand (although for a briquetting operation located in Tana there would be poultry farms and outdoor restaurants potentially interested in this application).

Using briquettes to heat water capitalises on the fuel's long steady burning characteristic, and Chardust in Kenya exploits this opportunity by manufacturing its own briquette-fired water heaters that can operate as stand-alone units (e.g. for tourist camps) or as pre-heaters for electric systems (e.g. in restaurants or homes). This could be a potential market in Diego once briquette production was underway and niche opportunities could be more thoroughly explored.

The main market, in the meantime, would be for cooking. The steady-burning nature of briquettes, with no sparking, makes them ideal for meat roasting or the preparation of slow-cooking foods. In Diego there is potentially high demand for commercial meat roasting (*grillade*) from street vendors (e.g. roasting *brochettes*) and for cooking beans or meat stews (slow-cooked cow hoof stew is a local delicacy). The mixing of briquettes with charcoal would offer a useful combination of heat and rapidity, combined with controllability and longevity, and would probably be the appropriate market positioning for this fuel.

3.4 Conclusion

Provisional, simplified costings suggest that it should be possible to produce and deliver briquettes from a facility in Diego or the closest GWE market for a lower price per kg than charcoal, which would allow a mark-up of just over 20% to give a final suggested price, with profit, of Ar. 3,900 per 8 kg bag. This is cheaper than charcoal per sack, though more costly per kg. Trials would be necessary to determine whether customers would accept this.

The costings do not include oversight and support from PGM-E staff, which for a rural operation would be significant and would need to be sustained over several years. The suggested price also gives no room for margins for distributors or agents. Therefore the producer would need to sell direct to the customer. While this would be feasible for an urban briquette producer who could deliver small volumes on request within the city, it would not be possible for a rural group to operate without its own bulk storage depot and distribution operation in Diego. If the costs of such an operation are also considered, in addition to project supervisory costs, then rural production no longer makes financial sense in comparison with a production facility in the city.

4. Operational Viability

4.1 Management options

The preceding financial analysis suggests that urban briquette production may represent a viable commercial enterprise. However, this will be a limited and quite marginal opportunity (given that profits may be only around 20%), and will need to be built up gradually over time. From that point of view it could be of potential interest to an existing entrepreneur who already has a light manufacturing or processing operation with utility connections, a facility with land for production and drying, covered storage, existing staff with technical and managerial competencies, and connections with potential fuel buyers in the urban domestic and commercial sectors. For such an individual, briquetting may represent a low-risk diversification opportunity, and something in which they could invest time and finance on an experimental basis. This is the model adopted by the commercial briquetting operations in Kenya and Tanzania, where the business owners have additional commercial interests and briquetting generates a supplementary revenue flow. PGM-E could provide co-financing or even full start-up support, as well as technical assistance (e.g. via consultants), after advertising the opportunity through local business and media channels.

The alternative production model is for PGM-E's project beneficiaries in rural areas to manage a briquetting operation as a stand-alone enterprise at one or more of the GWE centres. For a number of reasons this is not deemed a viable arrangement from an operational point of view:

- the GWE centres are constrained by limited raw material availability, allowing for only a very small scale of production and precluding economies of scale in all stages of production, packing, storage, transport and marketing;
- multiple, small production facilities would be required to build up an operation of meaningful scale, but this would be highly inefficient and much more costly than a centralised facility;
- the centres lack electricity and fully manual operations would therefore be required, inherently constraining quality and productivity;
- manual production needs more R&D, whereas mechanised production is now well understood by Chardust Ltd. and others, and could be rolled out relatively easily;
- the group members lack apparent entrepreneurial capacity and have no experience of managing complex industrial production and marketing operations;
- the group members demonstrate no ability to operate and maintain mechanical equipment, particularly of a new and experimental nature where trial, error and dynamic modification will be necessary and entrepreneurial motivation is a pre-requisite;
- the groups lack the capital to purchase or cost-share on asset purchase, meaning they would lack the kind of buy-in or risk exposure to the business that might engender real commitment;
- members work through a cooperative association in which they all hope to profit, directly or indirectly, from each group enterprise, whereas briquetting is a low profit business that cannot support a large number of shareholders (and certainly not with outputs of 20-40 kg per day);
- the groups would presumably be looking to maximise employment opportunities, contrary to notions of commercial efficiency and streamlining;

- group members lack expertise in sales and marketing, including branding, packaging, placement, advertising and customer relations;
- rural production for urban markets would introduce significant risks of briquette damage during handling and storage en route to market; and
- overall, the producers would depend very significantly on close support from PGM-E over many years; not only is this not sustainable, but project staff may also themselves not be well qualified to support an entrepreneurial venture of this nature.

4.2 Conclusion

In collaboration with a suitable entrepreneur, who could be invited through an open tendering process to bid for the opportunity, the production of briquettes within Diego has operational potential. For the reasons outlined, however, it is not deemed operationally and practically viable to establish briquette production at the Green Wood Energy marketing centres.

5. Summary and the Way Ahead

Given the prevailing price of charcoal in Diego and the availability of large volumes of discarded charcoal waste, the prospects for setting up a briquetting operation that would recycle this waste look encouraging. By converting the dust and fines to a fuel that directly displaces unsustainably produced charcoal, the operation would have measurable environmental benefits. At the same time it would create direct employment, generate supplementary income for charcoal vendors and transporters, and provide end-users with a cost-effective and clean-burning alternative fuel. There are opportunities for significant growth and the possibility of replication in other large towns.

For the technical, financial and operational reasons set out in this report, the establishment of briquetting facilities in rural locations is not recommended. A commercial opportunity - albeit with fairly tight margins - exists in the establishment of an urban facility, where the raw material, briquette production and market would all be situated within the confines of Diego. This is also where the greatest entrepreneurial and financial capacity exists, and hence the support burden on PGM-E would be substantially reduced. Whether this kind of operation would meet the objectives of PGM-E and its defined target groups is something for the project's implementers to consider.

If an urban operation is endorsed, bids could be invited from interested commercial partners, who could be offered a package of support in the form of equipment and technical assistance. All of the equipment could be bought or fabricated within Madagascar, although a sample agglomerator would ideally be imported from Kenya and could be copied by an engineering firm in Diego. Workers could be sent to Nairobi for training at Chardust Ltd. and a Chardust manager could visit Diego to give instruction in equipment operation and systems. GIZ may be interested in financing this support, and paying also for branding, marketing and an advertising campaign at product launch.

Two key challenges to be addressed in the establishment of such an operation would be:

- **Dust sourcing:** With charcoal waste scattered in small volumes throughout the city, its consolidation and delivery to the briquetting facility would be best out-sourced. Low pricing through large volumes would be vital, but the specific modalities of delivery (probably by hand-cart from charcoal dealers) would need to be explored, and a pricing structure established which was both affordable for the business and acceptable to the cart operators.
- **Product marketing:** It has been explained that briquettes are not a direct substitute for wood charcoal and have different handling and combustion characteristics. An honest approach to marketing would not mislead customers, but would balance the drawbacks with the benefits (e.g. price, longevity of burn and controllability). It seems sensible to position the briquettes as a supplementary fuel, for mixing with charcoal to provide controllability and extended burn time. Multiple marketing channels would be appropriate, through print media, radio, billboards, road-shows, open-air demonstrations and direct selling.

Finally, analysing the situation from an objective perspective, unconstrained by the aims of PGM-E, it may be more commercially attractive to consider a briquetting facility in Tana than Diego. A much larger population, higher charcoal prices, a richer urban middle class, stronger entrepreneurial and manufacturing capacity, a greater diversity of potential markets and a cooler climate are just some of the reasons why an operation there would be easier to set up and more profitable to run. Whether this would meet the objectives of PGM-E or GIZ more broadly is for others to determine.

Annex A: Terms of Reference

Short-term feasibility study on the Utilisation of charcoal dust in the city of Diego, Madagascar

Context

During the production as well as during the re-sacking of charcoal at rural markets, different amounts of charcoal dust and debris accumulate which are in this form not usable or unsalable, respectively. While during the production at forest site charcoal dust regularly develops at different locations and, at the same time, is heavily mixed with sand and clay which hardly allows any re-utilization, its processing at rural markets could, however, contribute to an increased income and thus, to an improved profitability/cost effectiveness of these markets. However, tests carried out in the city of Diego have so far not been successful for the following reasons: either the technique particularly with regard to the adhesive agent (binder) used was uncontrollable or the final products were rejected by the end consumers.

Objectives

The objective of the mission is to elaborate a study which analyses the:

- Feasibility of the recovery of this yet only to a limited extent utilized waste in a technically, economically, socially and logistically/organizationally way, and
- Potential of charcoal dust products as a charcoal equivalent.
- Furthermore, proposals shall be elaborated for a technical development and local production of necessary dust compacting or briquetting equipment in case of a positive - feasible – outcome of the study.

Activities

- Analyse activities which have so far been carried out, and their results achieved in the city of Diego;
- Analyse the expected accumulation of dust at two rural charcoal markets as well as urban locations in Diego (wholesaler/markets in the city);
- Study and analyse various alternatives with regard to locally available binders, if required;
- Present proposals for locally adapted compacting or briquetting equipment for charcoal dust suitable for the respective locations; if applicable include also proposals for their local production;
- Outline a possible production and marketing chain of the product;
- Provide lessons learned information from experience in East African countries.

Duration

The duration shall be 10 days in total, including 3 days for travel, 5 days field work in Madagascar and 2 days for reporting. International travel days shall include a stop-over in Kenya for a technical meeting with Mr Elsen Karstad, co-director of Chardust Ltd.

Annex B: Itinerary

Wed 12th Sep	Fly Bristol, UK to Nairobi. Overnight Nairobi.
Thu 13th Sep	Consultations at Chardust Ltd. Overnight Nairobi.
Sat 15th Sep	Fly Nairobi to Antananarivo. Overnight Tana.
Sun 16th Sep	Fly Antananarivo to Diego. Initial discussions with Georg Schneider (carbonisation consultant). Overnight Diego.
Mon 17th Sep	Introductory meeting with Christian Andriamanantseheno and project team. Joint visit to Ankitsaka village to see tree plantations, charcoal production (Cassamance kiln, Adams retort), wood energy association, charcoal sales and charcoal waste. Afternoon discussions at office with Allan Hong-wa (forest management and utilisation officer). Overnight Diego.
Tue 18th Sep	Visits in Diego with Armel Voavy (improved stove specialist) to charcoal wholesalers and retailers, aluminium pot producer, restaurant, supermarkets and university engineering workshop. Meeting with engineer from SECREN (Société d' Etudes, de Construction et de Réparation Navales). Data collection from Justin Ralainirina (M&E officer). Overnight Diego.
Wed 19th Sep	Return visit to Ankitsaka to sieve and weigh charcoal fines. Visits in Diego to SECREN, rice miller, charcoal dealer and bakeries. Initial data reconciliation. Overnight Diego.
Thu 20th Sep	Debriefing at PGM-E office. Further data analysis. Fly Diego to Antananarivo. Visit Soltec factory in Tana to assess equipment manufacturing capacity. Evening in Tana.
Fri 21st Sep	01:10: Fly Antananarivo to Bristol, UK.
Mon 24th Sep	Reporting writing, UK.
Tue 25th Sep	Reporting writing, UK.
Wed 26th Sep	Submission of draft report to ECO-Consult.
Thu 4th Oct	Submission of final report to ECO-Consult.

Annex C: Charcoal consumption and dust availability data

(a) Project-supported energy centres

Centre	Period	Charcoal produced (t/mth)	Charcoal sold (t/mth)	% discarded	Waste generated (t/mth)	% deemed salvageable	Waste accessible (t/mth)
Ankitsaka	Jan-Jun 2012	7.94	7.28	9%	0.714	95%	0.68
Saharenana	Jan-Jun 2012	5.87	5.38	9%	0.528	95%	0.50
Madirobe	Jan-Jul 2012	0.37	0.34	9%	0.034	95%	0.03

Source: Charcoal sales figures from PGM-E monitoring database. % discarded from consultant's sample weighing.

(b) City of Diego

Population	115,000	2012 extrapolation from 1993 census @ 3.5% p.a.
% using charcoal	97%	PGM-E survey
Annual consumption (kg/person)	118	PGM-E survey
Total domestic charcoal use (t/yr)	**13,149**	
Charcoal use for commercial cooking (t/yr)	824	PGM-E survey (400 outlets & street vendors, ave. 2.055 t/yr)
Charcoal use for pot-making (t/yr)	183	Consultant estimate (10 pot producers, ave. 5 x 10 kg sacks charcoal/day)
Grand total, charcoal consumption (t/yr)	**14,155**	
% discarded	9%	Consultant measurement
Waste generated (t/mth)	106.2	
% deemed salvageable	30%	Consultant estimate
Waste accessible (t/mth)	**31.8**	