



SYNTHESIS REPORT

Title: Recycling of Organic Waste for Energy and Small-holder Livelihood in The Gambia

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Executive summary

While firewood and charcoal continue to be widely used in the Gambia, agricultural waste for briquette production, groundnut shell in particular, constitutes an abundant resource in the country. Surveys have allowed to estimate the potential of agricultural and wood industry residues. Even so, surveys carried out around the locations of the women groups involved in this technical assistance indicate that the cost of mobilising residues in a perimeter close to the groups would be prohibitive. Indeed, the resource is dispersed there and is only available in limited quantities. 15 women groups were identified to benefit from the training proposed by CTCN.

A rigorous analysis of the briquette value chain and the evaluation of several possible scenarios for producing and selling them demonstrates that many production strategies are neither viable nor sustainable. Nevertheless, the organization of the production chain in two stages makes it possible to propose a profitable value chain model. On the one hand, women groups produce carbonized material from groundnut shells and mill it before bagging it and selling it to an intermediary (currently WIG) for transport. Two groups have been identified in Saro (near groundnut hulling plant) to carry out this task. On the other hand, other women groups buy bags of carbonized powder (and binder) from the same intermediary. The members of the latter groups transform the carbonized powder into briquettes thanks to the equipment made available by the CTCN. 14 groups have been identified for this purpose. It should be noted that the briquettes produced are primarily intended for use by the members who produced them. The sale of briquettes is a secondary aspect.

Customized equipment has been selected and made available to involved women groups. The groups tasked with producing carbonized powder are notably equipped with drums allowing the pyrolysis of groundnut shells and a hammermill fed by an internal combustion engine. The briquette producers are equipped with manual presses and all the equipment necessary to produce briquettes. The proposed production model considers the cost of these different tools and equipment and reflects their depreciation in the prices fixed at the different stages of the chain.

Trainings tailored to the needs of the different groups were organised: Pyrolysis/grinding on the one hand and production/use on the other. It should be noted that special attention was paid to training in the use of briquettes. After a 2-day training dedicated to production, the members of the group were then trained to prepare meals using briquettes as fuel. An additional weeks' follow-up was then organised. The complete "producer-user" training thus requires 2 weeks.

Following the trainings, 1500 kg carbonised and milled groundnuts shells were produced each week in Saro (Pyrolysis – grinding site) and were supplied to 14 other women communities (production - use) for processing into briquettes and subsequent replacement of traditional fuels. The total production of briquettes over the course of the CTCN intervention ran up to about 10 tonnes, including 6 tonnes produced in December 2018. In January 2019, production continued at the rate achieved in December rate, and an additional 5 tonnes of briquettes had been produced close to the end of January. Indeed, briquettes were found to be in high demand by users, and WIG (the intermediary between powder production site and briquettes production/use communities) receives many requests for more powder (from the women groups already involved) as well as for joining the project (from non-involved women groups). Moreover, briquette producing communities have received many requests from prospective buyers (who either express specific interest or are just curious for the time being). While these requests cannot be satisfied at this juncture for lack of production equipment, they nonetheless attest to the correctness of the chosen

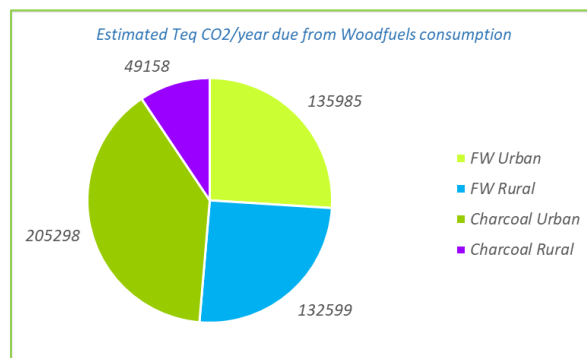
strategy and setup for the briquette value chain. By the end of January 2019, 12 tonnes of briquettes had been produced and used.

In the Gambia, according to the estimates shown in this report, the following agricultural residues were found accessible and available for briquetting: groundnut shells, maize cobs, coconut shells, sawdust, wood shavings and charcoal fines. The annually available amounts of these residues are 39,173 tonnes, 6,084 tonnes, 13.9 tonnes, 239 tonnes, 47 tonnes, and 1,884 tonnes, respectively.

The total residues potential is estimated at 83,088 tonnes, whereof 6,549 tonnes are already used. This means a total of 76,540 tonnes of available residues, representing 1,120 TJ. This amount of unused material emits 106,519 TCO₂eq in the atmosphere annually. Of this potential, 45,557 tonnes are accessible, representing a briquette production potential of 19,308 tonnes per year, with an energy content of 470 TJ. Emissions related to this briquette production are estimated at 69,151 TCO₂eq. The annually available charcoal fines amount has been estimated at 2,538 tonnes, of which 25.4 tonnes are used, so 2,512 tonnes are not used, representing 69 TJ. Charcoal fines do not degrade and therefore do not emit CO₂ due to their decomposition. The estimated quantity of charcoal fines available is 1,884 tonnes per year, equivalent to a potential briquette production of 2,077 tonnes per year (considering the binder proportion to be added). The energy content of these briquettes is 54 TJ.

The total potential for briquette production from residues in The Gambia is therefore estimated at 21,385 tonnes annually.

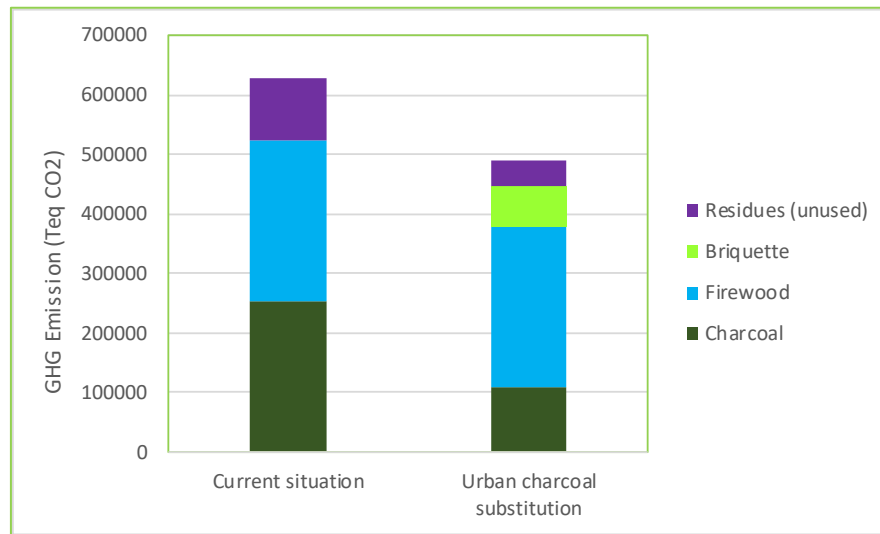
Calculations suggest that charcoal (25,000 tonnes) represents only a minor share of the cumulative total of the domestic fuels used (209,000 tonnes). This proportion increases slightly when the energy content is considered, accounting for 750 TJ out of the 3,500 TJ consumed annually in the country as household fuel. But charcoal is responsible for nearly half of the GHG emissions associated with this sector (250,000 TCO₂eq compared to a total emission of 523,000 TCO₂eq).



If 21,385 tonnes of briquettes were produced from the identified residues, this briquette amount would allow to substitute 14,444 tonnes charcoal used in urban areas (considering the conversion factor – 1 kg charcoal needs 1.48 kg briquettes to be substituted). This would result in a reduction of 71% of the urban charcoal consumption, or 57% of the national charcoal consumption – equivalent to a decrease of about 140,413 TCO₂eq annually (a reduction by 22.3%). This means avoided emissions to the tune of 6.5 TCO₂eq per tonne of briquettes used.

Given that technical assistance has led to the consumption of 15 tonnes briquettes, it may be assumed that its direct impact in terms of GHG reduction was 90 TCO₂eq within 2 months (December 2018 and January 2019). Moreover, by substituting charcoal, 15 tonnes of briquettes avoid the cutting of about 50 tonnes of anhydrous wood (considering the equivalence factor of 1,48 and a carbonisation yield of

20%). This amount equates 2 hectares of mature Eucalyptus plantation (considering a 5-year rotation and a production yield of 5 DMT/ha*year).



1. Introduction

It has been demonstrated that Solid Waste Management (SWM) is an important aspect in maintaining the public health in cities. Treatment and valorization of organic wastes (bio-waste) for carbon production could be one of the most promising options to stimulate waste collection. A variety of processes exist for converting biowaste to energy. Conversion of biomass into valuable liquids, gases and solids can be accomplished via biochemical (e.g., anaerobic digestion, enzymatic hydrolysis) and thermochemical (e.g. pyrolysis, torrefaction, gasification, and combustion) methods. The choice of conversion methods depends on the characteristics of the biomass (e.g., type, physiochemical properties and quantity), the desired form of the energy carrier, the end use requirements, the health and environmental standards, the economic conditions, and the project-specific factors

The use of biomass energy has many advantages, as it comes from familiar and affordable available resources, creates jobs, ensures diversification and energy security, and is deemed climate-friendly. Moreover, it has been shown that biomass energy is and will remain for the next decades the mainstay of domestic cooking in sub-Saharan Africa. In this context, the use of biomasses other than wood (ground nuts shells, coconut nuts shells, corn cobs, savanna straw, rice husk ...) is often proposed to produce substitutes for charcoal, in the form of briquettes. However, despite their many advantages (price, length of combustion, environmental sustainability, possibility of standardization ...) these fuels often fail to significantly substitute charcoal or firewood. Experience shows the implementation strategy is specific to each situation and must consider the opinions of users.

A briquette project is part of a social, economic and environmental reality. The use of briquettes requires households to change their habits. To this end, the use of novel fuels must first be learned thoroughly, because it differs – contrary to widely held notions – considerably from established practice. Cooking with briquettes often requires a change of kitchen routines. In order not to disturb

households overmuch and risk discouraging them, it is important to promote fuels whose qualities are sufficiently close to those of traditional fuels. For example, briquettes made of non-carbonised material have failed to meet consumer expectations. Indeed, they combust too rapidly in available stove and lead to excessive fuel consumption. Their efficient use requires very expensive stoves that are not available to households. It is therefore necessary to produce briquettes from carbonized material whose combustion more closely resembles the fuels already used by households.

The price at which the fuel will be sold is also very important. It depends on the combined cost of resource supply and production and competes with the cost of traditional fuels. Any fuel's relative competitiveness must be gauged by the cooking efficiency it offers, i.e. the fuel cost of preparing a meal. Any fuel offered at a higher price than existing alternatives will struggle to find its market.

The fuels currently used (wood and charcoal) have an impact on the forest and the environment in general. In addition to contributing to deforestation, charcoal production likewise releases significant quantities of GHG. Non-recovered residues, being prone to decomposition, equally cause GHG emissions.

Against the aforementioned backdrop, CTCN launched a Technical Assistance intervention titled "Organic wastes for Energy and Smallholder livelihood" with a view to promoting agricultural production, energy supply and livelihood conditions in The Gambia. Its principal goal was to raise capacity in generating income through waste management of women's groups, and to improve the waste management value and supply chain at scale. To this end, the project strives to provide short-term benefits at a pilot-scale, and longer-term benefits at local government area and potentially national scale. Direct beneficiaries of the technical assistance were more than 225 women organized in women communities that have been trained in waste management and charcoal briquette making. This report summarizes the information and data collected during the activities carried out as part of this technical assistance.

First, baseline data are collected, including production, consumption and cost of traditional fuels (fuelwood and charcoal) in The Gambia, average household fuel consumption, available resources surveys, calculation of GHG emissions related to these activities. Next, materials adapted to the situation were identified and provided to 15 women's groups who were trained in the production and use of briquettes. These trainings were also used to gather the information necessary for the economic evaluation of briquette production. To do this, the investment cost and productivity of the different production stages, as well as the transport costs, were considered.

Based on the information collected, different production scenarios were assessed in relation to their competitiveness with traditional fuels. The analysis of these scenarios showed that in order to be competitive with other fuels on the market, it was necessary to split the production chain into two distinct stages: 1) production of carbonized powder, and 2) transport and briquette production. It has also been shown that the self-consumption of briquettes is a major advantage for the profitability of this value chain. The users' acceptance of the briquettes produced was also studied.

All this information was used to propose a briquette production model that can be scaled up.

2. Why this work?

Despite their many apparent advantages (price, long combustion time, environmental sustainability, possibility of standardization etc.) briquettes often fail to substitute charcoal significantly. Experience shows the following factors determine the market outreach for charcoal substitutes:

- › To be agreeable to consumers, briquettes need to display properties comparable with established fuels – hence they need to contain charred material,
- › Briquettes are generally urban fuels,
- › Biofuel projects need to aim for a minimum critical consumption rather than to be preoccupied with supply,
- › Complementary markets to the domestic market must be sought: industrial consumers (agribusiness, hotels, tourism companies ...) or the barbecue niche market,
- › Government support is also needed, at least through the establishment of a legal framework that allows the production of briquettes without financial barriers,
- › Too many projects producing biofuels see themselves as competitors, whereas their direct competitors are rather the so-called traditional fuels: firewood and charcoal,
- › From a technical point of view, briquettes are often not suitable to replace charcoal and require adapted combustion equipment. Indeed, they are perceived by users as being difficult to ignite, not delivering much heat but allowing very long burning time. It is, however, possible to produce briquettes of very good quality, thanks to the mixture of different materials.

In short, briquette production projects are difficult to implement in a sustainable way. To do this, ECO Consult considers the following elements, in addition to those mentioned in the foregoing paragraph:

- › Projects should be designed to be market driven rather than production driven.
- › Projects must start on a small scale.
- › The produced briquettes must be of very good quality and meet the expectations of the consumers. To this end, raw materials and production processes should be carefully selected to meet the needs and scale of the project.
- › Briquette production projects are much more complex than they appear. The following aspects need to be considered: identification and classification of resources, the transformation process, and the expectations of the users. To this end, ECO Consult proposes adapted transformation technologies requiring limited investments.

The implementation strategy is specific to each project and must consider the opinions of users.

3. Baseline information

3.1. Energy cost in Banjul and Serrekunda

Surveys in Greater Banjul identified the prices of the different energy carriers available and to compare them. Attention has been paid to traditional fuels: firewood and charcoal. This price was also compared to the sales price of briquettes produced prior to the Technical Assistance (TA).

Results of this first survey are shown in Table 1 and illustrated in Figure 1 and Figure 2. It clearly appears the price of so called “traditional fuel” i.e. charcoal and firewood is lower compared to conventional fuels (i.e. fossil fuels). When traditional fuel prices are compared to briquette sales prices (for briquettes produced prior to the TA), it appears briquettes has prices comparable to the most expensive traditional fuels. Its price is at the same level as the higher quality charcoal while not having its standard. This is probably a reason why briquettes were not sold at higher volume and was consequently one of the main aspects the present TA has worked to improve. The sale of traditional fuels is illustrated by Picture 1 to Picture 6.

Table 1: Fuel prices in Banjul and Serrekunda

Fuel	Packaging	Consumer price (Dalasi)	Mass (kg)	Price (Dalasi/kg)	PCI (MJ/kg)
Diesel	Pump	51	0,8	61	43,0
Pétrole	Bottle	30	0,7	42	43,0
Benzine	Pump	52	0,8	68	43,0
Gaz 3kg	Bottle	200	3,0	67	49,4
Gaz 6kg	Bottle	400	6,0	67	49,4
Gaz 12kg	Bottle	700	12,0	58	49,4
Electricity T1	Na	10	1,0	10	0,0
Charcoal Quality 1	Small bag	15	1,1	13,6	33,0
Charcoal Quality 2	Small bag	13	0,8	15,6	33,0
Charcoal Quality 3	Small bag	10	0,9	11,3	33,0
Charcoal bag (selling price)	Big bag (selling price)	250	24,8	10,1	33,0
Charcoal bag (buying price)	Big bag (buying price)	220	24,8	8,9	33,0
Firewood	Bundle	25	4,1	6,1	18,4
Briquette	Cup	13	1,0	13,4	29,3

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Figure 1: Energy price in Banjul and Serrekunda – fossil and traditional fuels prices (in Dalasi/ kWh) compared to briquettes

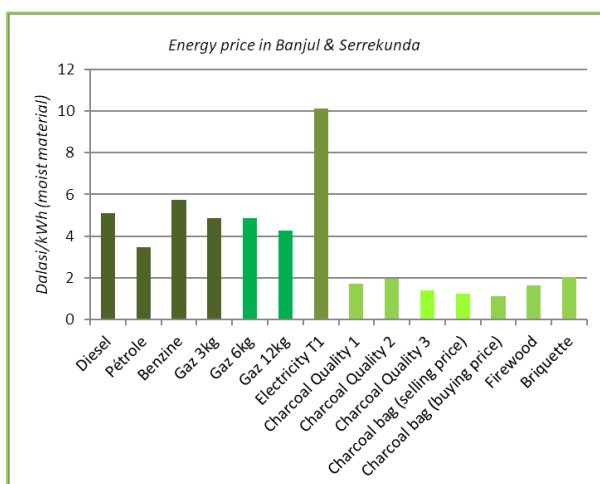
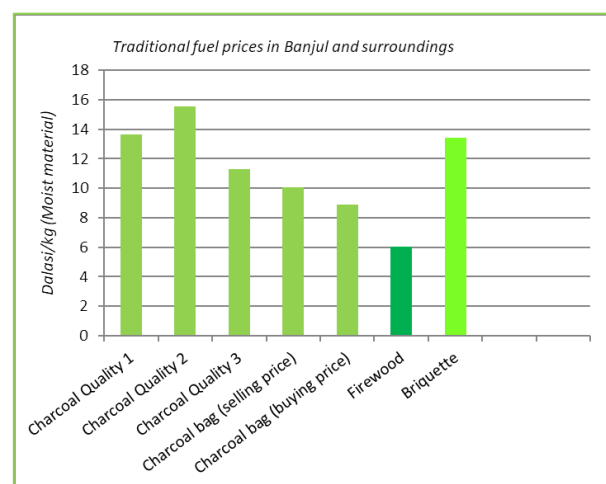


Figure 2: Traditional fuel price (in Dalasi/kg) compared to briquettes





Picture 1: Charcoal selling point



Picture 2: Firewood stock to be split into sticks



Picture 3: Firewood sticks and bundles for sale on Serrekunda Market



Picture 4: Firewood sticks for sale on Serrekunda Market



Picture 5: Firewood bundle for sale on Serrekunda Market



Picture 6: 3 charcoal qualities for sale on Serrekunda Market

3.2. Briquette production prior to the TA

Prior to the TA, briquettes were produced by using the hammer and piston method. The productivity of this method was found to be very low: 2 kg/hour*worker (Picture 7, Picture 8 and Table 2). Indeed, press productivity measurements in Cameroon and in Madagascar have shown it is significantly higher, as compared to the hammer and piston method. The press method was then selected, and the use of hammers and pistons discontinued. Later measurements have confirmed the productivity of the presses proposed by the Technical assistance had a higher productivity.

Table 3: Charred dust yield production for groundnut shells, coconut shells and mango leaves

Masse charbon	kg	27,7	N bois dans la charge	N	0,0	Taux	60	1
Masse poudre	kg	0,0	Masse moyenne des bois humides	kg	#DIV/0!	Charbon de bois	DLS	€
Masse Fumerons	kg	0,0	Masse moyenne des bois anhydres	kg	#DIV/0!	Prix du sac (à la production)	tdb	#VALEUR!
Mat Vol Charbon	%	22,2	N sac de charbon	N	3	Masse du sac	tdb	
C fixe Charbon	%	60,0	Masse moyenne des sacs	kg	9,2	Humidité	tdb	
In - Charge			In - Combustible					
Masse charge (M Cg h)	kg	133,2	Masse de combustible (M Cb h)	kg	0,0	Masse anhydre	#####	
Humidité charge (H Cg)	%	15,0	Humidité combustible (H Cb)	%	0,0	Prix chdB au kg (€/kg)	#####	#VALEUR!
PCI charge	MJ/kg	18,4	PCI charge	MJ/kg	18,4	Bois		
Masse anhydre (M Cg a)	kg	113,2	Masse anhydre (M Cb a)	kg	0,0	Prix d'une charge (bois + transport)	tdb	#VALEUR!
Taux de cendre	%	4,0	Taux de cendre	%	4,0	Masse de la charge	tdb	
Contenu énergétique anhydre (En Cg a)	MJ	2083,7	Contenu énergétique anhydre (En Cb a)	MJ	0,0	Humidité	tdb	
Pouvoir calorifique réel	MJ/kg	14,65	Pouvoir calorifique réel	MJ/kg	17,66	Masse anhydre	#####	
Contenu énergétique réel (En Cg h)	MJ	1952	Contenu énergétique réel (En Cb h)	MJ	0	Prix du Bois au kg (€/kg)	#####	#VALEUR!
Out - Ch de Bois commercial			Out - Braisettes & fines - Refus			Out - Incuits - Fumerons		
Masse charbon (M Ch h)	kg	27,7	Masse Braisettes & fines (M R h)	kg	0,0	Masse imbrûlés (M I h)	kg	0,0
Humidité charbon (H Ch)	%	8,0	Humidité Humidité braisettes & fines (Hbh)	%	5,0	Humidité imbrûlés (H I)	%	10,0
PCI charbon	MJ/kg	29,3	PCI Braisettes & fines	MJ/kg	29,3	PCI imbrûlés	MJ/kg	18,4
Masse anhydre (M Ch a)	kg	25,5	Masse anhydre (M R a)	kg	0,0	Masse anhydre (M I a)	kg	0,0
Taux de cendre	%	17,8	Taux de cendre	%	17,8	Taux de cendre	%	4,0
Contenu énergétique anhydre (En Ch a)	MJ	746,3	Contenu énergétique anhydre (En R a)	MJ	0,0	Contenu énergétique anhydre (En I a)	MJ	0,0
Pouvoir calorifique réel	MJ/kg	21,96	Pouvoir calorifique réel	MJ/kg	22,75	Pouvoir calorifique réel	MJ/kg	15,65
Contenu énergétique réel (En Ch h)	MJ	608	Contenu énergétique réel (En R h)	MJ	0	Contenu énergétique réel (En I h)	MJ	0
Rendements de carbonisation								
Rendement massique		22,5	Rendements énergétique réel		31,16	Rendement commercial		22,5
(M Cha + M Ra) / (M Cga + M Cba - M Ia)			(En Ch h + En R h + En I h) / (En Cg h + En Cb h)			M Cha / (M Cga + M Cba - M Ia)		
Rendement massique hors combustible		22,5	Pourcentage combustible dans masse totale		0,00	Rendement commercial hors combust		22,5
(M Cha + M Ra) / (M Cga - M Ia)			(M Cb a) / (M Cg a + M Cb a)			M Cha / (M Cga - M Ia)		
Rendement massique humide		20,8	Rendement énergétique PC anhydre		35,81	Rendement commercial pondéré		#####
(M Cg h + M Cb h) / (M Ch h + M R h + M I h)			(En Ch a + En R ha + En I a) / (En Cg a + En Cb a)			M Cha * Px Ch a / (M Cga + M Cba - M Ia) * Px Cg a		

3.3. Biomass resources

3.3.1. Residues availability

Table 4: Average production of agricultural and forest residues – estimations based on Field measurements and questionnaires (wood and charcoal residues) and on FAO Stat yearly production surveys (agricultural residues)

Unit	Ground nuts	Maize	Mango...	Cashew nuts	Rice, paddy	Sorgho	Mils	Coco nut	Sawdust	Wood Shavir	Charcoal	
2011 Tons/year	83858	23613	1300	2750	51136	20556	87234					
2012 Tons/year	119617	30106	1300	2800	54219	23146	116089					
2013 Tons/year	93862	33060	1358	2927	69704	30390	93799					
2014 Tons/year	80650	30289	1430	3060	46674	20289	76816					
2015 Tons/year	103081	35701	1441	3125	50187	25798	90174					
2016 Tons/year	109849	39467	1491	3094	59636	29372	101872					
Mean Value	98486	32039	1387	2959	55259	24925	94331		703	158	25375	
Residues ratio	0,43	0,211	0,05	0,3	0,15	0,2	0,2		1	1	0,1	
Residues amount	Tons/year	42349	6760	69	888	8289	4985	18866	21	703	158	2538
Share of used residues	%	7,5	10	7	10	10	5	5	33	66	70	1
Est share of accessible residues among unused	%	100	50	0	0	100	0	0	100	100	100	75
Share of unused residues	%	92,5	90,0	93,0	90,0	90,0	95,0	95,0	66,7	34,0	30,0	99,0
Amount of used residues	Tons/year	3176,2	676,0	4,9	88,8	828,9	249,3	943,3	6,9	464,0	110,6	25,4
Amount of unused residues	Tons/year	39173	6084	64	799	7460	4736	17923	14	239	47	2512
Amount of unused & accessibles residues	Tons/year	39173	3042	0	0	7460	0	0	13,9	239	47	1884
Est Amount of non accessible residues	Tons/year	0	3042	64	799	0	4736	17923	0	0	0	628
Est Amount of non accessible or used residues	Tons/year	3176	3718	69	888	829	4985	18866	7	464	111	653
Global Availability Share	%	93	45	0	0	90	0	0	67	34	30	74

The supply estimate of agricultural residues is based on data available from FAO Stat. - coconut shells being the sole exception, for which estimates are not included in this website and thus has to be based on field observations. Similarly, estimates of residues from wood- and charcoal production are based on field observations. These data are included in Table 4.

The available FAO stat data are about agricultural production. It is therefore necessary to apply a residue production ratio. The annual supply of agricultural residues can thus be estimated as 42,349 tonnes of groundnut shells, 6,760 tonnes of maize stalks, 69 tonnes of mango stalks, 888 tonnes of

cashew nuts shells, 8,289 tonnes of rice husks, 4,985 tonnes of sorghum stalks, 18,866 tonnes of millet stalks and 21 tonnes of coconut husks.

Not all these residues are available, some are already used or inaccessible. Of the remainder, a certain portion is not suitable for briquette making. In order not to overestimate the actual available amount, additional corrective factors were applied. For example, it was estimated that 7,5% of peanut shells were already in use (chicken litter, compost, fuel, etc.), and their accessibility was estimated at 100%. The quantity available for briquette production is therefore 39,173 tonnes per year. Regarding mango pits, their accessibility was estimated to be nil due to their dispersion. For rice husks, it was estimated that they were fully accessible and 10% were used, but these residues are not of sufficient quality to be used for briquette production, so their potential was estimated to be zero. According to the estimates made, the following supplies were considered accessible and available: groundnut shell, maize cob, coconut shell, sawdust, wood chips and charcoal fines. The quantities of these residues available annually are estimated as 39,173 tonnes, 6,084 tonnes, 13.9 tonnes, 239 tonnes, 47 tonnes, and 1,884 tonnes, respectively.

3.3.2. Groundnut shells specific case

A groundnut processing plant is located at Saro. This plant processes 35,000 tons of groundnuts annually. The groundnut shells are not currently used and are dumped on landfills, very close to the plant. Groundnuts are there sorted by women (gleaners) in order to recover the few seeds that production has allowed to pass.

Part of the shells is bagged and carted away on pick-ups to an unknown destination. At the TA's start, attempts to trace the use of the shells gave rise to some tensions.

At a meeting held in February, the plant manager stated an intention to recover shells for energy generation (scheduled to commence in 2018). This seemed surprising because no modification of the unit was in progress, and technical adjustments of this kind take a lot of time. At the beginning of 2019, no activities regarding the use of this resource could be observed, and groundnut shells continued to be dumped at the same place.



Picture 10: Saro groundnuts shells landfill

For a time, this resource was bought by Senegalese traders who allegedly use it in boilers (no more detail was obtained). An alternative explanation might be that shells are being used to feed livestock, which would likewise seem amazing because the shells' nutritional value is low. Maybe it's a bedding application. It was agreed to send a letter of request to the Director to authorize WIG to collect the shells. The current gleaners have no authorization. The letter has been sent but received no official answer.

Informally it was agreed that groundnut shells may be used with no restriction of amount. Groundnut shells, due to their huge potential, were foreseen as one of the major resources to be used by the project. Consequently, a solution had to be found to legally secure this supply. To this end, contacts have been made with the Ministry of Agriculture.

Discussions with the gleaners made it possible to involve them in the briquettes value chain, by organizing them into women's groups.

3.3.3. Waste around women groups locations

The women's groups survey aimed to assess the availability of resources in the neighbourhoods where the groups are located.

It appears that while the population can identify the various biomass-resources available, statements regarding their classification and quantity are far less reliable. Similarly, biomass-resources were found to be dispersed in almost every case, and the costs associated with their collection and transport to processing sites are hard to gauge. Due to the need for transport, related costs were found to impair the briquette value chain's economic viability. Moreover, more centralised resources are available.

3.3.4. Emissions due to biomass residues and briquettes production potential

Table 5: Available residues - Estimation of the current related emissions and calculation of the briquette production potential

Unit	Ground nuts	Maize	Mango...	Cashew nuts	Rice, paddy	Sorgho	Mils	Coco nut	Sawdust	Wood Shavir	Charcoal
2011 Tons/year	83858	23613	1300	2750	51136	20556	87234				
2012 Tons/year	119617	30106	1300	2800	54219	23146	116089				
2013 Tons/year	93862	33060	1358	2927	69704	30390	93799				
2014 Tons/year	80650	30289	1430	3060	46674	20289	76816				
2015 Tons/year	103081	35701	1441	3125	50187	25798	90174				
2016 Tons/year	109849	39467	1491	3094	59636	29372	101872				
Mean Value	98486	32039	1387	2959	55259	24925	94331		703	158	25375
Residues ratio	0,43	0,211	0,05	0,3	0,15	0,2	0,2		1	1	0,1
Residues amount Tons/year	42349	6760	69	888	8289	4985	18866	21	703	158	2538
Share of used residues %	7,5	10	7	10	10	5	5	33	66	70	1
Est share of accessible resi %	100	100	0	0	100	0	0	100	100	100	75
Share of unused residues %	92,5	90,0	93,0	90,0	90,0	95,0	95,0	66,7	34,0	30,0	99,0
Amount of used residues Tons/year	3176,2	676,0	4,9	88,8	828,9	249,3	943,3	6,9	464,0	110,6	25,4
Amount of unused residue Tons/year	39173	6084	64	799	7460	4736	17923	14	239	47	2512
Amount of unused & acces Tons/year	39173	6084	0	0	7460	0	0	13,9	239	47	1884
Est Amount of non accessi Tons/year	0	0	64	799	0	4736	17923	0	0	0	628
Est Amount of non accessi Tons/year	3176	676	69	888	829	4985	18866	7	464	111	653
Global Availability Share %	93	90	0	0	90	0	0	67	34	30	74
Emissions due to Agricultural residues											
Unused residue amount Tonnes/year	39173	6084	64	799	7460	4736	17923	14	239	47	2512
Est MC %	15	12	15	15	10	12	12	25	35	35	5
Anhydrous Biomass Tonnes/year	33297	5354	55	679	6714	4167	15772	10	155	31	2387
Est Carbon content %	45	45	45	45	35	45	45	45	50	50	85
Est Carbon Mass Tonnes/year	14984	2409	25	306	2350	1875	7097	5	78	15	2029
CO2/C ratio	3,67	3,67	3,67	3,67	3,67	3,67	3,67	3,67	3,67	3,67	3,67
Est CO2 Teq Teq/year	54940	8834	90	1121	8616	6876	26024	17	285	56	0
Residues Energy content											
Considered GCV MJ/kg	14,5	15,4	15	15	13,1	15,2	15,2	13,5	11	11	27,44
Est Energy Content TJ/year	568,01	93,70	0,97	11,99	97,73	71,98	272,43	0,19	2,63	0,52	68,93
Solid biofuel potentiel											
Suitable for briquettes making	Yes	Yes	Yes	Yes	No	Probably	Probably	Yes	Probably	Yes	Yes
Production yield %	40	30	30	30	NA	NA	NA	30	NA	30	100
Possible amount of brique Tonnes/year	16453	1917	0	0	NA	NA	NA	4	0	NA	1978
Solid biofuel Energy content											
Considered ash content %	10	8	8	4	60	10	10	8	2	2	7
Considered MC %	5	5	5	5	5	5	5	5	5	5	5
GCV MJ/kg	25,5	26	26	27	11,7	25	25	26	26	27	27,4
Energy content TJ/year	420	50	NA	NA	NA	NA	NA	0,11	NA	0,40	54
Emissions due to Solid Biofuel transformation											
Anhydrous biomass at origin Tonnes/year	33297	5354	55	679	6714	4167	15772	10	155	31	
Est Carbon content %	45	45	45	45	45	45	45	45	45	45	
Est Carbon Mass at origin Tonnes/year	14984	2409	25	306	3021	1875	7097	5	70	14	
Est fix charcoal fix carbon %	65	70	70	70	70	70	70	70	70	70	
Carbon Mass in charcoal Tonnes/year	10694	1342	0	0				3		10	
Emitted C during carboniza Tonnes/year	4289	1068	25	306				2		3	
Est CO2 proportion in carb %	99	99	99	99	99	99	99	99	99	99	
Est CH4 proportion in carb %	1	1	1	1	1	1	1	1	1	1	
C emitted Under CO2 form Tonnes/year	4247	1057	24	303	0	0	0	2	0	3	
C emitted under CH4 form Tonnes/year	43	11	0	3	0	0	0	0	0	0	
CO2/C ratio to Teq CO2	3,67	3,67	3,67	3,67	3,67	3,67	3,67	3,67	3,67	3,67	
CH4/C ratio to Teq CO2	102,67	102,67	102,67	102,67	102,67	102,67	102,67	102,67	102,67	102,67	
Téq CO2 due to CO2 Tonnes/year	15571	3876	90	1109	0	0	0	6	0	12	
Téq CO2 due to CH4 Tonnes/year	4404	1096	25	314	0	0	0	2	0	4	
Téq CO2 due to carbonisati Tonnes/year	19974	4972	115	1423	0	0	0	8	0	16	
Téq CO2 due to briquette Tonnes/year	39212	4919	0	0	0	0	0	11	0	38	
Téq CO2 due to charcoal Tonnes/year	59187	9891	0	0	NA	NA	NA	19	NA	54	0

Table 6: Summary of residues availability for briquetting and current GHG emission of these

	Total	Charcoal fines	Unit
Residues amount	83088	2538	Tonnes/year
Amount of Used residues	6548,8	25,4	Tonnes/year
Unused residue amount	76540	2512	Tonnes/year
Energy content of unused residues	1120	69	TJ/year
Est CO ₂ Teq from unused residues	106519	0	Téq CO ₂
Amount of unused & accessibles residues	53017	1884	Tonnes/year
Amount of used & non accessible residues	30071	653	Tonnes/year
Briquetting potentiel	19308	2077	Tonnes/year
Briquettes Energy content	470	54	TJ/year
Emissions due to briquette production	69151	0	Téq CO ₂
Briquettes production potential		21385	Tonnes/year

Table 5 further elaborates the figures presented in Table 4, and illustrates the approach used to estimate the energy-content of the various residues as well as the amount of briquettes that may be produced from the respective resources. CO₂ emissions related to the disposal of residues under current conditions were also estimated. These emissions were then compared to corresponding estimates, assuming the transformation of available residues into fuel briquettes. It must be noted that briquette production likewise generates emissions.

Table 6 summarizes the most important values from Table 5. Estimates related to briquette production from non-carbonised residues must be treated differently from briquettes produced from charcoal fines. Thus, the total of non-carbonized residues is estimated at 83,088 tonnes, of which 6,549 tonnes are already used. This means a total of 76,540 tonnes of available residues, representing 1,120 TJ of thermal energy. This amount of unused material releases 106,519 TCO₂eq into the atmosphere annually. Of the total potential, 53,017 tonnes are accessible (including 7,460 tonnes rice husks), representing a briquette production potential of 19,308 tonnes per year (with an energy content of 470 TJ). Emissions related to this briquette production are estimated at 69,151 TCO₂eq. The annually available charcoal fines amount has been estimated at 2,538 tonnes, of which 25.4 tonnes are used – leaving a potential 2,512 tonnes (equivalent to 69 TJ). Charcoal fines do not degrade and therefore do not emit CO₂ due to their decomposition. The estimated quantity of charcoal fines available is 1,884 tonnes per year, representing a potential briquette production of 2,077 tonnes annually (considering the binder proportion to be added). The energy content of these briquettes is 54 TJ.

The total potential for briquette production from residues in The Gambia is therefore estimated at 21,385 tonnes per year.

3.4. Fuel consumption

Surveys have been conducted to assess the household fuel consumption. During these surveys, questions were asked about the users and their households' characteristics, size of women's groups, number of persons interviewed, number of persons per household as well as the availability of resources around the group location and consumption habits.

Information gathered during the mission identified the main fuels in the Gambia and the form in which they are sold. Charcoal can be sold in cups or bags. Firewood can be sold as sticks, bundles or

cart-loads. Gas is to be had in either 3.6 or 12 kg bottles. Briquettes can be sold individually, in pots or in bags.

For each of these fuels, test participants were asked to indicate the consumed amounts and related costs. Some estimates had to be made in order to account for the masses of the forms in which fuels are sold.

4. Data base

4.1. Data base design

Based on the elements discussed in section 3, a database was established. It is available in Excel format. The main results of his analysis are presented in section 4.2.

4.2. Data based analysis

4.2.1. Gambian population

The Gambian Office for Statistics gives the following figures:

- Total population 1,857,181
- Urban Population: 1,073,827 (57,8%)
- Rural Population 783,354 (42,2 %)

4.2.2. Share of rural and urban households

Surveys conducted during the project established the average household size as 12.7 with only minor differences between Rural and Urban areas. Households were found to use one single fuel-type instead of several. Based on the population share between rural and urban areas, this allows to estimate the following share of households:

- 84,590 households in urban areas
- 62,140 households in rural areas

4.2.3. Household fuel consumption

The surveys allowed the TA to estimate the average characteristics of Gambian household regarding traditional fuels. Results are shown in Table 7. Accordingly, urban households on average consume 1.55 kg Charcoal/day or 5.24 kg fire wood. 43% households were found to use charcoal, whereas 57% use firewood. Rural households display more parsimonious use of wood-based fuels, with average shares 1.43 kg Charcoal/day versus 4.7 kg firewood. Overall, 15% of households were found to use charcoal while 85% stick to firewood.

These data combined with population figures and the relative shares of rural and urban households enable calculations of the amount of traditional fuels consumed both in rural and urban areas:

- Charcoal estimated total consumption: 20,473 tonnes in urban areas and et 4,902 tonnes in rural areas.
- Firewood estimated total consumption: 92,717 tonnes in urban areas and 90,573 tonnes in rural areas.

It appears that the total firewood consumption is equivalent in urban and rural areas. But, the total consumption of charcoal is much higher in urban areas than in rural areas.

The Gambian charcoal total consumption is estimated at 25,375 tonnes annually, whereas the firewood consumption was shown to stand at 183,291 tonnes, annually.

Table 7: Traditional fuel consumption estimation

Traditional fuel consumption estimation		Unit
Urban		
Share of charcoal users	43	%
Share of Firewood users	57	%
Average Charcoal Consumption	1,55	kg/day*household
Average fire wood consumption	5,24	kg/day*household
Est. total Charcoal Consumption	56091	kg/day
Est. total Charcoal Consumption	20473	Tonnes/year
Est. Total FW Consumption	254020	kg/day
Est. Total FW Consumption	92717	Tonnes/year
Rural		
Share of charcoal users	15	%
Share of Firewood users	85	%
Average Charcoal Consumption	1,43	kg/day*household
Average fire wood consumption	4,70	kg/day*household
Est. total Charcoal Consumption	13431	kg/day
Est. total Charcoal Consumption	4902	Tonnes/year
Est. Total FW Consumption	248146	kg/day
Est. Total FW Consumption	90573	Tonnes/year
Total consumption		
Total consumption Charcoal	69522	kg/day
	25375	Tonnes/year
Total consumption FW	502166	kg/day
	183291	Tonnes/year

4.2.4. GHG emissions due to traditional fuel production and consumption

Table 8 shows how the energy equivalent of the used fuel masses was calculated. The calculation method related to the production and consumption of these fuels is also presented.

Resulting values are summarized in Table 21. For the energy content estimate it was presumed that the calorific value of wood, considering its estimated moisture content, is 14.5 GJ/tonne and that the calorific value of charcoal is 29.5 GJ/tonne. The energy conversion has been made based on the wet calorific value considering MC of 5% for the charcoal and 20% for firewood. Estimation of GHG have considered the methane emission of the charcoal production and the major impact of this gas on the greenhouse effect (28 times the CO₂ effect).

Table 8: Firewood and charcoal use in mass, energy equivalent and related emissions calculation for urban and rural areas

Emission due to traditional fuels production & use (burning)				
Firewood				
	Unit	Urban	Rural	Total
Fire wood mass	Tonnes/year	92717	90573	183291
Est MC	%	20	20	20
Anhydrous wood	Tonnes/year	74174	72459	146632
Est Carbon content	%	50	50	50
Est Carbon Mass	Tonnes/year	37087	36229	73316
CO ₂ /C ratio		3,67	3,66	3,66
Est CO ₂ Teq	Teq/year	135985	132599	268337
Charcoal				
	Unit	Urban	Rural	Total
Charcoal mass	Tonnes/year	20473	4902	25375
Est MC	%	5	5	5
Anhydrous wood	Tonnes/year	19450	4657	24107
Est carbonisation yield	%	20	20	20
Anhydrous wood at origin	Tonnes/year	97248	23286	120533
Est Carbon content	%	50	50	50
Est Carbon Mass at origin	Tonnes/year	48624	11643	60267
Est fix charcoal fix carbon content	%	85	85	85
Carbon Mass in charcoal	Tonnes/year	16532	3959	20491
Emitted C during carbonization	Tonnes/year	32092	7684	39776
Est CO ₂ proportion in carbonisation	%	97,5	97,5	97,5
Est CH ₄ proportion in carbonisation	%	2,5	2,5	2,5
C emitted Under CO ₂ form	Tonnes/year	31289	7492	38782
C emitted under CH ₄ form	Tonnes/year	802	192	994
CO ₂ /C ratio to Teq CO ₂		3,67	3,67	3,67
CH ₄ /C ratio to Teq CO ₂		37,33	37,33	37,33
Téq CO ₂ due to CO ₂	Tonnes/year	114728	27471	142199
Téq CO ₂ due to CH ₄	Tonnes/year	29952	7172	37124
Téq CO ₂ due to carbonisation	Tonnes/year	144681	34643	179324
Téqu CO ₂ due to charcoal burning f	Tonnes/year	60618	14515	75133
Téqu CO ₂ due to charcoal consump	Tonnes/year	205298	49158	254456
Charcoal & Firewood together				
Téqu CO ₂ due to FW & charcoal cor	Tonnes/year	341284	181757	522941

Thus, the 92,717 tonnes of fuelwood used in urban areas are equivalent to 1,344 TJ and emit 135,985 TCO₂eq over the course of their production and consumption. The 90,573 tonnes of fuelwood consumed in rural areas are equivalent to 1,313 TJ and emit 132,599 TCO₂eq over their entire life-cycle. The 20,473 tonnes of charcoal consumed in rural areas are equivalent to 604 TJ and emit 205,298 TCO₂eq during their production and consumption. The 4,902 tonnes of charcoal consumed in rural areas are equivalent to 145 TJ and emit 49,158 TCO₂eq during their production and consumption. In total, domestic fuel consumption in The Gambia represents 3,406 TJ (3.4 PJ) and is responsible for the emission of 523,041 CO₂.

These different figures are illustrated in Figure 3 to Figure 5, suggesting that charcoal is only a small share of the mass of the domestic fuels used, about 25,000 tonnes out of 183,000 tonnes. This proportion is slightly higher when the energy content is considered: 750 TJ out of the 3,500 TJ consumed annually in the country in terms of domestic fuels. But charcoal is responsible for nearly half of the GHG emissions associated with this sector (250,000 TCO₂eq compared to a total emission of 523 000 TCO₂eq).

Table 9: Summary of wood fuels (wood and charcoal) consumption (in mass and in energy) and related GHG emission

Estimated Woodfuels consumption in the Gambia (Tonnes/year)		
FW Urban	92717	
FW Rural	90573	
Charcoal Urban	20473	
Charcoal Rural	4902	
Estimated woodfuels energy used in the Gambia: Moist GCV (GJ/tonne)		
FW Urban	1344	14,5
FW Rural	1313	14,5
Charcoal Urban	604	29,5
Charcoal Rural	145	29,5
Total	3406 Tj	
	3 PJ	
Estimated Teq CO ₂ /year due from Woodfuels consumption		
FW Urban	135985	
FW Rural	132599	
Charcoal Urban	205298	
Charcoal Rural	49158	
Total	523041	

Figure 3: Estimated mass of wood fuels consumption in the Gambia (Tonnes/year)

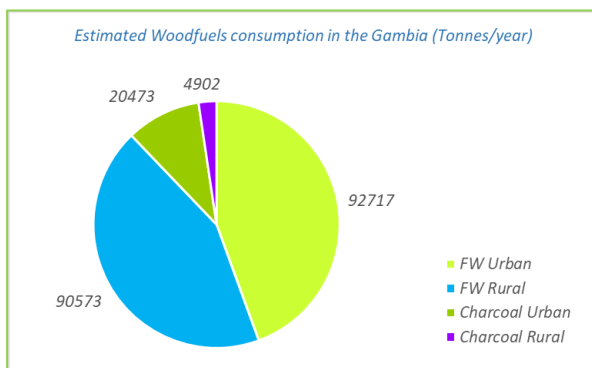


Figure 4: Estimated energy content of wood fuels consumption in the Gambia (TJ/year)

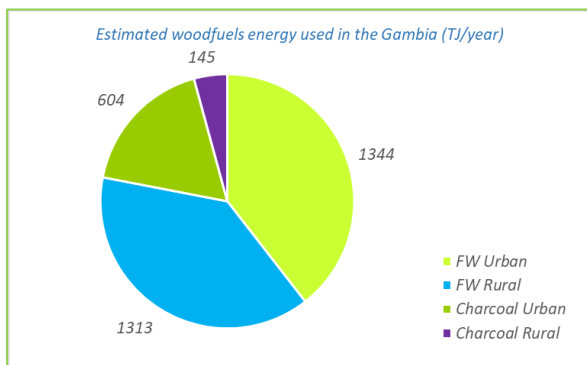
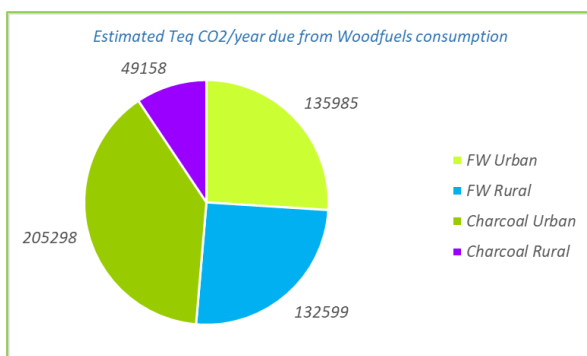


Figure 5: Estimated GHG emissions due to wood fuels consumption in the Gambia (TCO₂eq)



4.2.5. Balance between current situation and the situation where briquettes are used instead of urban charcoal

Table 10 shows emissions related to the current state of affairs, assuming the use 21,385 tonnes of briquettes produced from the identified residue potential. This briquette amount could replace 14,444 tonnes of charcoal in urban areas (considering the conversion factor – replacing one 1 kg charcoal requires 1.48 kg briquettes) which would lead to a reduction of 71% of the urban charcoal consumption, or 57% of the national charcoal consumption.

Table 10: Fuel consumption (mass) for the current situation and a scenario which includes the of briquettes in substitution to urban charcoal

Current situation			Consumption	
	Urban	Rural	Total	Unit
Charcoal	20473	4902	25375	Tonnes/year
Firewood	92717	90573	183291	Tonnes/year
Briquette	0	0	0	Tonnes/year
Residues (unused)	-	-	76540	Tonnes/year
Charcoal fines	-	-	2512	Tonnes/year
Urban charcoal substitution			Consumption	
	Urban	Rural	Total	Unit
Charcoal	6024	4902	10926	Tonnes/year
Firewood	92717	90573	183291	Tonnes/year
Briquette	21385	0	21385	Tonnes/year
Residues (used or non accessible)			30071	Tonnes/year
Charcoal fines			653	Tonnes/year

Table 11 calculates current GHG emission levels (including charcoal production and consumption, FW production and consumption, decomposition of organic residues). Charcoal fines are considered as a non-emitting material (almost no degradation). When briquettes are used as a substitute for charcoal, they reduce emissions from charcoal production and use. Emissions from the use of fuel-wood are not affected. However, emissions from briquette production and the reduction of emissions from the degradation of agricultural residues (part of which is used to produce briquettes) must be considered.

The total reduction would amount to 140,413 TCO₂eq annually, equivalent to 22.3%. Corresponding values may be gleaned from Figure 6 and Figure 7. The values likewise show that the use of 1 ton briquettes would help avoid the emission of 6.5 TCO₂eq.

Table 11: GHG emissions related to the current situation and a scenario which includes the use of briquettes in substitution to urban charcoal

GHG Emissions	Current situation	Urban charcoal substitution
Charcoal	254456	109563
Firewood	268585	268585
Briquette	0	69151
Residues (unused)	106519	41849
Charcoal fines	0	0
Somme	629560	489148
	Teq CO2	%
Difference	140413	22,3

Figure 6: Fuel consumption (mass) for the current situation and a scenario which includes the of briquettes in substitution to urban charcoal

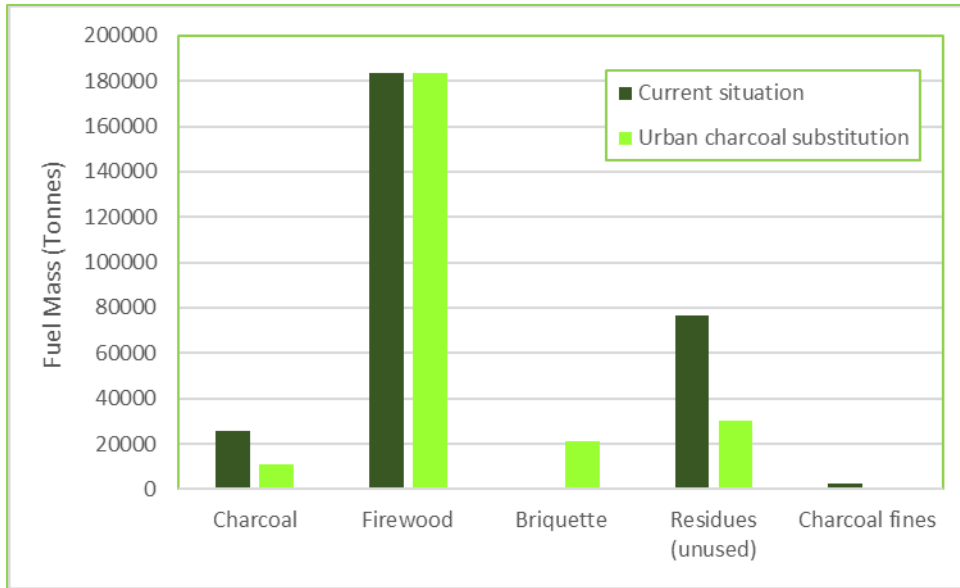
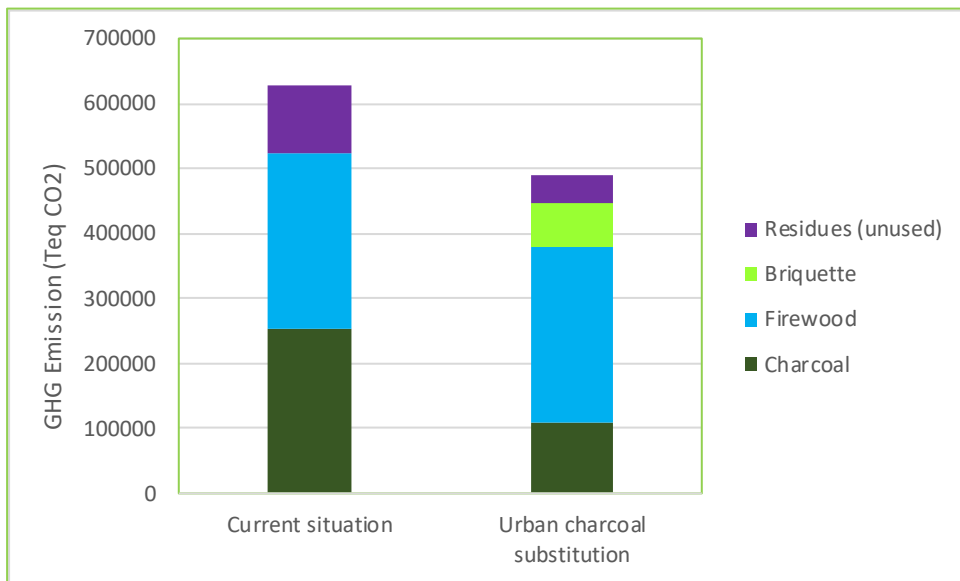


Figure 7: GHG emissions related to the current situation and a scenario which includes the use of briquettes in substitution to urban charcoal



5. Briquettes cost structure

5.1. Transport

The main objective of the transport survey was to identify three different service providers, cost of transportation, contact details and freight capacities to ferry both groundnuts shells from Denton Bridge (Saro) to the WIG processing center at Yarabamba and processed powder from Yarabamba to 15 community women groups within the wider Banjul Area. This includes loading and offloading. Three (3) categories of transports from three (3) different locations (Jimpex, Tipper Garage and Abuko Garage) were surveyed; details of which have been tabulated in the table below.

NB: The costs presented are based on current (May 2018) fuel pump price and may increase over time.

Table 12: Lorries transport costs in Banjul

Service provider	Contact details	Volume	Cost of transportation	Journey
Jimpex				
Ebou Secka	7861571	2x2x7m	5,500 DIs	Kartong/Sotokoi
Yaro Bah	3194574	2x2x7m	9,000 DIs	Kartong/Sotokoi
Ablie Ceesay	7930296	2x3x5m	5,000 DIs	Kartong/Sotokoi
Tipper Garage				
Bella Nyang	7096871	22 m ³	8,000 DIs	Saro-WIG
Salifu Ndong	7821533	10 m ³	6,000 DIs	Saro-WIG
Kebba Touray	7555806	12 m ³	5,500 DIs	Saro-WIG
Abuko Garage				
Sheikh Jobe	7992643	2x2x14m	9,000 DIs	Saro-WIG
Pa Marrong	7948851	2x2x7m	7,000 DIs	Saro-WIG
Yankuba Bayo	7036341	2x2x12m	6,000 DIs	Saro-WIG



Picture 11: Jimpex Lorry 1



Picture 12: Jimpex Lorry 2



Picture 13: Jimpex Lorry 3



Picture 14: Tipper Garage, Tipper 1



Picture 15: Tipper Garage, Tipper 2



Picture 16: Tipper Garage, Tipper 3



Picture 17: Abuko Garage, Lorry 1



Picture 18: Abuko Garage, Lorry 2



Picture 19: Abuko Garage, Lorry 3

Based on the information gathered during the transport survey and the characteristics of the materials to be transported, the transport cost was calculated for a journey between Saro (groundnut production site) and Kartong (city where the most remote group of women is located), using a 30 m³ truck. To highlight the influence of the kind of transported material, these costs were estimated for groundnut shells, charcoal fines, and coconut shells, regardless that these materials are not available in Saro. These three materials were considered in 4 different forms: raw material, carbonized material, carbonized and ground material and briquettes.

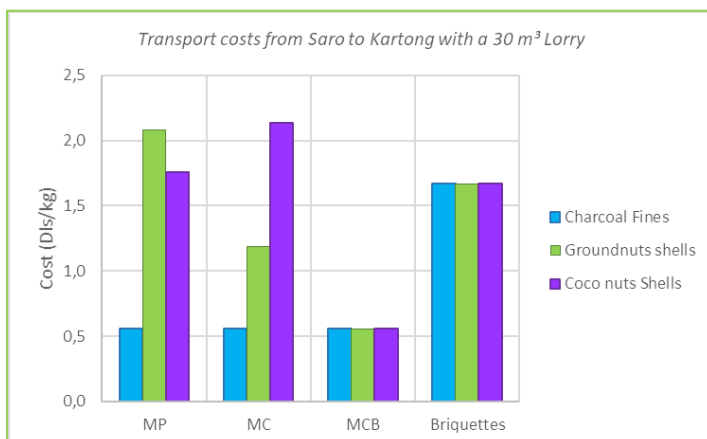
Results are presented in Figure 8, vividly confirming that transport costs are highly variable depending on both, the type of material and the form in which it is transported.

For the transport considered, the groundnut shell would cost 2.1 Dls/kg if when transported without pre-treatment. The cost would be 1.2 Dls/kg for carbonized shells, which are easier to compact. If, in addition to being carbonized, the shells are also crushed, the cost drops to 0.6 Dls/kg. The transport of briquettes produced from this material would cost 1.7 Dls/kg.

Coconut shells, by contrast, would entail transport cost of 1.8 Dls/kg, without pre-treatment. The cost would be 2.1 Dls/kg for carbonized shells, because their density indeed less than that of raw material. If, in addition to being carbonized, the coconut shells are also milled, the cost drops to 0.6 Dls/kg. Transporting briquettes would cost 1.7 Dls/kg. Secondly, it appears that when fuels are standardized (after milling or briquetting), the cost of their transport no longer varies.

Finally, carbonized and ground materials are least expensive to transport is (0.6 Dls/kg, for any all material). This form should hence be promoted. Therefore, it is preferable to transport carbonized powder, rather than briquettes (or non-carbonized raw material). Consequently, briquettes should be produced close to where they are used. Moreover, briquettes are generally not very resistant to transport.

Figure 8: Transport costs for a 30 m³ Lorry from Saro to Kartong



5.2. Carbonization

Tests were conducted in parallel with the training of trainers sessions, with results shown in Picture 20 to Picture 24. Evidence suggests that it would be difficult to achieve more than one carbonization per day and per drum. However, a confirmation test should be performed outside the Ramadan period. Before additional information is obtained, the value of one carbonization per day is considered.

It should be noted that the mass produced per drum varies significantly according to the material (see Table 13): the output of a drum containing peanut shells averaged a little over 12 kg, while it is only 8,2 kg for coconut shells. There are several reasons for this. First, the moisture content of coconut shells is higher than that of peanut husks and therefore has a negative influence on yield. Then the carbonization of groundnuts shells generates a significant quantity of non-carbonized leftovers that it are neither realistic nor feasible to separate before weighing out the carbonized material. For the same reason the carbonization yield of the coconut shells is sometimes overestimated.

Table 13: Carbonization Test Ground and Coco nuts shells, anhydrous mass yield calculation

Place	Date	Repetition	Initial Mass (Est MC (%)	Char Mass(kg)	Masse Fume	Initial Mass a	Char Mass an	Unburned	Mass yield at Material	
Serrekunda	29-05-18	1	33,2	17	9,1	Undeterminé	27,6	8,6	0	31,4 Ground nuts Shell
Serrekunda	1-06-18	1	37,8	17	12,1	Undeterminé	31,4	11,5	0	36,6 Ground nuts Shell
Serrekunda	2-06-18	1	32,45	17	13,3	Undeterminé	26,9	12,6	0	46,9 Ground nuts Shell
Serrekunda	2-06-18	2	40,1	17	17,9	Undeterminé	33,3	17,0	0	51,1 Ground nuts Shell
Serrekunda	2-06-18	3	39,2	17	13,4	Undeterminé	32,5	12,7	0	39,1 Ground nuts Shell
Serrekunda	1-06-18	1	34	17	10,48	Undeterminé	28,2	10,0	0	35,3 Ground nuts Shell
Mean							30,0	12,1		40,1
Std							2,7	2,9		7,5
N							6,0	6,0		6,0
Serrekunda	31-05-18	1	49,91	30	8,5	2,5	34,9	8,1	2,25	24,7 Coco Nut Shell
Serrekunda	31-05-18	2	36,57	25	10,3	3	27,4	9,8	2,7	39,6 Coco Nut Shell
Serrekunda	31-05-18	3	45,2	25	9,9	6,2	33,9	9,4	5,58	33,2 Coco Nut Shell
Serrekunda	1-06-18	1	40,9	30	7,75	0	28,6	7,4	0	25,7 Coco Nut Shell
Serrekunda	2-06-18	1	45	38	7,1	0	28,1	6,7	0	24,0 Coco Nut Shell
Serrekunda	2-06-18	2	56,8	35	6,8	5,7	36,9	6,5	5,13	20,3 Coco Nut Shell
Serrekunda	2-06-18	3	48,5	35	8,6	0	31,5	8,2	0	25,9 Coco Nut Shell
Serrekunda	30-05-18	1	33,27	20	9,3	0	26,6	8,8	0	33,2 Coco Nut Shell
Serrekunda	30-05-18	2	32,87	20	9,1	0	26,3	8,6	0	32,9 Coco Nut Shell
Mean							30,5	8,2		28,8
Std							4,0	1,1		6,1
N							9,0	9,0		9,0



Picture 20: Carbonization process, drying phase



Picture 21: Groundnuts carbonization, methane burning



Picture 22: Coconut shells carbonization, methane burning



Picture 23: Partly pyrolyzed groundnut shells



Picture 24: Pyrolyzed coconut shells

5.3. Milling

Pending delivery of the (new) project hammermill, the supplier provided a second-hand equivalent mill. This hammermill made it possible to carry out preliminary tests to estimate crushing productivity. The type of mill supplied corresponds perfectly to the needs of the project: diesel engine powered, with self-generated ventilation. It is illustrated in Picture 25 to Picture 28.

One test has been performed: 64 kg of carbonized groundnuts shells were ground using 0.14 kg diesel fuel. Assuming a Diesel density of 840 g/l, it can be estimated 0.167 liters have been used to grind the 64 kg. In other terms 0.0026 liter/kg. The price for diesel price in June 2018 was about 50 Dls/liter. The fuel price for milling may thus be estimated at 0,13 Dls/kg.

In terms of energy, the grinding of pyrolyzed groundnuts shells would thus require 0,0022 kg diesel/kg powder or 0,094 MJ/kg powder – 0,026 kWh/kg powder, considering a GCV of 43 MJ/kg for diesel.

One test has been performed: 64 kg of carbonized ground nuts shells were ground within 36 min. Based on that measurement milling productivity may be estimated at 107 kg/hour.

The productivity may be improved by improving the change of powder collecting bags.



Picture 25: Hammermill suitable design



Picture 26: Hammermill, milling chamber



Picture 27: Hammermill, productivity test



Picture 28: Hammermill, productivity test

5.4. The binder

The binder used by WIG up to now is called "Gum" and is starch for ironing clothes. This starch is obtained from the purification of cassava roots. It is sold at 75 Dls/kg.

The cost of this ingredient for briquette production can be influenced in two ways. First, the type of binder can be changed - rice starch which is excellently suited for this purpose, may be purchased at the prices as low as 20 Dls/kg in Gambia. It should be noted that it has been demonstrated that non-food binders do not allow the production of briquettes that can compete with charcoal.

The second way to modify the cost of the binder is to change the amount of binder used. However, to ensure the good reputation of briquettes sold in markets, it is essential that they are of excellent quality. This was the case for the briquettes produced by WIG before this TA. The proportion of gum has therefore been maintained at 6.5% of weight of the finished product. If rice is used, it is likely that this proportion will need to be slightly increased. The starch content of this cereal is lower than

that of pure starch obtained from cassava. The necessary proportion will therefore probably be 7.5%, as corroborated by the experience of other projects (the produced briquettes quality is excellent in terms of impact resistance and combustion properties).

These binder proportions, necessary to promote the acceptability of briquettes at the beginning of the production, can probably be reduced later. Indeed, the production scenario selected (cf. Section 6) is based on the premise that users will self-produce their briquettes. They are therefore also the ones who will buy the binder required for production and may likely tend to cut their production costs by reducing the amount of binder. Since briquettes under this scenario will not have to be transported over long distances, they may be a little more fragile. However, this aspect should not be addressed from the market opening, since briquettes are more complicated to use than charcoal and training in their use is necessary. Reducing the proportion of binder should therefore only be addressed when users are fully familiar with briquette-based food preparation. Moreover, even with a relatively high proportion of binder, it is possible to produce briquettes at a much lower cost than charcoal (cf. Section 6).

5.5. Pressing

Two tests, without productivity pressure, were performed to assess the efficacy of briquette production using the manual press. Test results are illustrated by Picture 29 to Picture 36, showing the sequence of production. The data obtained are included in Table 14. It should be noted that these trials were carried out during the fast of Ramadan, which is strictly followed in Gambia. This explains, at least partially, the significant drop in yield between the two trials. These tests suggest an average productivity of 16.4 kg/h, close to the results obtained with the same press (using charcoal fines) in Madagascar (14.3 kg/h). It stands to reason that target-communities producing briquettes will achieve similar productivity standards. This productivity might be doubled if the operators are given additional incentives (for example if they are paid), in which case a productivity of about 30 kg/h would seem reasonable (similar values are reported from Cameroon, where sawdust was compacted with a similar press).

Table 14: press productivity trials

<i>Productivity Mixing & Pressing</i>			
	<i>Unit</i>	<i>Trial 1</i>	<i>Trial 2</i>
<i>Start</i>	T1	11:25	02:05
<i>End</i>	T2	12:52	03:50
<i>Delta T</i>	h	01:27	01:45
	min	87	105
<i>Briquette number</i>		600	450
<i>Briquette average mass</i>		0,049	0,049
<i>Productivity</i>	n/h	414	257
	kg/h	20,3	12,6
<i>Mean</i>	kg/h	16,4	



Picture 29: Binder, ready to use



Picture 30: Binder mixing with milled groundnut shells (1)



Picture 31: Binder mixing with milled groundnut shells (2)



Picture 32: Pyrolyzed powder and binder mixing



Picture 33: One cup is filled with the mix, while one briquette is pulled out another cup and arranged on the drying tray



Picture 34: One cup is taken out the press, while another one is placed



Picture 35: While one cup is pressed, another one is filled and the third one is emptied



Picture 36: The empty cup is placed in a place where it is easy to be taken for filling

5.6. Drying

The racks loaded with briquettes are placed in the sun to dry. The racks have been designed in such a way that they can be stacked and covered with a tarpaulin during rain showers. The drying time required is estimated at 3 days. It is very important that the briquettes are very dry when used.

5.7. Wood stoves and fuel use comparison

Boiling water tests were carried out to evaluate the most suitable stove for briquettes and compare the latter with traditional fuels. To this end, the water evaporation efficiency was calculated. It indicates the energy efficiency, the amount of energy required to evaporate a given amount of water. The energy used is calculated based on the mass of fuel used and its estimated moisture.

5.7.1. Tested stoves



Picture 37: 3 stones



Picture 38: Traditional charcoal cooking stove



Picture 39: Improved firewood cooking stove



Picture 40: Sakanal, improved cooking stove



Picture 41: Jambar, improved cooking stove

5.7.2. Tested fuels

The different fuel/stoves combinations which were tested are presented in Table 21. Only fuels suitable for stoves were tested.

Table 15: Tested stove-fuel combinations

	Firewood	Charcoal	Briquettes
3 Stones	X		
Tradionnal Firewood Stoves	X		
Tradionnal Charcoal Stove		X	X
Sakanal	X	X	X
Jambar		X	X

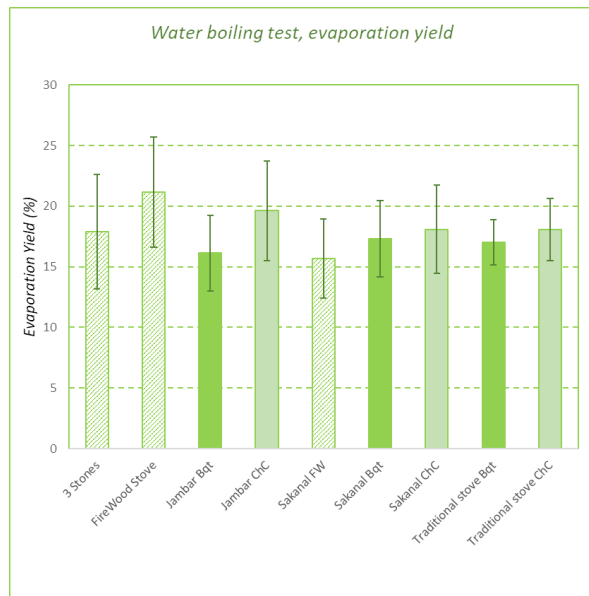
5.7.3. Results

It is known that household performance tests are fraught with high variability, which is why it is generally recommended to practice many simultaneous repetitions. The number of repetitions performed here (see Table 17) is probably a little too low compared to best practices, but it gives an indication. A proper comparison of the efficiency of the improved stoves used is beyond the scope of this intervention.

Similarly, the amount of fuel, more precisely the amount of energy used, influences the result of this test. The stove comparison should preferably be made using the same amount of energy for each stove. In this case, the operator was not instructed about the amount of fuel to be used and she used the amount of fuel she found appropriate for each “fuel-stove” combination. The charcoal or firewood amount was weighed and recorded, but the results are probably less reliable than they would otherwise have been.

The first finding is that the evaporation efficiencies obtained during these tests are very similar regardless of the stove or fuel/stove combinations considered. It is therefore unlikely that these results will be significantly different.

According to these trials, the best results obtained with firewood are those of the traditional wood stove (21.2%), followed by the “3 stones” fireplace (17.9%) and finally the Sakanal used with firewood (15.7%). The latter is a mixed stove allowing the use of both firewood and charcoal (and briquettes). It seems however that its use with firewood is not optimal, as the generated fire flames are not directly in contact with the pan. This finding should be confirmed by other measurements.



The yields obtained with charcoal are 19.6% for Jambar, and 18.1% for both the traditional stove and Sakanal. The yields obtained with briquettes are generally equal for the three tested stoves. Consequently, no fireplace outperforms the others when used with briquettes, and it seems very likely that the traditional stove will be the most used.

Figure 9: Water boiling test yield, comparison of different stoves used with different fuels (fire wood - FW, charcoal - ChC, briquettes - Bqt)

Consequently, the water boiling test data from traditional stove (and 3 stones) were used to evaluate the fuel-requirements of briquettes and other fuels for evaporating one liter of water. Results are shown in Table 16. It follows that to evaporate 1 l of water, 1.1 kg of wood or 0.57 kg of charcoal or 0.84 kg of briquettes are necessary. In terms of mass, the amount of briquettes required is 149 % compared to charcoal, but only 73 % compared to firewood, all other parameters being equal. These findings may be used as corrective factors for cost-comparisons between different fuels available on the market (section 6.2).

Table 16: Firewood, Charcoal and Briquettes mass needed to evaporate 1 l water (mean values for traditional stoves and 3 Stones)

Fuel needed to evaporate one 1 l water (kg)			
Fuel type	Mean	Std	Briquette ratio (%)
Firewood	1,1	0,45	73,4
Charcoal	0,57	0,04	148,8
Briquettes	0,84	0,10	100,0

Table 17: Water boiling test yield, comparison of different stoves used with different fuels (fire wood - FW, charcoal - ChC, briquettes - Bqt) – Std, Standard deviation – N, Number of replications

	Mean	Std	N
3 Stones	17,9	4,7	6
FireWood Stove	21,2	4,5	6
Jambar Bqt	16,1	3,1	9
Jambar ChC	19,6	4,1	7
Sakanal FW	15,7	3,2	6
Sakanal Bqt	17,3	3,1	5
Sakanal ChC	18,1	3,6	6
Traditional stove Bqt	17,0	1,9	6
Traditional stove ChC	18,1	2,6	5

6. Scenarios

6.1. Description

Based on the elements of the resource inventory (section 3.3), the cost structure (section 5), and the assumptions included in Table 18, the briquette cost for five production and logistics scenarios were calculated in order to identify one or several that display the most favorable efficiency compared to charcoal or firewood. The scenarios all depart from the observation that groundnut shells are available in large quantities, exceeding the needs of the TA-intervention at the Saro plant by a large margin. However, supply assessments suggest that it would be difficult to mobilize sufficient resources at a bearable cost close to women groups. The main differences between scenarios are explained in section 6.1.1 to 6.1.5 and are summarized in Table 19.

Table 18: Considered hypothesis for the briquette production scenario cost calculation

Paramètres	Unité	Productivité	Observation
Groundnuts Shells Carbonization	kg/Barrel	14	Carbonization mass yield: 26,31 %
Coco Shells Carbonisation	kg/Barrel	8	Carbonization mass yield: 25,43 %
Milling	kg/h	107	Based on one productivity test only, could be improved
Milling fuel consumption	l/kg	0,0026	Based on one productivity test only, could be improved
Pressing low tempo	kg/h	16	Unpaid operators
Pressing High tempo	kg/h	25	Payed operators
Barrel	Dls/unit	700	Swegam Cost
Number of carbonisations on the barrel lifetime	N	220	1 carbonisation per working day for 1 year
Hammermill	Dls/unit	89.500	Swegam Cost
Hammermill lifetime	h	10.000	estimation
Hammermill sparepart for groundnut and coco shells m	Dls/kg MC	0,1	estimation
Hammermill sparepart for charcoal fines milling	Dls/kg MC	0,2	estimation & stones contain
Drying trays	Dls/unit	925	Swegam Cost
Drying trays life time	N	220	220 dryings/ drying trays
Briquette number/drying tray	N	90	estimation based on WIG trials
Briquette mass	kg/bqt	0,049	estimation dry bone
Press + cylider & piston	Dls/unit	2.850	Swegam Cost
Press lifetime	h	5.000	estimation
Presse spareparts	Dls/kg MC	0,1	estimation
Manpower	Dls/jour	225	estimation
	Dls/heure	28	estimation
Charcoal price	Dls/kg	14	Premium Charcoal
	Dls/kg	11	3rd Quality Charcoal
Firewood price	Dls/kg	6	Bundles prices estiamtion in Serrekunda
Diesel	Dls/l	52	Diesel price in June 2018
Casava Starch (gum-binder)	Dls/kg	75	60 Dls for 800g
Rice Starch (gum-binder)	Dls/kg	30	20 dls/kg + 10 dls/kg for milling
Briquette / charcoal efficiency yield	%	148,8	based on the amount fuel needed to evaporate the same mass of water (to be confirmed)
Briquette / Firewood efficiency yield	%	73,4	based on the amount fuel needed to evaporate the same mass of water (to be confirmed)

Table 19: Main characteristics of the considered scenarios

	Sc 1	Sc 2	Sc 3	Sc 4	Sc 5
Raw material transport	X	X	X		
Pyrolysed & milled material transport			X	X	X
Man Power paid	X				
High level of productivity	X				
Low level of productivity		X	X	X	X
Casava starch	X	X	X	X	
Rice starch					X

6.1.1. Scenario 1: Raw groundnut shell transport and paid processing at women group

Scenario 1 foresees transport of raw materials from Saro to each of the women's groups (Table 20). The groups organize pyrolysis, grinding, briquette production and drying. In this scenario, the remuneration of operators was considered in relation to different production stages. The considered production rate is therefore 25 kg/h. It should also be noted that, when the groundnut shells are exported from Saro, it is customary to pay the women present on the site to fill and load the bags onto the trucks. The price is 10 Dls/bag. Using a truck with a load-capacity of 30 m³ allows to supply all the women's groups by a single round-trip. Purified cassava starch was used as binder.

6.1.2. Scenario 2: Raw groundnut shell transport and unpaid processing by women's groups

This scenario (scenario 2 in Table 20) differs from the previous only in the fact that the operators of the different production stages are not paid. Their remuneration consists of savings realized through the use of briquettes. In this case, the rate considered for briquette production is the slowest.

6.1.3. Scenario 3: Central pyrolysis and grinding center near Saro and powder transport to communities

This scenario (scenario 3 in Table 20) involves transporting the raw material over a short distance for centralized pyrolysis and grinding. The powder produced is transported to the various women's groups where it is transformed into briquettes. In this scenario, the remuneration of the operators

is not considered, because it comes from the savings achieved through substitution of traditional fuels with briquettes for the preparation of meals. The binder used is purified cassava starch.

6.1.4. Scenario 4: Central pyrolysis and grinding at Saro, and powder transport to communities

This scenario (scenario 4 in Table 20) is based on the involvement of women present in Saro (the gleaners), their organization into groups, their training in pyrolysis and grinding so that they prepare the powder that will be directly sold and transported to the other groups of women and transformed into briquettes. The savings generated using briquettes by the people who produced them constitute their remuneration. The binder used is purified cassava starch.

6.1.5. Scenario 5: Scenario 4 and cheaper binder

This scenario (Scenario 5 in Table 20) is identical to the previous one except it considers the use of rice starch, whose cost is lower, as a binder. This scenario is further detailed in section 6.3.

6.2. Analysis and selection

Information on the different scenarios was fed into the briquette cost-model, the summary sheet of which is presented in Table 20. This information is also presented in Figure 10, indicating the total cost of the produced briquettes pursuant to the scenarios selected, as well as the different cost-items used to calculate them (transport, binder, labour, depreciation, margin, etc.), the price of charcoal per kg (Dls/kg) and finally the price of charcoal and firewood needed to carry out the same cooking work as with briquettes: 7,6 Dls and 8,3 Dls respectively.

First, it appears that even with identical material and origin, production costs can be very variable. Moreover, some production scenarios lead to cost-prices that are much higher than the selling price of traditional fuels (with or without considering the equivalence factor). The choice of a competitive production scenario (compared to traditional fuels) is therefore essential for the sustainability of a briquette project.

Among the scenarios considered, only two allow the production of briquettes at a competitive price compared to charcoal; these two scenarios consider the pyrolysis and grinding of carbonized material in Saro, which considerably reduces transport costs.

The second important item in the production cost is the binder. The use of starch from rice reduces the production cost from 9 Dls/kg to 5,6 Dls/kg. This makes the fuel competitive with wood and charcoal, even considering the equivalent fuel consumption.

In conclusion, the briquette production scenario must be studied carefully and on a case by case basis for the different materials. Indeed, it is possible to produce competitive fuels, albeit with a very narrow range of logistical options. Among the 5 scenarios considered, only scenario 5 allows the production of a sustainable and competitive fuel. Moreover, this scenario also seems competitive compared to firewood, which is uncommon for briquette projects and particularly interesting in a country where firewood is the main fuel.

Figure 10: Briquette cost structure for different scenarios compared to low quality charcoal price (11 Dls/kg) - small dotted line, equivalent charcoal price (7,6 Dls/kg eq charcoal) - plain line, equivalent firewood price (8,3 Dls/kg eq firewood) - long dotted line

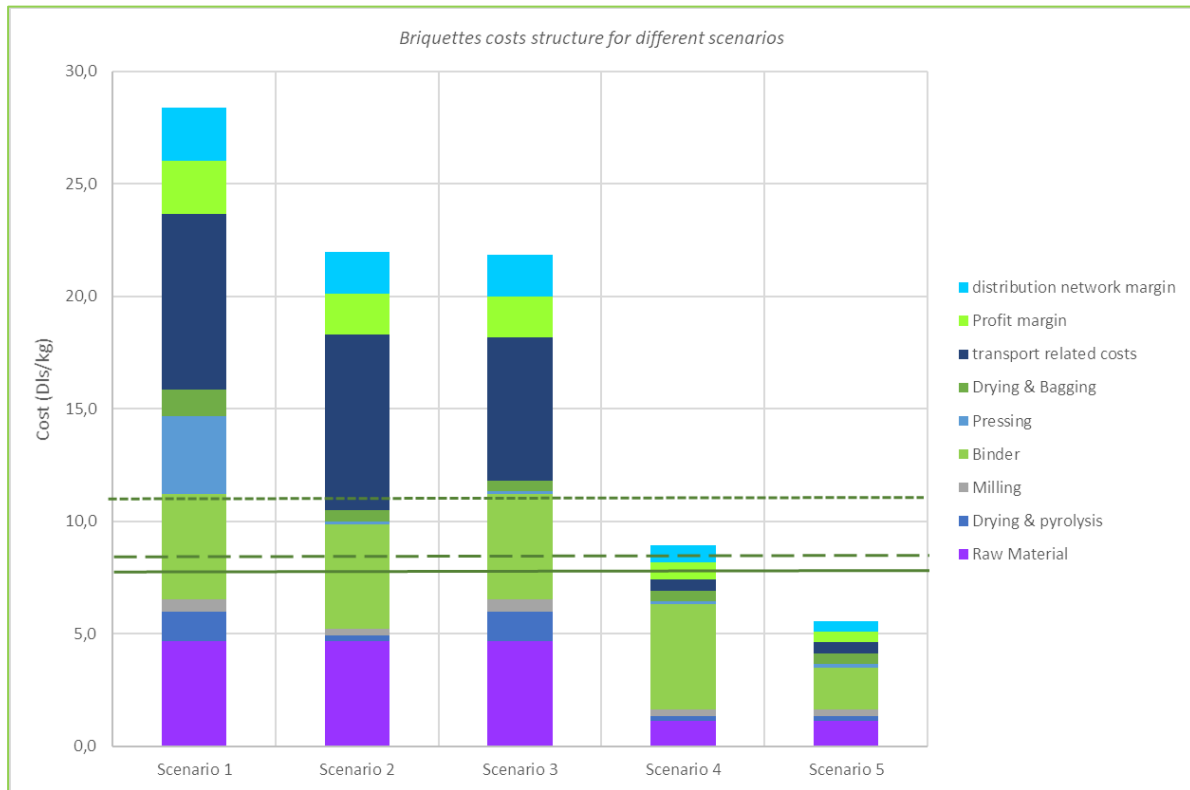


Table 20: Summary page of the global scenario analysis file (MP-Raw Material, MC Charred Material, MCB-Charred and milled material, Bqt- Briquettes)

	C/kg	Unité	Included in the scen.		1=YES	0=NO	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5
Assumptions											
Labour cost	225	225	225	Dls/day							
Working hours/day	8	8	8	h/day							
Diesel price	52	52	52	Dls/l							
Groundnut amount	1000	for	267	kg Briquettes							
Transport											
transport price Unit											
Saro-Wig 22 m³											
Transport cost MP	17	Dls/kg briquette	0	0	0,0		0,0	0,0	0,0	0,0	0,0
Transport cost MC	2	Dls/kg briquette	0	0	0,0		0,0	0,0	0,0	0,0	0,0
Transport cost MCB	1	Dls/kg briquette	0	0	0,0		0,0	0,0	0,0	0,0	0,0
Transport cost Bqt	4	Dls/kg briquette	0	0	0,0		0,0	0,0	0,0	0,0	0,0
48 m³ Saro WIG (Yankuba Bayo)											
Transport cost MP	6	Dls/kg briquette	0	0	0,0		0,0	0,0	5,9	0,0	0,0
Transport cost MC	1	Dls/kg briquette	0	0	0,0		0,0	0,0	0,0	0,0	0,0
Transport cost MCB	0	Dls/kg briquette	0	0	0,0		0,0	0,0	0,0	0,0	0,0
Transport cost Bqt	1	Dls/kg briquette	0	0	0,0		0,0	0,0	0,0	0,0	0,0
30 m³ Saro Kartong (Ablic Cessay)											
Transport cost MP	8	Dls/kg briquette	0	0	0,0		7,8	7,8	0,0	0,0	0,0
Transport cost MC	1	Dls/kg briquette	0	0	0,0		0,0	0,0	0,0	0,0	0,0
Transport cost MCB	1	Dls/kg briquette	1	1	0,5		0,0	0,0	0,5	0,5	0,5
Transport cost Bqt	2	Dls/kg briquette	0	0	0,0		0,0	0,0	0,0	0,0	0,0
Raw Material											
Total price briquettes	1,13	Dls/kg Briquettes	1	1	1,1		4,7	4,7	4,7	1,1	1,1
Raw Material drying											
Briquettes drying costs	0	Dls/kg Briquettes	0	0	0,0		0,0	0,0	0,0	0,0	0,0
carbonisation											
Barrel depreciation cost/briquettes	0	Dls/kg Briquettes	1	0	0,2		0,2	0,2	0,2	0,2	0,2
Carbonisation labour cost/briquettes	1	Dls/kg Briquettes	0	0	0,0		1,1	0,0	1,1	0,0	0,0
Broyage											
Milling depreciation cost/briquettes	0	Dls/kg Briquettes	1	0	0,1		0,1	0,1	0,1	0,1	0,1
Milling Wearing & spare parts cost/briquettes	0	Dls/kg Briquettes	1	0	0,1		0,1	0,1	0,1	0,1	0,1
Milling consumables cost/briquettes	0	Dls/kg Briquettes	1	0	0,1		0,1	0,1	0,1	0,1	0,1
Milling labour cost/briquettes	0	Dls/kg Briquettes	0	0	0,0		0,2	0,0	0,2	0,0	0,0
Pressage											
Binder cost/briquettes	1,86	Dls/kg Briquettes	1	2	1,9		4,6	4,6	4,6	4,6	1,9
Press depreciation cost/briquettes	0,03	Dls/kg Briquettes	1	0	0,0		0,0	0,0	0,0	0,0	0,0
Wearing & spare parts cost/briquettes	0,10	Dls/kg Briquettes	1	0	0,1		0,1	0,1	0,1	0,1	0,1
Press labour cost/briquettes	5	Dls/kg Briquettes	0	0	0,0		3,4	0,0	0,0	0,0	0,0
Drying & bagging											
Trays depreciation cost/briquettes	0	Dls/kg Briquettes	1	0	0,5		0,5	0,5	0,5	0,5	0,5
Drying labour cost/briquettes	1	Dls/kg Briquettes	0	0	0,0		0,7	0,0	0,0	0,0	0,0
Coûts											
Raw Material					1,1	Dls/kg Briquettes	4,7	4,7	4,7	1,1	1,1
Drying & pyrolysis					0,2	Dls/kg Briquettes	1,3	0,2	1,3	0,2	0,2
Milling					0,3	Dls/kg Briquettes	0,5	0,3	0,5	0,3	0,3
Binder					1,9	Dls/kg Briquettes	4,6	4,6	4,6	4,6	1,9
Pressing					0,1	Dls/kg Briquettes	3,5	0,1	0,1	0,1	0,1
Drying & Bagging					0,5	Dls/kg Briquettes	1,2	0,5	0,5	0,5	0,5
Production cost without transport					4,1	Dls/kg Briquettes	15,9	10,5	11,8	6,9	4,1
transport related costs					0,5	Dls/kg Briquettes	7,8	7,8	6,4	0,5	0,5
total cost					4,6	Dls/kg Briquettes	23,7	18,3	18,2	7,4	4,6
Profit margin			10 %		0,5	Dls/kg Briquettes	2,4	1,8	1,8	0,7	0,5
distribution network margin			10 %		0,5	Dls/kg Briquettes	2,4	1,8	1,8	0,7	0,5
Selling price					5,576	Dls/kg Briquettes	28,4	22,0	21,8	9	5,6
Charcoal price					11	Dls/kg	11	11	11	11	11
Firewood price					6	Dls/kg	6	6	6	6	6
Charcoal price for the same cooking work					7,6	Dls	7,6	7,6	7,6	7,6	7,6
Firewood price for the same cooking work					8,3	Dls	8,3	8,3	8,3	8,3	8,3

7. Proposed scalable model

7.1. Implementation

According to the selection of scenario 5, an implementation methodology was defined. It is presented in Table 21. The aim is to simplify the price structure calculated in section 6.2 with simple (round) amounts with a view to making it easier to handle by stakeholders. Indeed, exchanges take place at three levels:

- Producer groups, producing carbonized groundnuts shells powder
- WIG, acting as logistics intermediary
- Briquette producer and consumer groups.

7.1.1. Producer groups

Saro's gleaners were organized into two women's groups, and received the necessary training to carbonize the groundnut shells and to mill the groundnut char. The equipment used was made available by the technical assistance: pyrolysis drums and a diesel-powered hammermill.

Carbonized groundnut shell powder is purchased by WIG from Saro women's groups. According to the calculations for scenario 5, the cost stood at 1.7 Dls/kg. However, for ease of calculation, the purchase price was fixed at 2 Dls/kg. Of this amount, 1 Dls/kg will be returned by the group to the producers and 1 Dls/kg will be retained to cover production costs: fuel for the hammermill, repair and replacement of carbonization drums. Any surplus can be used according to the management rules of women's groups (personal emergencies, health, schooling of children...)

7.1.2. WIG, logistic intermediary

Besides its role in the implementation of trainings (pyrolysis and briquetting) during this TA, WIG is also involved in the perpetuation of the project by ensuring the crucial role of the logistic intermediary between the producer and user groups of carbonized powder. In practice, WIG:

- buys the carbonized and milled groundnut shell from producer groups (2 Dls/kg)
- buys and prepares rice starch (30 Dls/kg or 2 Dls/kg briquette)
- organizes and pays for the transport (0.65 Dls/kg of briquette)
- takes a trade margin of 0.75 Dls/kg (the value has been slightly modified from the calculated values to allow the sale of 25 kg bags of carbonized powder and the binder necessary for its transformation into briquettes at the round price of 135 Dls)
- Sales of bags of carbonized powder and binder required by briquette producer groups (powder 85 Dls / 25kg bag - binder required: 50 Dls / 1.6 kg), or 135 Dls per bag of 25 kg.

7.1.3. Briquettes producers and user groups

The women group oversees purchasing the material from WIG, organizing briquette production, controlling the use of briquettes use, and ensures the recovery of the payment relating to the material used. In practice:

- The necessary material (powder + binder) is bought, from WIG, by the women's group at the price of 135 Dls/bag of 25 kg + 1.6 kg binder.
- The group organizes the briquette production
 - determines production periods for each member (if required)
 - controls of the amount of material (number of bags of powder and binder) used by members
 - calculates the number of bags, or part of bags used by each member

- The group recovers the amounts corresponding to the material used by the members at the price of 160 Dls/bag of 25 kg + binder, distributed as follows:
 - 85 Dls for powder (WIG refund)
 - 50 Dls for binder (WIG refund)
 - 25 Dls to ensure the operating needs of the equipment (repairs, replacement...), kept by the women's group or placed in a bank account.

Table 21: Price structure in practice and for a 25 kg bag groundnut (pyrolyzed and milled) to be process into briquettes at women group

	Calculated	In practice	For a 25 kg powder bag	
Mass (kg)	1	1	25	
Price @ Saro	Dls/kg	Dls/kg	Dls/25 kg bag	TO be paied to
Raw Material	1,1	1	25	producer by Women group
Equipment cost	0,5	1	25	Women group (safe box or account)
Min to be paied to Saro	1,7	2	50	Women group by WIG
Price @ WIG	Dls/kg	Dls/kg	Dls/25 kg bag	
Powder	1,7	2,0	50	Women group by WIG (see above)
Transport	0,5	0,65	16,25	Transporter By WIG
Margins	0,9	0,75	18,75	WIG account
Binder	1,9	2	50	Rice & milling to be paied by WIG
Min to be paid @ WIG	5,0	5,4	135	
Price @ Community	Dls/kg	Dls/kg	Dls/25 kg bag	
Powder	3,1	3,4	85	To be paied to WIG by women group
Binder	1,9	2	50	To be paied to WIG by women group
Equipment	0,6	1	25	Women group (safe box or account)
Min to be paid @ commur	5,6	6,4	160	User to women group

7.2. Generated savings

The use of briquettes generates savings for users (who are also producers) compared to traditional fuels (see Table 22). The user pays 160 Dls/26.6 kg - 25 kg powder + 1,6 kg binder for the briquettes. The same mass of charcoal would cost 293.3 Dls. So, a potential saving of 133.3 Dls if the quality of charcoal and briquettes were equivalent. That, however, is not the case. Considering the fuel equivalency factor, this saving will be 42.7 Dls if briquettes are used as a substitute for charcoal and 61.3 Dls if they replace firewood. The savings generated therefore remain limited! But it makes briquettes competitive compared to traditional fuels.

However, cost reductions can still be envisaged in the binder. A proportion of 6.2% was considered here because it leads to the production of very good quality briquettes necessary to promote the acceptability of briquettes at the beginning of the project. This proportion can likely be reduced during the project once users get used to the fuel and understand the savings they can still make using less binder.

Regular use of briquettes is also likely to improve the fuel equivalency factor to a factor closer of 1:1 relative to charcoal and reduce fuel costs by 40-45% relative to charcoal use and probably by 50% or more relative to cooking with firewood.

Table 22: Savings by using briquettes instead of charcoal or firewood

Fuel prices for considered Dls/kg	Dls/25 kg	Savings (Dls/25 kg)
Briquettes	5,6	160
Charcoal	11	293,3
Equivalent charcoal	7,6	202,7
Equivalent fire wood	8,3	221,3

7.3. Equipment design for scaling-up

Table 23: Feasibility of implementing an upscaling of the scenario developed during this TA – Option 1

Project design for 20 000 Tonnes briquettes / year	
Briquettes amount	20000000 kg/an
Drum design	
carbonized material/Cycle	12,5 kg/cycle
Needed carbonization shifts amount	1600000 carbonisation/year
Yearly working days	300 day/year
Needed cycle amount	5333 cycles/day
shifts	2 Shift/day
Needed Barrels	2667 Barrels
Production/barrels	25 kg
N Barrels/worker	30 units
Number of workers	89
Daily production/worker	750 kg
Powder price	1 Dls/kg
Worker income	750 Dls/day
Presses	
Productivity	15 kg/h
Working hours/day	8 h
Productivity/day	120 kg/day
Working days/year	300 day
Productivity/year	36000 Kg/year
Number of press needed	555,6 units
Generated savings	5,6 dls/kg
Generated savings	672 dls/day
Mean women/communities	20
Mean savings/day	33,6 Dls
Mean working time	24 minutes
Investment	
Global price for equipment	512 €/press
Globla investment need for 20,000 tonnes	284314 €

Table 23 estimates the investment-needs required to transform all available biomass residues into fuel briquettes. As mentioned in section 3.3.4, this resource would produce 20,000 tonnes of briquettes of carbonized material. To achieve this production, more than 2,600 drums will be needed and more than 550 briquette presses. This is based on the following assumptions: one carbonization cycle allows the production of 12.5 kilos of material and two cycles can be performed each day, one worker can manage 30 drums. Similarly, it is assumed that the presses can produce 15 kilos of briquettes per hour.

This would allow, at the carbonization centre, the creation of 89 jobs, each paid 750 Dalasi per day. Considering that the involved communities each have an average of 20 women and that each of them devotes just under 24 minutes a day to the production of briquettes, this production would save each of them nearly 34 Dalasi per day.

Based on the prices obtained during negotiations for the purchase of equipment during this TA, the total investment linked to the purchase of the equipment to produce 20,000 tonnes of briquettes per year would be €284,314. This investment volume remains lower than that of an industrial briquette production plant and allows production to be developed in line with market conditions, and not the other way around.

The steps of implementation of such a project will be developed in the final report but this observation demonstrates the large-scale feasibility of the approach developed by this technical assistance.

8. Briquettes production training

After designing the production and use model, trainings were organized for involved women’s groups to make the value chain possible. These trainings are presented in the “training manual”.

9. Briquette acceptance

At the end of the training (including briquettes use), surveys about participant opinion have been made to assess both the training and the briquettes as a cooking fuel. Both feedbacks were very positive. Concerning the briquettes (Figure 11), 100% of respondents consider it a positive experience, 75% of respondents say they use briquettes every day. However, respondents equally stated that they do not exclusively use briquettes and continue to use charcoal (71%) and firewood (5%) as well. Over 90% of respondents consider it easy to produce briquettes but want more training in their use (44%); the image of fuel is particularly good among households that have tested it. Indeed, the last 3 questions intended to evaluate this aspect (expensive/cheap, easy to use or not, smoky or not) each receive a 100% positive rating.

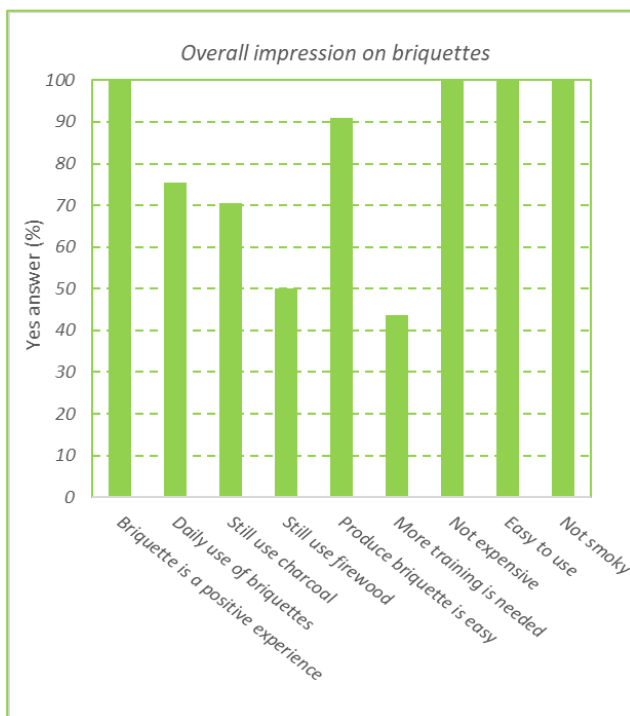
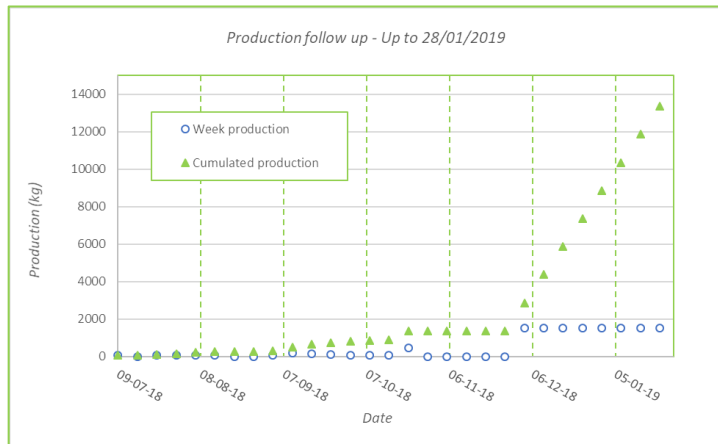


Figure 11: Overall impression of trainees about briquettes, percentage of ‘Yes’ answer to the questions asked

9.1. Briquette production follow-up

Figure 12: Carbonized ground nuts shells production at Saro Follow-up



Briquette production took time to set up. It only reached its nominal production from the beginning of December 2018. Since then, 1,500 kilos of carbonized and milled groundnuts shells have been produced each week and taken to the various women groups for transformation into briquettes and were used to replace charcoal or firewood. From the beginning, a bit less than 15 tonnes briquettes have been produced. Since the equipment provided by the TA is fully in operation, it produces 6 tonnes briquettes/month. Given that it has been estimated (section 4.2.5) that the use of 1 tonne briquettes will avoid the emission of 6.5 TCO₂eq, it may also be concluded the briquettes produced during the project have avoided the emissions of 90 TCO₂eq. Moreover, used to substitute charcoal, 15 tonnes briquettes avoid the cutting of about 50 tonnes anhydrous wood (considering the equivalence factor of 1.48 and a carbonisation yield of 20%), which corresponds to the wood standing on 2 ha of mature Eucalyptus plantation (considering a 5-year rotation and a production yield of 5 DMT/ha*year).

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9.2. Conclusions and lessons learned

This Technical assistance and its implementation have confirmed the validity of “briquette projects rules” already mentioned in this document:

- › The produced briquettes must be of very good quality and meet the expectations of the consumers. To do this, raw materials and production processes should be carefully selected to meet the needs and scale of the project. From the users’ point of view, no fuel will reach the charcoal quality! Hence the price must be lower than that of charcoal (for the same cooking work!)
- › To meet the charcoal consumers’ needs, the produced briquettes must have comparable characteristics - that is why they must contain charred material.
- › Briquettes are generally urban fuels.
- › The primary objective of Substitution Biofuels projects must be to achieve a minimum critical consumption, rather than to implement projects whose production is based on supply. Projects should be designed to be market driven rather than production driven.

- › Projects must start on a small scale.
- › The implementation strategy is specific to each project and must consider the opinions of users.

The in-depth analysis of the conditions under which briquette production is foreseen (available resources, cost of competing fuels, cost of production factors, etc.) made it possible to estimate the cost of the various production scenarios.

The analysis of these scenarios has highlighted the great disparity in the production costs depending on the selected options, even when using the same raw material and the same production tools. If no precautions are taken, production costs can be much higher than the cost of competing fuels, charcoal and fuelwood. However, some scenarios allow the production of briquettes at a competitive price, by separating the sites where raw material is prepared from the sites where briquettes are produced and used. In addition, the self-consumption of briquettes is encouraged.

Even under these favourable conditions, the savings compared to the use of traditional fuels are not very significant. But they are enough to make briquettes competitive.

The situational analysis showed a potential for unused and easily accessible agricultural and forestry residues. This potential would allow the annual production of 20,000 tonnes of briquettes. The benefit of their substitution to charcoal would reduce the use of the latter by 71% and avoid the emission of 140,000 TCO₂eq, a reduction of 22,3% per year.

It has also been calculated that the present technical assistance, through which nearly 15 tons of briquettes have been produced so far, has prevented the emission of 90 TCO₂eq, and avoided the cutting of 50 tons of anhydrous wood. This is the equivalent of 2 ha of mature Eucalyptus plantations.

In terms of implementation, this technical assistance has demonstrated:

- › The transport and cost of the binder remain two major factors in the cost of producing briquettes.
- › The need to provide close support for users until they use the briquettes independently and with the same ease as traditional fuels.
- › The very positive effect of the delivery of manufacturing equipment (presses) to women's groups and the self-consumption of briquettes. They induce an appropriation of the briquettes and fewer requirements on them.
- › Gambian consumers are very open to the use of briquettes and very sensitive to respect for the environment.