Case Study: Feasibility of Composting Food Waste at a Fresh Produce Market

Robert Relou. South Africa, GCS Environmental Engineering. robertr@gcs-sa.biz

ABSTRACT

Earth Probiotic Industrial (EPI) operated a pilot food/green waste compositing plant at the Tshwane Fresh Produce Market (TFPM) in 2014. The plant received food waste and is able to compost cardboard from waste packaging material as well. The pilot plant uses bokashi (probiotic inoculated bran) to assist in breaking down the food/green waste and converting it to compost with a turnaround time of approximately two weeks. GCS Environmental Engineering compiled a feasibility study (economic and environmental) for this project to determine if the project will present a cost saving to the counsel and at the same time benefit the environment. This could motivate the Market to implement additional plants to handle all their food/green waste. Factors considered in the study was, direct cost for waste management and transport, and indirect costs in terms of landfill airspace and CO2 reductions. The results of this study forms part of this presentation.

1. INTRODUCTION

The capacity of the pilot plant was 30 tons per month or a ton a day. If the pilot project was successful the plan was to implement a 24m^3 plant. This will be done with the possibility of progressively implementing more plants if the TFPM wishes to do so.

2. BACKGROUND INFORMATION

2.1 Purpose of the Feasibility Study

The purpose of the feasibility study was to analyse and document the results from the pilot project and model the implementation of a larger scale plant to allow the TFPM to make an informed decision on the way forward. The following scope had to be incorporated: it had to analyse the performance of the current pilot project and model the performance of the larger plant, it had to consider the economic benefit to the TFPM to implement the 24m^3 composting system, factors like the environmental and social benefits of the system for the TFPM had to be documented and presented to TFPM for consideration and use, operational constraints or benefits had to be considered and documented.

2.2 Current Disposal Practices

The TFPM currently uses waste disposal to landfill for their waste management choice. The waste from the market is mostly green waste from vegetables and fruit that could not be sold. Additionally packaging material such as cardboard and plastic is disposed of by the TFPM. The waste stream goes to a central waste storage area and is loaded into 28m^3 roll on roll of skips. When the skips are full they are taken to the Onderstepoort landfill for disposal. It is estimated that 4 to 8 skips are taken to the Onderstepoort landfill for disposal each month.

The following table shows the waste generation at the market over the last 13 years.

Table 1: Yearly waste generation figures at the TFPM

Year	Waste Quantity (kg)	Waste Quantity (Ton)
1999	8728551	8729
2000	7505792	7506

Year	Waste Quantity (kg)	Waste Quantity (Ton)
2001	6063024	6063
2002	4239379	4239
2003	4395359	4395
2004	6845670	6846
2005	7242069	7242
2006	7290752	7291
2007	7174775	7175
2008	6343769	6344
2009	8135288	8135
2010	8465730	8466
2011	7368445	7368
2012	6728199	6728
2013	4406663	4407

For the purpose of this study a trend line was drawn through the results to establish a representative average for the purpose of the estimations done for this study. As can be seen from the graph, the trend line is just under 7000 tons per year. This average is taken as 7000 tons of food waste per year including cardboard and plastic. Assuming that the market operates 5 days a week for 12 months of the year the daily waste generation for the market is taken as 7000 tons / 260 days which is equal to 27 tons per day.

The density of uncompacted food waste can range from 350kg/m^3 to 500kg/m^3. The density of uncompacted dry cardboard is in the range of 55kg/m^3. For the purpose of this study we assume that the waste cardboard ratio is approximately 1:10. An average density of the uncompacted food waste (total waste stream) is estimated at 400kg/m^3. Therefore the market disposes of an average of approximately 17 500m^3 of uncompacted food waste a year.

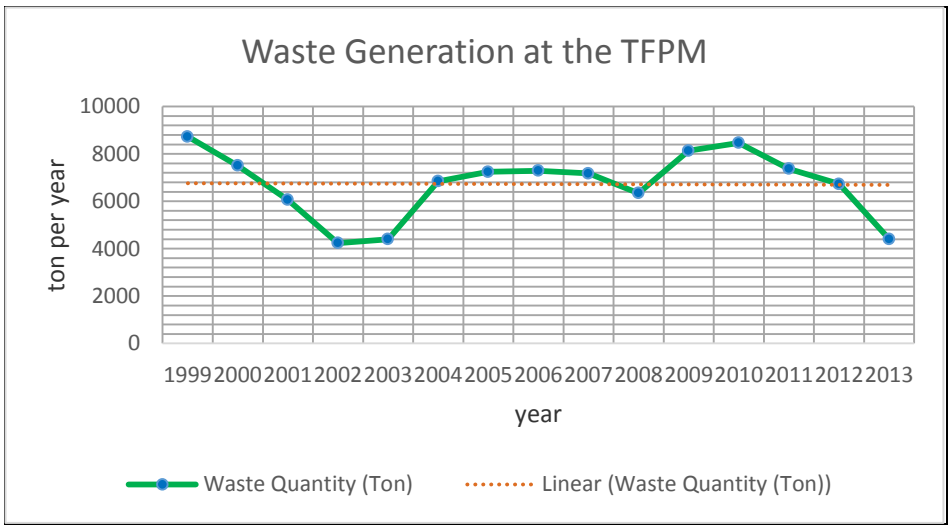

Figure 1: Yearly waste generation and trend

The TFPM is currently paying R 944.91 per ton to dispose of their waste to landfill. If the yearly average waste generation is applied the current cost for the TFPM waste disposal equates to approximately R 25 512.57 per day for 27 ton per day and R 6 552 950.85 for the current year (260 days). For

simplification purposes the seasonal months with higher waste discharge rates (December and January) are not considered in the calculation.

3. EARTH PROBIOTIC INDUSTRIES - HERON IVC COMPOSTING PLANT INFORMATION

EPI utilised a plant called the heron IVC to simulate this natural process of composting in a fraction of the time. The heron IVC incorporates these processed namely: (a) mechanical and forced aeration, and (b) the addition of probiotic bacteria and fungi. The mechanical auger functions to aerate the matrix through a vertical lifting process. The following figure shows the different components of the system and in what arrangement the system operates.

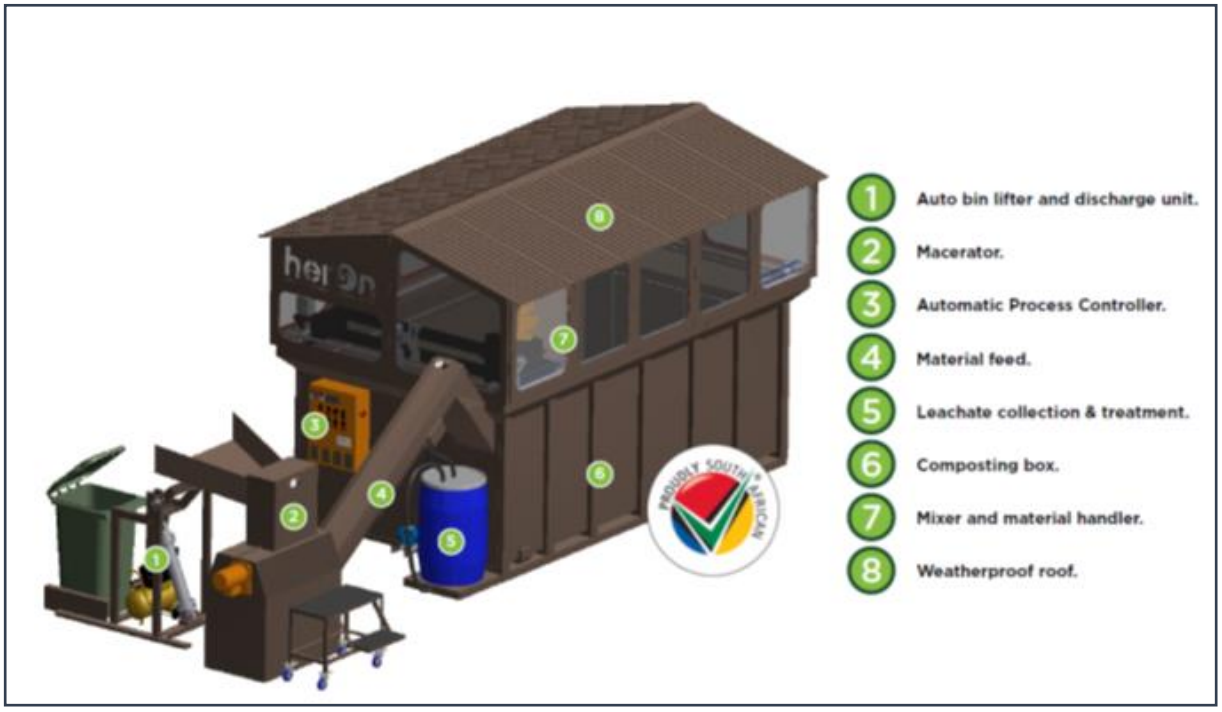

Figure 2: Heron IVC Layout

4. ASSUMPTIONS AND CONSTRAINTS

- The maximum power usage for the current 12m^2 unit is 3 phase 25kWh running for an average of 2 hours a day. Therefore a maximum of 50 KW per day. The larger 24m^2 system will utilise approximately 25kWh running for an average of 4 hours a day. Therefore a maximum of 100 KW per day.
- The Tshwane guideline for electricity charges is calculated for this category is 101 – 400 kWh is 121.20c per kWh for the 2013/2014 year. An 8% increase was implemented in June 2014 therefore the assumed rate per KWh is taken at 130.90c.
- An escalation of 7% according to the Producer Price Inflation (PPI) index is assumed for the yearly increase in electricity costs for the purposes of this study.
- The worst case scenario has been used i.e. the maximum electricity usage of the larger 24m^2 composting plant of 100 kW per day is assumed for the purposes of this study.
- It is assumed that the larger 24m^2 system will be operated for three years whereby it will be evaluated again and EPI will be allowed to renegotiate their rate for the system.
- The EPI has completed the pilot phase and no comparison for alternative systems have been allowed for in this study. This study will compare the probiotic system versus the current system of disposal to landfill.

- The larger system will have to be evaluated with regards to the financial, social and environmental advantages and disadvantages to the end user (client).
- An average density of the uncompacted food waste (total waste stream) is estimated at 400 kg/m^3
- An average density of compacted food waste (total waste stream) is estimated at 1000 kg/m^3
- The system produces a leachate which is being discharged into the sewer system. Although the leachate would be organic in nature as it is produced during the decomposition process of the green waste, no information is available on the chemical make-up of the leachate and the quantity being produced as the pilot project did not allow for this testing. For the purpose of this study it is assumed that the leachate is safe for disposal into the sewer system.
- The larger system will have a leachate management system in place and testing will be part of the process. The leachate might be beneficial for use as a compost tea.
- For the purposes of this study the Producer Price Inflation rate has been averaged at 7% over the last two years and used to future cost estimations.
- Compost is produced at a ratio of 1m^3 to 3,000kg waste. Two compost samples are being tested at the Agricultural Research Council in Pretoria (ARC) (see attached results). Live testing has taken place where the compost output has been (a) applied in gardening and (b) used as a feed in vermi-composting (using composting earthworms of the Eisenia Fetida species).
- Anecdotal evidence indicates that the matrix has satisfactory performance in gardening and no-adverse reactions have been found. In vermicomposting the matrix is rapidly processed by composting earthworms (Eisenia Fetida) – indications are that this matrix has significant promise as a feed stock for commercial vermicomposting operations (the commercial implications of this method have not been calculated in this evaluation).

5. KEY FINDINGS FROM THE PILOT PROJECT

The findings from the pilot project are as follows:

1. For every 1,000kg processed, approximately ⅓ m^3 of compost is produced.
2. Landfill airspace savings is calculated at a compacted waste density of 1000kg/m^3 of waste produced and a 1:6 ratio of cover material. The Pilot project saved 15.3m^3 or airspace at the Onderstepoort Landfill during the trial period.
3. The pilot project was operated by EPI at no cost the TFPM.
4. The total volume of uncompacted waste diverted from the landfill is 33m^3. Therefore the total saving to the Tshwane Municipality was R 2048 over the pilot project timeframe which represents an indirect saving to the TFPM.
5. Qualitative evaluation indicates that the quality of this compost is acceptable and marketable - however, more on-site management of the composting process was needed on this aspect of the trial.
6. No leachate measurement or management was implemented for the trail.
7. The total potential financial benefit to the TFPM during the pilot project was R 16 588.77
8. The estimated CO_2 reduction during the pilot project was 3 091.4kg
9. Potential social benefits are to support the community and farmers and to use the compost for improving city parks.
10. It was shown that the pilot project was overall successful in composting a portion of the food waste at the TFPM.
11. The test results is sufficient to prove that the compost is of a good quality, however a full report is expected from ARC and further testing if the TFPM decides to sell the compost.

6. FEASIBILITY OF IMPLEMENTING A LARGER COMPOSTING PLANT

The larger IVC is capable of processing upwards of 2,200kg of fruit/veg and cardboard waste per day and thus delivers the scale necessary for the Market to reduce waste disposal costs.

6.1 Waste Quantities

The 24m^3 unit that is being proposed can process up to 2200kg or 2.2 ton of wet waste per day. It would be operated on the basis of a 22 working day month. Therefore in a year it would be able to process 580 800kg or 580.8 tons of green waste.

The quantities can be seen in the following table:

Table 2: Larger IVC Waste Processing Quantities

MONTH	FOOD WASTE (22 DAYS)	CARDBOARD (22 DAYS)	CUMULATIVE VEG WASTE DIVERTED	CUMULATIVE DIVERTED FROM LANDFILL
JAN	44 000.kg	4 400.kg	44 000.kg	48 400.kg
FEB	44 000.kg	4 400.kg	88 000.kg	96 800.kg
MAR	44 000.kg	4 400.kg	132 000.kg	145 200.kg
APR	44 000.kg	4 400.kg	176 000.kg	193 600.kg
MAY	44 000.kg	4 400.kg	220 000.kg	242 000.kg
JUN	44 000.kg	4 400.kg	264 000.kg	290 400.kg
JUL	44 000.kg	4 400.kg	308 000.kg	338 800.kg
AUG	44 000.kg	4 400.kg	352 000.kg	387 200.kg
SEP	44 000.kg	4 400.kg	396 000.kg	435 600.kg
OCT	44 000.kg	4 400.kg	440 000.kg	484 000.kg
NOV	44 000.kg	4 400.kg	484 000.kg	532 400.kg
DEC	44 000.kg	4 400.kg	528 000.kg	580 800.kg

Over the proposed three year period the waste processing quantities is shown in the following table:

Table 3: Three Year Waste Processing Quantities

Year	TOTAL FOOD WASTE	TOTAL CARDBOARD	VEG WASTE DIVERTED	CUMULATIVE DIVERTED FROM LANDFILL
2015	528 000.kg	52 800.kg	528 000.kg	580 800.kg
2016	528 000.kg	52 800.kg	1 056 000.kg	1 161 600.kg
2017	528 000.kg	52 800.kg	1 584 000.kg	1 742 400.kg

6.2 Time and Resource Costs

The Tshwane Fresh Produce Market participates in the Tshwane Municipalities “Public Works Programme”. During the trial three people were allocated to the management and operations of the heron IVC working for approximately 3 hours per day (each).
It is envisaged that for the roll out of the larger machine an addition of one person will need to be allocated to the operations of the machine.
Resources required are therefore:

- Supervisor/operator.
- Three labourers for the loading the wet waste into wheelie bins and then into the macerator.

Included in the responsibilities of these employees will be a requirement for them to additionally manage (turn) the compost lines in the CMA once per week.

It is envisaged that these employees would be allocated to the machine from the current public works programme – this will represent a reallocation of existing human resources in the market.
The implementation of the composting plant will therefore increase employment for the municipality.

6.3 Cost Benefit Disposal VS Composting

As shown previously the total amount of food waste that the large IVC will be able to process is 1 742.4 ton over the three year period. The compare the cost of the IVC vs the cost of the current waste disposal practices and equivalent amount of waste is used.

6.3.1 Disposal Cost to Landfill Calculation

The disposal cost (Landfilling) over a three year period is represented in the following table:

Table 4: Three Year Waste Processing Quantities

Waste disposal to Landfill						
Year	R/Ton	Max Waste Processed per day (kg)	Max Waste Processed per month (22 days) (ton)	(Ton) per annum	Disposal to landfill Cost	Avg Producer Price Inflation
2015	R 944.91	2200	48.4	581	R 548 803.73	7%
2016	R 1 011.05	2200	48.4	581	R 587 219.99	7%
2017	R 1 081.83	2200	48.4	581	R 628 325.39	7%
				1742	R 1 764 349.11	

The comparative cost for the same amount of waste for the current waste disposal practice (landfilling) is R 1 764 349 over a three year period. It must be noted that when we look at inflation we can argue that the figures are conservative estimates as the expectation of waste disposal costs would increase by an estimated minimum of 15%. However the exact inflation amount cannot be substantiated at this time. The real cost to the Tshwane Municipality could be much higher that estimated above.

6.3.2 Cost of Larger IVC Composting System

The same calculation is now used to determine the cost of the larger IVC composting system. However other factors like electricity usage and labour cost will be considered in addition to the above calculation. The direct cost to the TFPM is shown in the following table:

Table 5: Comparative composting cost for the larger IVC

EPI Composting (Larger IVC)				
Year	R/Ton	Max (Ton) per annum	Max Cost per annum	Avg Producer Price Inflation
2015	R 885.23	581	R 514 141.58	7%
2016	R 947.20	581	R 550 131.49	7%
2017	R 1 013.50	581	R 588 640.70	7%
		1742	R 1 652 913.78	

The comparative direct cost for the composting system is therefore R 1 644 854 to process the same amount of waste.

6.3.3 Electricity Costs for the Larger Composting System

The larger 24m^3 system will utilise approximately 25kWh running for an average of 4 hours a day.

Table 6: Electricity Cost Estimation for the Larger IVC Composting System

Therefore a maximum of 100 KW per day. The electricity cost is estimated in the next table.

Year	Electricity Consumed per day (max) (Kwh)	PPI	Rate per Kwh (cent)	Cost of electricity per day	Cost of electricity per day (260 days)
2015	100	7%	130.90	R 130.90	R 34 034.00
2016	100	7%	140.06	R 140.06	R 36 416.38
2017	100	7%	149.87	R 149.87	R 38 965.53
				Total	R 109 415.91

6.3.4 Labour Costs

It is the assumption that TFPM will reallocate labour from the public works programme to assist and manage with the IVC system and assist with the CMA. We estimate that at least two additional non-skilled labourers and one semi-skilled labourer would have to be utilised for the system. However EPI indicated that the TFPM will utilise labour from its current staff compliment. Therefore there would not be an additional labour cost to the TFPM. All training of labour involved with this project will be conducted by EPI at no additional cost to the TFPM.

6.3.5 Cost Comparison

The total cost to the market for implementing the system would be R 1 754 270. The evaluation shows that the EPI larger IVC would be R 2 019.42 cheaper than the current system over a three year period. This would constitute a direct saving to the TFPM over the three year period.

Table 7: Final cost comparison composting vs landfilling

Waste disposal to landfill	
Cost over three years	R 1 764 349.11
Total	R 1 764 349.11
EPI Composting larger IVC	
Cost over three years	R 1 652 913.78
Electricity cost over three years	R 109 415.91
Total	R 1 762 329.69
Difference Composting VS Landfilling	R 2 019.42

6.4 Indirect Savings

The TFPM and the Tshwane Municipality are different branches of the same legal entity. We therefore have to consider the saving in airspace at the Onderstepoort landfill site for the larger IVC system. Additionally we have to consider the operational cost saving in reduced transport to and from the site with regards to waste removal. These savings will represent indirect savings to the TFPM.

The Tshwane Municipality charge for bulk removal of waste is R 62.30 per m^3. This figure can be used as the potential saving to the Tshwane Municipality for the reduction in waste transport and disposal at

the landfill (OPEX). We further assume that the cost for landfill airspace is calculated into this rate (CAPEX).
Therefore the tariff/m^3 = (OPEX + CAPEX)/m^3.

The total volume of uncompacted waste diverted from the landfill over the three year period is 4 356m^3. Therefore the total saving to the Tshwane Municipality which is an indirect saving to the TFPM was R 271 378 over the project timeframe. These figures can be seen in the following table:

Table 8: Saving in OPEX and CAPEX for Tshwane Municipality for the larger IVC system

Year	CUMULATIVE DIVERTED FROM LANDFILL	CUMULATIVE VOLUME OF WASTE AT UN-COMPACTED WASTE DENSITY 400kg/m3)	SAVING TO TSHWANE MUNICIPALITY R 62.30 PER m3
2015	580 800.kg	1 452.m3	R 90 459.60
2016	1 161 600.kg	2 904.m3	R 180 919.20
2017	1 742 400.kg	4 356.m3	R 271 378.80

6.5 Compost Generation and Potential Revenue

EPI estimates that compost is being produced at a ratio of 1m^3 (compost): 3 ton (waste). It is estimated that the potential revenue generation for the compost is R300 per m^3, this would be valid as a point of sale or if used by the Tshwane Counsel it would present an indirect saving. The total compost generation over the three year lifespan of the project is therefore estimated at 580m^3. If the compost is donated to assist the community of small subsistence farmers it would present no potential revenue generation. However it would add to the TFPM measurable social responsibility goals. For the purposes of this study it will be taken as a potential revenue stream. The potential revenue and the quantities of compost produced during the pilot project is shown in the following table:

Table 9: Estimated Compost Generation

Year	CUMULATIVE TOTAL DIVERTED FROM LANDFILL	CUMULATIVE VOLUME OF WASTE AT UN-COMPACTED WASTE DENSITY 400kg/m3)	Compost Generation (3:1 ratio)	Potential Revenue R300/m3
2015	580 800.kg	1 452.m3	193.6m3	R 58 080.00
2016	1 161 600.kg	2 904.m3	387.2m3	R 116 160.00
2017	1 742 400.kg	4 356.m3	580.8m3	R 174 240.00

The total potential revenue generation for the pilot project is therefore R 174 240.00 over the three year period.

6.6 Economic Findings and Recommendations

The total financial benefit to the TFPM for the larger IVC is estimated at R 447 638.22 and is shown in the following table:

Table 10: Total financial benefit for the pilot project

Savings and Revenue	Amount
Direct Savings	R 2 019.42
Indirect Savings	R 271 378.80
Potential Revenue	R 174 240.00
Total	R 447 638.22

This benefit is an estimate and is subject to change upon changing the operating criteria of the compost distribution and labour situation at the TFPM. These calculations can be calibrated as and when required for changing conditions. It is strongly recommended that due to the potential revenue generation of the compost that a full time site clerk or manager be assigned at the compost management area.

6.7 Environmental Factors

For the larger IVC plant we will consider the reduction in CO_2 generation for the waste that is being composed on not ending up in the landfill and therefore show the environmental benefit of the system. We will also estimate the reduction in transport to the landfill and comment on the less measurable environmental benefits of the system.

The TFPM does not compact their waste before sending it to landfill therefore the uncompacted waste volume is used for this estimate. For the larger IVC plant the estimated total reduction in waste quantities that are going to landfill is approximately 4356m^3. The TFPM utilises 28m^3 roll-on roll-off skips for storage and transport to the landfill.

If we assume that the skips are 90% full when they are transported to the Onderstepoort landfill, the TFPM will save a total of 173 trips to the landfill site. The distance from the Onderstepoort landfill and the TFPM is approximately 15km. Therefore each round trip to the site and back will be approximately 30km. Taking into account the distance of the Onderstepoort Landfill to the TFPM it translates into a total of 173 trips multiplied by 30 km = 5 190 km that is saved. This would have a reduction in pollution for a longer term project as there would be a reduction in vehicles trips to and from the TFPM and the Onderstepoort Landfill as well as a reduction in the use of landfill equipment. This could have a measurable reduction in the use of fuel and carbon emissions and a less measurable reduction in the pollution from the maintenance of these vehicles i.e. hydrocarbons like oil and grease. A Diesel truck emanates approximately 24kg or CO_2 per 100 km. **The total CO_2 saving for the reduced transport is 1245.6 kg or 1.25 ton over the three year period.** In addition to the CO_2 reduction there will be reduction in other pollution sources that emanate from transport e.g. hydrocarbons (oil, diesel, grease), brake dust, rubber from tires etc.

The total landfill airspace saved by the Tshwane Municipality is calculated by the same amount of waste in its compacted state and a 1:6 cover material ratio. The estimated total amount of airspace saved at the Onderstepoort landfill over the three year period would be 2032m^3 which is equivalent to about 73 x 28m^3 roll on roll off skips.

Table 11: Landfill airspace saving – Larger IVC

	TOTAL DIVERTED FROM LANDFILL	CUMULATIVE VOLUME OF WASTE AT COMPACTED WASTE DENSITY (1000kg/m3)	CUMULATIVE VOLUME OF LANDFILL COVER MATERIAL 1:6 RATIO	CUMULATIVE AIRSPACE SAVED
2015	580 800.kg	580.8m3	96.8m3	677.6m3
2016	1 161 600.kg	1 161.6m3	193.6m3	1 355.2m3
2017	1 742 400.kg	1 742.4m3	290.4m3	2 032.8m3

Landfilling produces approximately 335kg CO_2 per ton of waste disposed and in comparison composting produces approximately 100kg CO_2 per ton of waste. The total CO_2 reduction is then 235 kg CO_2 per ton of waste. Therefore a factor of 0.235 can be applied to the mass of the waste that is diverted from landfill to calculate the CO_2 reduction. This calculation is based on DEFRA (UK) calculations.

The estimated CO_2 reduction is shown in the following table and represented graphically after the table:

Table 12: CO_2 Reduction quantities – Larger IVC

	TOTAL DIVERTED FROM LANDFILL	CO2 SAVED vs. LANDFILL
2015	580 800.kg	136 488.kg
2016	1 161 600.kg	272 976.kg
2017	1 742 400.kg	409 464.kg

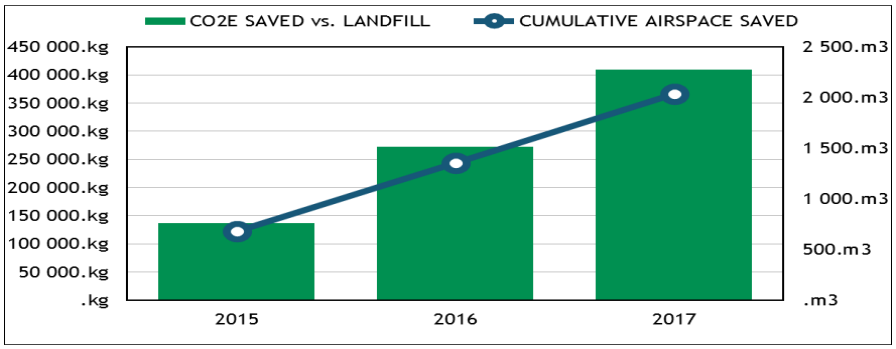

Figure 3: CO2 Reduction during pilot project

The above graph and table shown the reduction in CO_2 for the project (composting) versus landfilling to be approximately 409 464 kg which is substantial.

6.8 Social Benefits

The TFPM can choose to donate the compost produced during the project to the community, or they can use in the city for the maintenance of the city parks, or they can sell it at a reduced rate to support farmers. Any of these actions would contribute to the social benefits of the project.

Other social benefits to implement the system include the following:

1. Reduction in traffic due to reduced transport of waste.
2. Cost savings and potential revenue generation would translate into lower taxes for waste disposal in the community.
3. Upliftment: Assisting the community with growing better crop yields which would have a financial and health benefit.
4. Greener parks for the city would contribute to the image of the city but also for the enjoyment of the community.
5. Improvement of the TFPM overall image and the promotion of the TFPM for the fresh produce industry.

ACKNOWLEDGEMENTS

EARTH PROBIOTIC INDUSTRIES – GAVIN HERON (OPERATIONS MANAGER) AND ROB BOURDILLON (DIRECTOR)