

Feasibility study to use waste as fuel for cement factories

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Economic study of producing RDF from MSW and its use as fuel for cement factories

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1. Economic activities associated with the current use of waste materials

Formal economic activities related to MSW in Maputo are mostly performed in a small-scale. According to AMOR (2016), approximately 450t to 500t of waste are recycled in Mozambique each month, 85% of it in Maputo/Matola. The Mozambican Association for Recycling (AMOR) estimates that only 1% of the urban waste produced in Mozambique, especially in Maputo and Beira, is recycled by the formal sector with designated companies in charge of the operations (Tas, Belon, 2014).. In addition to the formal recycling activities, Maputo has a substantial informal recycling sector, where waste pickers collect recyclable material, both at established waste collection points, and at the Hulene landfill. The waste pickers mostly gather hard plastic material, iron, glass, aluminium, paper and cardboard, and sell them at local markets in the city, providing an average income of 97,3 Mt/day (1,3 USD/day) (Mertanen et.al, 2013).

Formal recycling activities are mostly limited to metal scrap recycling, mainly exported to South Africa, hard plastic waste (HDPE, PP) is pelletized and sold in the national market, glass bottles are collected and sold to the national brewery for re-use, and finally, some operators buy paper and cardboard waste, mainly for export to South Africa.

The figures below are estimates of the recycling market in the area of Maputo and Matola sourced by the Mozambican Recycling Association (AMOR) (table 1). The table presents an estimation of the purchase and selling prices, taking into account the different existing stakeholders. As such, these numbers are only applicable for stakeholders purchasing and re-selling the waste, without transformation process i.e. without any added value process.

Table 1 Estimated amounts and prices of recycled waste materials in Maputo (AMOR, 2016)

Recycled Materials	Sold amount (Tonnes/month)	Revenues (USD/month)	Main clients for products
Compost	Compost was previously produced out of organic waste by the cooperative Fertiliza (about 5 t/month). However, the production stopped in late 2014		
Plastic	250	2,971	National market
Metal	50	3,396	International market (South Africa)
Glass	30	1,698	National market (National Brewery)
Paper and cardboard	70	1,782	National and international market (South Africa)

Due to the various formal and informal stakeholders involved in recycling, it is difficult to evaluate revenues and track all financial flows. However, an average has been calculated with the available data, listed in Table 1. It should also be noted that market prices for recycled material have suffered a dramatic fall within the last year, partially due to the low price of oil, which has led to cheaper raw material (AMOR, 2016).

2. Economic flows related to the current energy consumption of the cement factories

Cimentos de Moçambique (CdM) used coal in the past to generate the required heat for its clinker production. Progressively, the plant has changed its energy matrix, with natural gas being now the main energy source in the production. Co-processing of waste is already taking place in small quantities, with the use of shredded paper (calorific value of 1,500-1,800 Kcal/kg), carbon dust and small amounts of medical waste. In 2015, around 32 tonnes of shredded paper, mainly old banknotes coming from Bank of Mozambique, were burnt in the pre-calculator of the cement kiln. CdM also receives some carbon dust (calorific value of 5,000 Kcal/kg) from Mozal, a Mozambican factory producing Aluminium. The carbon dust is mixed with the other raw materials to increase the calorific value of the fuel. At the moment, only waste motor oil is co-processed directly in the main burner. The table below shows the fuel consumption of CdM in 2015.

Table 2 Fuel consumption Cimentos Mozambique (AMOR, 2016)

Item	Consumption	Costs for purchasing energy/fuels
Electricity	42,527,724 kWh/year	46,064,800 MZN/year, or 1.083 MZN/kWh
Natural gas	33.233 Tonnes/year	253,659,610 MZN/year, or 7,632.8 MZN/t, or 0.002944 USD/MJ
Shredded paper and biomedical waste	50 Tonnes/year	No costs, CdM charges for co-processing
Liquid waste	300 m ³ /year	No costs, CdM charges for co-processing
Carbon dust	2,700 Tonnes /year	No costs, CdM charges for co-processing

3. Economic assessment and cash flows of producing RDF from MSW and its use in cement factories.

3.1 Description and economic calculations

As described in the report on the technical feasibility of the utilization of unsorted MSW as RDF for the cement industry in Mozambique, a number of technical providers were contacted, in order to obtain technical descriptions of their technology, reference economic indicators (investment, operation costs, etc.), and general purchase conditions. As a result, five companies showed interest in the project, providing reference technical information. The following enterprises were contacted:

For RDF technology:

- HERHOF (Germany) <http://www.herhof.com/>
- CONVAERO (Germany) <http://www.convaero.com/>
- ENTSORGA (Italy) <http://www.entsorga.it/>
- TAIMWESER (Spain) <http://www.taimweser.com/>
- COMPOST SYSTEMS (Austria) <http://www.compost-systems.com/>

Out of these five companies, ENTSORGA, CONVAERO and TEIMWESER provided enough technical information, making it possible to compare them. The company ENTSORGA was selected as an ideal example of a flexible and adaptable option to the Mozambican context, with experience of RDF plants in the African Region. Normally, the technology provider offers to deliver the machinery, electrical and further specialized equipment, including technical capacity building regarding the daily operation and maintenance of the plants. Costs and activities excluded are import/transport costs to Mozambique, import taxes in Mozambique, and engineering and civil work in Mozambique.

3.2 Assumptions for the study

Given the fact that currently there is a limited amount of official updated data about the MSW situation of Maputo, this economic study has supplemented with different international and national literature sources and local reports provided by some of the stakeholders involved in the project, the NGO AMOR and Carbon Africa.

Important technical and economic parameters such as waste composition, expected calorific value of the RDF, inputs and outputs quantities, energy price for the RDF, investment for the RDF plant, operative costs, have been estimated based on the sources mentioned above. These parameters and further assumptions have a key role on the results of this economic

study. The most important assumptions considered for the economic study are mentioned in Table 3 below:

Table 3: List of main assumptions considered for the economic study

Parameter	Assumption	Value
Waste quantities in Maputo	Projected based on information from years 2008, 2010 (AMOR)	
Expected calorific value of the RDF	Based on information from year 2014, provided by the technology provider	
Expected amount of RDF	Based on a theoretical waste composition (2014) and the process parameters given by the technology provider	
Technology provider	Chosen based on a reference offer by ENTSORGA, not 100% adjusted to the project, due to lack of updated data	
Investment for machines and equipment for the RDF plant	Based on a reference offer. The offer is for a plant of 120,000 tonnes MSW capacity, providing an indication of costs USD/tonne of MSW treated.	76 USD/tonne + VAT
Civil work associated with the RDF plant	Based on a reference offer by ENTSORGA. A combination information about the kind of civil work required and reference indicators. Not 100% adjusted to the project, due to lack of updated data.	USD/m ² , based on local costs.
Purchase of location	This is still under negotiation with the municipality. The final location of the plant is still not fixed, but expected to be placed in the planned new landfill area provided free of charge by the municipality.	0
Import costs and customs	Mozambique has rules allowing the exemption from payment of customs duties and VAT on import of equipment for the creation of basic infrastructures. It was therefore decided not to include these costs.	0
Equity capital/debt	Important for the finance structure	30% equity capital, 70% loan

Commercial debt	Interest rates from the local national bank, Bank of Mozambique, were utilized to calculate the impact of interest rates on the financial performance of the investments. More favourable interest rates could be achieved through e.g. development banks or climate finance providers, although, due to the uncertainty of the availability of alternative finance sources, the national local bank was used as main reference.	Interest rate loan: 14.25% Interest rate of a deposit: 7.5 (date: 14.08.2016) Assumed payment period: 15 years
Operational costs	Estimation based on data provided by AMOR (2016). Costs include maintenance, staff, insurance, and administrative costs, and are based on the cost for a local recycling plant. The power consumption needed for operation was calculated based on the information provided by the RDF technology provider ENTSORGA.	Indicators expressed as USD/tonne treated MSW.
Taxes	Corporate taxes and Value added tax (VAT). Both are standard taxes for all kind of projects. Fiscal benefits were not considered in this study, due to high uncertainties about the kind of benefits that may apply to this specific kind of project, with positive environmental and social impacts.	Corporate tax: 32% of the revenues (after operating costs and payment of debt) VAT: 17%
Price of the RDF	According to the Mozambican authorities, and communication with CdM, there is a genuine interest in utilizing RDF as fuel in the cement production. Although there would be no incentive to utilize RDF if the price is not competitive with current fuels utilized by CdM. Therefore the best price that can be expected to be paid by CdM is the current and expected price for natural gas.	Cost of currently utilized fuel (natural gas) in the cement production: 0.002944 USD/MJ

3.3 Investment and associated costs

The investment costs for the RDF plant, including civil work, local engineering costs, and operating costs for the first year of the project amount to 6,236,262 USD (see Table 4). The costs of the plant and its component are based on the reference offer by ENTSORGA, costs of civil work were estimated based on information provided by the technology provider about the required structures and local costs. The modality of acquisition of the area where an eventual RDF plant would be placed has not been decided yet and is being negotiated with the Municipality, although, it is expected that the plant could be situated in the area dedicated to the new landfill and provided free of charge by the municipality.

The Initial investment does not include taxes and import customs. Mozambique has rules allowing the exemption from payment of customs duties and VAT on import of equipment for the creation of basic infrastructures. It was therefore decided not to include additional import costs in the calculations.

Table 4: Total investment of the project (Includes VAT, 17%)

EUR-USD exchange rate	1.1103
USD-EUR exchange rate	0.9007
MZN to USD exchange rate	69
Investment RDF plant (ENTSORGA) (USD)	3,689,796
Civil work, montage, electric work, etc. RDF plant (USD), according to ENTSORGA specifications	2,255,145
Purchase of location (USD) (assumed)	0.00
Payment of tariffs and taxes on imports of machinery (USD) (assumed)	0.00
Import costs (transport) machinery (USD) (assumed)	0.00
Total investment infrastructure (USD)	5,944,942
Local engineering costs (USD)	75,000
OPEX costs first year (USD)	216,320
Total Investment (USD)	6,236,262

3.4 Operating costs

Error! Reference source not found. lists the indicators used to estimate for the operating costs of the RDF plant. The indicators on power consumption were calculated based on the information provided by ENTSORGA. Reference costs for staff, maintenance, insurance and administration were sourced by the NGO AMOR, based on costs for a recycling plant in Mozambique.

Table 5: Estimated operating costs for RDF plant (Includes VAT, 17%)

Operational costs RDF plant	
Power consumption (kWh/tonne MSW)	37.6
Staff (persons) (USD/tonne MSW)	2.56
Maintenance (USD/tonne MSW)	0.56
Insurance (USD/tonne MSW)	0.26
Administrative costs (USD/tonne MSW)	0.35

The yearly operating costs for the RDF plant were calculated using these indicators (costs/tonne MSW) and the amount of MSW to be treated per year.

Table 6 Yearly operating costs of the RDF plant

Year	Operating costs (USD/year)
2017	216,320
2018	217,015
2019	217,740
2020	218,480
2021	219,223
2022	219,962
2023	220,699
2024	221,438
2025	222,171
2026	222,892
2027	223,596
2028	224,283
2029	224,956
2030	225,609
2031	226,234
2032	226,822

2033	227,369
2034	227,875
2035	228,338
2036	228,756
2037	229,128
2038	229,454
2039	229,735
2040	229,969

3.5 Taxes

There are different taxes associated with the operation of the RDF plant, such as the municipal tax, corporate tax (32% of the revenues after costs), and the VAT (17%). For the purpose of this study and considering the uncertainties regarding possible arrangements and cooperation agreements with the municipality, the calculations only consider the applicable corporate tax and VAT.

Regarding tax benefits, Mozambique has some rules regarding tax benefits for boosting private investment like accelerated depreciation and a 5% tax credit. Therefore, in principle, this project could be entitled to use some of these benefits (For the purpose of this project and considering uncertainties regarding the kind and the scope of benefits to be applied to the RDF project, it was decided not to apply any additional tax benefits.

3.6 Revenues

Due to the lack of existing MSW handling fees and gate fees at the landfill in Maputo, the only remaining main source of potential revenues is the sale of RDF to the CdM cement plant, as no other potential client and has been identified. According to Carbon Africa (2016), the rest of the cement plants in Mozambique do not have cement kilns.

There is no formal agreement between CdM and the Municipality of Maputo (or any other stakeholder) that guarantee the purchase of the RDF if eventually produced. However, CdM has expressed the intention to adapt its plant to be able to receive more waste in the future (as RDF), and is willing to buy it from a RDF facility operator if prices are compatible with the existing cost of fuel. Table 7 list the expected future RDF consumption capacity estimated by CdM.

Table 7 RDF future requirements of Cimentos de Mozambique at Matola I plant

Year	RDF consumption (tons)	RDF consumption (tons/day)
2018	9,512	30
2021	25,031	80
2026	33,375	107

In order to calculate the potential revenues for the sale of RDF, it is assumed that the selling price of RDF (USD/MJ) should as a minimum be competitive with the energy cost of the main fuel (natural gas) which is currently being used by CdM. The potential selling price of the RDF produced, is therefore estimated based on total energy consumption of CdM from natural gas, and the yearly costs related to its consumption (see Table 8).

Table 8 Energy costs CdM

Costs Gas natural CdM (USD/year)	3,693,715
Heat consumption (MJ/year)	1,254,867,885
Price per MJ gas natural (USD/MJ)	0.002944

3.7 Finance structure

As a starting point for this section, it was assumed that the project would be mainly externally financed by a local bank (70%). The rest 30% is assumed to be equity capital. The possibility of other combinations and sources of external financing (international banks, grants, etc.) will be presented and shortly discussed in the section for final recommendations.

Table 9 Finance structure for the project

Source	%	USD
equity capital	30.00%	1,870,878
Loans/others	70.00%	4,365,383
Total	100.00%	6,236,261

Financing conditions

Debt: 4,365,383 UDS

Payment period (years): 15

Yearly interest rate: 14.25 % (bank of Mozambique)

Table 10 Payments debt project

Year	Debt (USD)	Interest (USD)	Amortization (USD)	Balance due (USD)	To pay (USD)
2017	4,365,383	622,067	97,558	4,267,825.20	719,625
2018	4,267,825	608,165	111,460	4,156,365.10	719,625
2019	4,156,365	592,282	127,343	4,029,021.93	719,625
2020	4,029,022	574,136	145,490	3,883,532.36	719,625
2021	3,883,532	553,403	166,222	3,717,310.53	719,625

2022	3,717,311	529,717	189,908	3,527,402.09	719,625
2023	3,527,402	502,655	216,970	3,310,431.69	719,625
2024	3,310,432	471,737	247,889	3,062,543.02	719,625
2025	3,062,543	436,412	283,213	2,779,330.20	719,625
2026	2,779,330	396,055	323,571	2,455,759.56	719,625
2027	2,455,760	349,946	369,679	2,086,080.11	719,625
2028	2,086,080	297,266	422,359	1,663,721.33	719,625
2029	1,663,721	237,080	482,545	1,181,176.43	719,625
2030	1,181,176	168,318	551,308	629,868.88	719,625
2031	629,869	89,756	629,869	0.00	719,625

3.8 Cash flow analysis

Table 11: Cash flow analysis

	Year	Cash IN	Cash OUT	Project Cash flow (Gross)	debt service payments		Taxes	Net cash flow	
		Total revenues from sales (USD/year)	Operating costs (USD/year)	USD/year	Loan interest (USD/year)	Amortization (USD/year)	USD/year	USD /year	Equity capital
				-6,236,262				-6,236,262	-1,870,879
1	2017	546,078	216,320	329,758	622,067	97,558	0	-389,867	-389,867
2	2018	547,834	217,015	330,818	608,165	111,460	0	-388,807	-388,807
3	2019	549,664	217,740	331,923	592,282	127,343	0	-387,702	-387,702
4	2020	551,531	218,480	333,051	574,136	145,490	0	-386,574	-386,574
5	2021	553,407	219,223	334,184	553,403	166,222	0	-385,441	-385,441
6	2022	555,271	219,962	335,309	529,717	189,908	0	-384,316	-384,316
7	2023	557,131	220,699	336,433	502,655	216,970	0	-383,192	-383,192
8	2024	558,997	221,438	337,559	471,737	247,889	0	-382,066	-382,066
9	2025	560,848	222,171	338,677	436,412	283,213	0	-380,948	-380,948
10	2026	562,669	222,892	339,777	396,055	323,571	0	-379,848	-379,848
11	2027	564,445	223,596	340,849	349,946	369,679	0	-378,776	-378,776
12	2028	566,181	224,283	341,897	297,266	422,359	0	-377,728	-377,728
13	2029	567,879	224,956	342,923	237,080	482,545	0	-376,702	-376,702
14	2030	569,528	225,609	343,919	168,318	551,308	20,110	-395,817	-395,817
15	2031	571,105	226,234	344,871	89,756	629,869	45,554	-420,309	-420,309
16	2032	572,588	226,822	345,767	0	0	74,563	271,204	271,204
17	2033	573,971	227,369	346,602	0	0	74,830	271,772	271,772
18	2034	575,249	227,875	347,373	0	0	75,077	272,296	272,296
19	2035	576,416	228,338	348,078	0	0	75,303	272,776	272,776

20	2036	577,471	228,756	348,715	0	0	75,507	273,209	273,209
21	2037	578,411	229,128	349,283	0	0	111,771	237,512	237,512
22	2038	579,235	229,454	349,780	0	0	111,930	237,851	237,851
23	2039	579,942	229,735	350,207	0	0	112,066	238,141	238,141
24	2040	580,534	229,969	350,565	0	0	112,181	238,384	238,384

3.9 Financial analysis

Table 12 Financial performance of the project

Project IRR (pre-tax and debt services payments)	2.3%
IRR (after taxes and debt service payments)	-10.6%
IRR_equity	-8.9%
NPV pre-taxes (Net present value)	-3,654,391
NPV (after taxes and debt services)	-8,590,795

4. Conclusions

Based on the assumptions taken into consideration in this economic analysis (see Table 3) and the technical specifications for an RDF plant outlined in the technical feasibility study, focused on the production of RDF from unsorted MSW, it is concluded that the project would not be economically feasible.

Main economic barriers:

- **Competitiveness of RDF as fuel:** The only source of revenues considered for the RDF plant is the sale of RDF to CdM. RDF would have to compete with the other fuel currently utilized by CdM. Given the price of natural gas, the investment in an RDF plant would not be economically viable if RDF is to be sold at the same price as natural gas. The price for RDF would have to be around 42 USD/tonne (0.002944 USD/MJ), this is a very low price compared to other MSW to RDF experiences (e.g. e.g. Beja City in Tunisia, Elnaas et al. 2015) the RDF price is substantially higher: 134 USD/tonne RDF (0.0092525 USD/MJ).
- **Lack of alternative revenue sources:** The lack of a gate fee for receiving and treating MSW at landfill and therefore for an eventual RDF plant, is also seen as a barrier. As reference for comparison, in the UK where the RDF process from MSW is a well established, MBT plants producing RDF charge gate fees between 85 to 106 USD/tonne¹. The possibility of a gate fee is being discussed with the Municipality of Maputo. However, neither the establishment of a gate fee, nor the amount has been decided yet. Waste treatment is currently financed through having the residents pay a fee for the waste management service, charged through the electricity bill, covering approximately 90% of the costs of running the system. The municipality would have to either subsidize the RDF production through these fees, or reorganize the financing of MSW management with gate fees to finance the production of RDF.
- **The limited demand of RDF in the country:** Currently, the only client for RDF is CdM. There is no possibility of expanding the RDF market in the short-term. CdM is the only cement company with the infrastructure to process RDF in the cement kiln, while other cement companies focus on gridding. Therefore, there would be no bargaining power regarding RDF prices, and there would also be a limit to the RDF that could be utilized by the cement industry.

¹ WRAP, 2013: *Gate Fees Report 2013*,
http://www.wrap.org.uk/sites/files/wrap/Gate_Fees_Report_2013_h%20%282%29.pdf

- **High interest rates:** The Bank of Mozambique was considered to be the appropriate loan provider of the project. although, the high interest rates might influence significantly on the profitability of the project and its capacity to pay back the loan. Alternative financing sources through development banks or climate finance providers could be pursued.
- **Lack of updated data:** The results of the analysis are based on the limited amount of available data required for determining the real performance of the project, in terms of RDF quantities, composition, quality and calorific value, adjusted investment according to real waste quantities, operating costs, etc. (see section 3.2)

5. Recommendations for a finance strategy for the project

The results and conclusions of the study, provide indications that RDF production from unsorted MSW would not be a technologically feasible option, given CdMs current technical requirements. The financial analysis shows that even if the technical specifications from CdM would change, aligning themselves with existing RDF requirements elsewhere, allowing for the utilization of RDF from unsorted MSW in Maputo, the RDF would still not offer a financial viable option as replacement of fuel. Nevertheless, Mozambique still faces environmental, social and economic challenges in its current handling of MSW, and should investigate alternative approaches to overcome these challenges. The following recommendations provide alternative approaches on how MSW challenges could be addressed in the future:

- **Other MSW treatment options:** Recycling, composting, biodigestion and their combination offer the possibility of producing different outputs, which may be sold at national or international markets, depending on their demand and the current legal framework of the project's country; e.g electricity, compost, and recyclable materials. The case of Tunisia does not base its revenues only on RDF, but also on the sale of recyclables, compost and a gate fee, increasing the profitability of the investment. For instance, for Mozambique, the cost of electricity for large consumers is around 0.04 UDS/kWh (0.011 USD/MJ) (AMOR, 2016). This price is higher than the highest price considered for the RDF in the economic analysis (0.002944 USD/MJ). This might represent an opportunity for considering other MSW treatment options that generate electricity, and their combination with the RDF production. Other income source could also come from recyclable materials such as plastic, metal, glass, compost etc.
- **Analysis and adaptation of the current Mozambican legal framework regarding MSW and especially the Renewable Energy framework:** Currently, the policies and strategies consider biomass as a renewable energy source but only focusing on biodiesel. The

Renewable Energy Framework could include MSW (the organic fraction) as a kind of renewable energy source, thus opening the doors to all kind of benefits specifies in the renewable energies policies in Mozambique. This may happen not only for RDF from the organic fraction but also for enabling other energy recovery options from waste (e.g. biodigestion).

- **Long-term agreements:** It is recommended to negotiate long-term agreements with the municipalities and other local authorities involved, ensuring the waste availability, and waste handling fees. The agreements should also consider other aspects such as the kind of conditions of the legal cooperation between the municipality and the project (concession, contracting, etc.)

- **Establishment of a gate fee:** Normally, the municipalities consider public budget for paying collection, transport and disposal. The treatment of waste at a plant would redirect waste to be disposed of in dumps or landfills. Therefore, the assignment of a gate fee should be possible. The amount of this fee should be defined by the municipality and the project, after performing an accurate technical and economic assessment to find out an appropriate and fair fee for the project.

- **Alternative source of finance:** It is recommended to consider other sources of financing, such as soft-loans from development banks, international funds, climate funds, etc. This would provide the project with better financing conditions, e.g. lower interest rates, grace periods for payments, grant components and other potential benefits. However, this measure should be considered just for enabling the investment of the project. Before coming to this point, all aspects specified above should be analysed and included in the project according to its convenience.

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