Residential Recycling: An Industrial Engineering Approach to Strategic Waste Collection

by

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Submitted in partial fulfilment of the requirements for the degree of

BACHELORS OF INDUSTRIAL ENGINEERING

in the

FACULTY OF ENGINEERING, BUILT ENVIRONMENT AND INFORMATION TECHNOLOGY

UNIVERSITY OF PRETORIA

OCTOBER 2011

Executive Summary

Residential recycling has become something of a proverbial carrot or stick situation: either residents have the moral motivation to recycle, the carrot, or are forced to recycle due to local law, the stick. Households need to consider the recycling option as municipalities are not far from implementing recycling bylaws to conserve our natural environment in line with the 2008 waste act. This project proposes initiatives by presenting profit and non-profit business models with different waste collection strategies, drop-off and pick-up, to effectively sustain residential recycling in residential estates (gated communities) and conventional residential developments. The project also investigates international recycling systems. Systems-, process- and financial engineering are supported by a Monte Carlo simulation to further enhance the business models. A hands-on waste profile study provides a cornerstone to the project.

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List of acronyms

AVG Average

BGE Blue Gill Estate

BGWPS Blue Gill Waste Profile Study

CWGM Community Waste Generation Model

DSD Duals System Deutschland

EE Environmental Education

HOA Home Owner Associations

IE Industrial Engineering

IWMP Integrated Waste Management Plan

MEAT Minister of Environmental Affairs and Tourism

NPO Non-Profit Association

NWMS National Waste Management Strategy

POS Point of Source

POSM Point Of Source Model

STEDV Standard Deviation

SWMS Solid Waste Management Systems

SWS Solid Waste Stream

WCS Waste Collection Strategy

WTP Willingness To Pay

QQ Quantile-Quantile

Chapter 1

Introduction and background

Throughout the world, different recycling systems have been implemented in conjunction with Solid Waste Management Systems (SWMS) to help reduce the amount of solid waste that is taken to landfills. According to Sakai et al. (1996) recycling forms an important component within the SWMS of municipalities as it diverts between 10% and 30% of the total Solid Waste Stream (SWS) from landfills. All over the world, landfill sites are reaching their maximum capacity and the creation of new sites are becoming less feasible as a result of increasing land prices and tightening of government regulations. It is therefore important to strengthen the use of recycling in an integrated SWMS.

Read (1999) defines recycling as "the conversion of waste into a useful material". Recycling can be effectively managed and prioritised within a waste management hierarchy. The levels within this hierarchy in Figure 1.1 can be described as a system for the management of waste. This is done by first reducing, then re-using, recycling, incineration with energy recovery, and finally disposing waste materials in landfills (Schmidt et al., 2007), while priority is given to reduction rather than disposal. Many integrated SWMS and waste management acts and policies are based on this hierarchy.

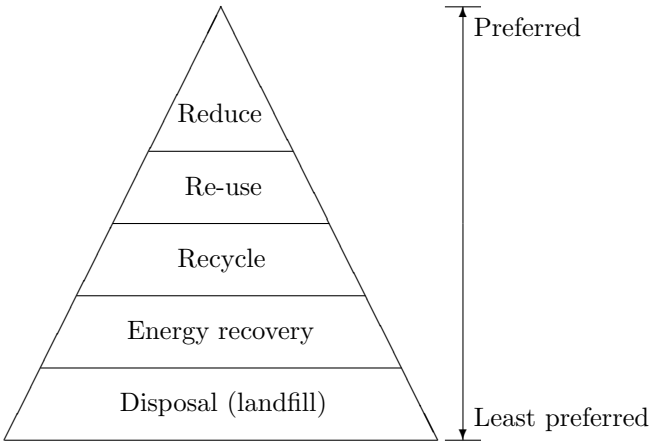

Figure 1.1: Waste management hierarchy

The South African government has adopted a National Waste Management Strategy (NWMS), aimed at a 50% reduction in waste to landfills by 2012 and a 100% reduction by 2022 by means of an integrated SWMS (Department of Environmental Affairs and Tourism, 2005). The Department of Environmental Affairs and Tourism (2009) empowers the Minister of Environmental Affairs and Tourism (MEAT) to compile and implement a NWMS. Recycling and waste minimisation are considered to be the most effective ways of achieving the NWMS goals of reducing the amount of waste sent to landfills.

The collection of recyclables from the Point of Source (POS) is an essential part in the creation of a functioning SWMS. Recycling communities differ from one another in terms of geographical outlay,

average household income, culture and motivation for recycling. Each community requires a unique collection strategy, the manner in which recyclable materials are obtained from the POS, to optimise the amount of waste collected, especially when focusing on residential areas. Implementing the incorrect strategy may have a detrimental effect on the number of participants in the community and increase the amount of resources needed to collect the recyclables. Developing the right waste management strategy for each community is therefore important in promoting a sustainable recycling initiative.

The motivation to recycle is either determined by the proverbial *carrot* or the *stick*. Recycling initiatives may evolve out of the moral obligation felt by communities towards conserving the environment or by monetary incentives offered by recycling centres i.e. the *carrot*. Other communities may be forced to participate in recycling initiatives by law i.e. the *stick*. Some new initiatives are combining the *carrot* and *stick* motivations, companies are encouraging payment for a convenient recycling services they offer to their customers. Thus forcing the customer to recycle on account of the service paid for i.e. the *stick*, but at the same time satisfying the moral obligation felt by the customer i.e. the *carrot*. It is vital to consider the motivations of communities when designing successful recycling initiatives.

Recycling in South Africa is mainly done by privately owned packaging companies aimed at reducing their costs and raising their social responsibility profiles with the public, business and government. Government funded buyback centers mainly operate in the large cities throughout the country. The private sector is filling the gap between the municipal waste collection services and the informal sector waste picking by collecting recyclables for their own profit. With the development of non-profit recycling initiatives, communities can recycle with ease while they can benefit from the funds gained by selling the recyclable materials.

1.1 Problem statement

Communities are not actively being encouraged to recycle household waste. Individuals may be aware of the environmental problems looming, but are neither informed nor supported to be part of an initiative to minimise waste sent to the landfill sites.

The challenge is therefor to create profit and non-profit driven business models, to be implemented in communities who are not yet part of a recycling initiative. Companies need to be able to adapt to the changing industry of recycling, and therefor implement the right Waste Collection Strategy (WCS) for the particular community, at the right time.

Issues on practical implementation of the business models are also discussed and validated to existing initiatives such as Blue Gill Estate (BGE).

1.2 Research design

This project proposes initiatives by presenting profit and non-profit business models to effectively sustain residential recycling in residential estates (gated communities) and conventional residential developments. Each business case would be governed by a certain set of assumptions unique towards the specific WCS and supported by the Blue Gill Waste Profile Study (BGWPS) which determined the specific waste profile of each recyclable material. The WCS must strive to optimised the specific combination of environmental factors, costs related factors, moral motivations for recycling and the business models' processes in place to determine the amount of residents needed to satisfy the requirements of the system for feasibility.

A community, for the purposes of this document, can be defined as a collection of households in the medium to high income bracket, in a common geographic location, generating waste, recyclable and non-recyclable. In some instances it refers to gated communities, a geographical area secured by controlled access points and managed by a Home Owner Associations (HOA). A non-gated community can also form a non-profit company similar to a HOA, with specific aims such as a recycling initiative.

1.3 Research methodology

The project involves an Industrial Engineering (IE) approach which is greatly influenced by non-human and human interactions. An IE approach has to consider *Man, Money, Machine* and the *Environment* in which the problem is located. *Man* is defined as residents who can contribute to recycling and who has the moral motivation that make them willing to participate in a recycling initiative. *Money* is referred to as in the traditional financial sense, including the value an individual places on his time and effort. *Machine* refers to the non-human interactions such as technology and processes in place designed by humans. The *Environment* places the whole system within an area with outside interactions and operations, both natural and built-up.

Data were collected in the BGWPS, analysed and matched to a specific statistical distribution and used within the creation of the business models.

1.4 Document structure

Chapter 2 deals with the literature study explaining recycling in the residential environment as well as the background of business models. Chapter 3 describes the methods of data collection as well as the BGWPS, distribution matching of the data collected within BGE and further data collection and analysis done.

Chapter 4 introduces 5 business models in a structured hierarchy. Each business model is introduced, assumptions explained, financially evaluated whiles being supported by data generated from the BGWPS in Chapter 3. Chapter 5 identifies which business model would be best suited for a particular community. It also emphasises the value of recycling initiatives in residential estates such as BGE. Data and lessons that can be learnt and analysed for further initiatives are also discussed as well as future research and initiative possibilities.

Chapter 2

Literature review

The question of how recycling can become part of daily household waste activities is an important one. In a study done by Kamara (2006) in the City of Tshwane, it was found that Environmental Education (EE) has a direct influence on household recycling participation and that recycling in the area was low as a result of this.

Does time spent on household recycling by the residents justify the moral satisfaction? Halvorsen (2004) found that most residents find recycling to be a pleasant activity and that local government mandatory recycling policies reduces the residents' Willingness To Pay (WTP) for recycling services and thus increasing their motivation for managing their own recycling. Sidique et al. (2010) found that residents are motivated to recycle more by the convenience of recycling initiatives, familiarity with recycling infrastructure and social pressure placed on residents by friends, family or local municipality's recycling policies.

2.1 South Africa's current recycling environment

The recycling industry in South Africa is currently under-developed with great opportunities to be explored. Over the last decade, companies such as Ronni Recycler has placed large bins, or *igloos* at selected residential street corners as well as at schools (mPact Recycling, 2011). The public can dispose of waste paper and cardboard at the recycling *igloos*. Ronni collects the recyclables for their own recycling processes. Ronni also encourages informal sector curbside paper collections by paying for the recyclable materials and providing trolleys to ease the collection. Those individuals participating in informal sector recycling can generate an income to support better living conditions (Masocha, 2006). Other companies also have drop-off recycling depots in place, but these are few and far between.

The current culture of South African waste disposal is characterised by municipalities needing to meet high standards in service delivery of waste collection with limited financial resources (Matete and Trois, 2008). Most of the recycling in South Africa is done by the private sector seeking cost effective raw materials with little to no support from local authorities.

The National Environmental Management Waste Act, Act 59 of 2008, legislates that municipalities must have an integrated waste management plan for implementation in accordance with the waste hierarchy (Department of Environmental Affairs and Tourism, 2009). The Act further encourages municipalities to include recycling in their local waste management initiatives.

2.2 International waste management systems

The manner in which recycling takes place is normally determined by the geographical outlay, income of residents and their country's culture of caring for the environment. In a study done by Chen (2008) on the differences between recycling initiatives in Waterloo (Canada) and Dalian City (China), Waterloo had an already established curbside collection service in place accompanied by an organic curbside waste

collection service, while in Dalian City most recycling are being done by informal waste collectors who sell their recyclables to centralised buyback centers.

Germany has implemented various recycling acts as early as the 1990's, placing the recycling responsibility on product manufacturers to utilise methods of re-using and recycling of materials (Germany Government, 1996). Zhang et al. (2010) describe that the Duals System Deutschland (DSD), was established to promote the recycling of packaging. Manufactures can participate and place a "*Green dot*" on their products indicating that the packaging should be recycled through the DSD system and not returned directly to the manufacturer. In Germany 35% of recyclable materials are recovered from domestic waste (Zhang et al., 2010).

Singapore has a tremendous economic growth resulting from rapid industrialisation and urban development increasing their solid waste generated two–fold every 10 years. In 1990 the Ministry of Environment formulated a waste minimisation policy to minimise the waste generated (Seik, 1997). In 2001 the National Environment Agency in Singapore launched a National Recycling Program which placed recycling bins in public areas, specially pedestrian walkways, bus stops, petrol stations, commercial areas and some residential areas (Zhang et al., 2010). The National Environment Agencies uses two initiatives to accelerate a viable recycling industry within Singapore: recycling parks was created to enhance the environment of recycling and make it more approachable, and recycling industrial areas are promoted. Unfortunately recycling within Singapore have lately received its support mostly from the commercial and industrial sections and not from residential areas. Initiatives to promote recycling within residential areas are underway with a door to door collection service being implemented. Statistics released by the Singapore Government (2011) on recycling for 2010 were 58% of the total waste generated were recycled and of which 40% were organic and used as bio fuel.

In 1990 the Singapore Ministry of Environment launched a 3 month pilot project on the separation and recovery of recyclable material in different income housing estates (Seik, 1997). The study followed numerous steps to accomplish its goal in each community. These steps were:

1. Provide bins for the recycling scheme.
2. Send out publicity materials to inform residents of the scheme.
3. Identify the communities involved and obtain assistance from residents' committees to ensure participation.
4. Set up recycling bins at strategic points.
5. Engage waste collectors to collect waste from a centralised point or recycling bin.
6. Designate storage area for the waste materials.
7. Engage a waste dealer for regular collection of recyclables.
8. Use proceeds to fund activities or donate to charitable organisations.
9. Educate the community to sustain the programme.

It is estimated that 96% of residents participated in some form throughout the pilot projects' duration. The project is a good indication of the possible outcome when communities participate in recycling initiatives and is estimated to generate a positve net profit.

In Delhi 17% of all recycling is done by informal waste collectors going from door to door at shops and homes or collecting waste on landfills (Uiterkamp et al., 2011). Most of these collectors and pickers are from poor areas in India and Bangladesh. The Indian government has estabished formal recycling systems but has been hampered by financial losses, low priority at top level and poor marketing efforts in promoting the inititves.

2.3 Local waste collection strategies

BGE is a gated community located in Ekurhuleni, Gauteng where the residents and management of the estate established a drop-off recycling bin (Otto, 2011). The drop-off facility is a non-profit initiative with a local waste management and recycling company, Interwaste, that collects the recyclable materials on a weekly basis. The initial investment in terms of the centralised recycling bin was sponsored by Buyisa-e-bag and Interwaste (Grobbelaar, 2011). Buyisa-e-bag is a government established company that is funded out of local plastic bag taxes to develop and operate local buyback centers within communities (Buyisa-e-bag, 2011). The BGWPS will be discussed in detail in Section 3.1.

The concept of curbside recycling is also not new. Municipalities and waste collection companies have initiated curbside collections of recyclable materials in the United Kingdom (Read, 1999), Canada and in South Africa (Chen, 2008). In Cape Town, a company called Waste Plan is implementing a curbside recyclable collection service, *Think 2wice*, as of July 2011. *Think 2wice* is free to anyone who want to participate and the service is linked to their municipal utilities bills (Waste Plan, 2011). Waste Plan is contracted and subsidised by the city of Cape Town municipality in implementing part of their Integrated Waste Management Plan (IWMP) to recycle POS separated residential waste. Participation is also actively monitored with a bar-coding system, where the bar code located on the bin is scanned each time waste is collected, currently clear bag collection is used as the bin's are still being distributed to residents. Non participation will result in penalties on municipal services accounts. The project is set to reach 38 000 households with its weekly curbside recycling collections. In an interview with the Cape Town operational manager of Waste Plan, Pietersen (2011) estimated that the *think 2wice* collection service are obtaining between 60% to as high as 95% household participation rates in some communites and that a total of 1200tons of residential waste is collected and recycled each month.

Some households and companies want to recycle but do not have the time or the means to sort and transport the materials and need the help of recycling specialist organisations to achieve this. There are companies like Open-Sky who operate mainly in the City of Tshwane and Mama-she's-waste-recyclers, who operate in the greater Johannesburg area (Mama she's waste recyclers, 2011; Open-Sky, 2011). These companies will collect the customers' recyclable materials at the source for a monthly payment and will then sort and sell the recyclables for a profit. Such a collection strategy may be more attractive to customers as they only need to separate recyclable material from non-recyclables and organic waste and then forget about the problem of dealing with the disposal and finer sorting of the recyclable materials.

Many recycling schemes experience problems in sustaining themselves due to the intrinsic motivations of consumers and industries, who are quick to buy into the idea of recycling but lose interest when there are little monetary incentives involved (Sakai et al., 1996). Fluctuations in raw material prices also affect recycling and creates uncertainty within the recycling industry (Otto, 2011). To establish a successful recycling initiative, it is important to take matters such as these into consideration.

2.4 Business modeling

Doganova and Eyquem-Renault (2009) describe the workings of business modeling as it "...works as both a calculative and a narrative device. It allows entrepreneurs to explore a market and to bring their innovations ...". Thus business models are effective tools to develop and prove new concepts and ideas to undeveloped markets. Business models also explain the simple workings of a system before any detailed design has been done (Bentley and Whitten, 2007). Business models presents the opportunity to develop and present business ideas and concepts broadening the investment opportunities. Business models do not have to be generic to all forms of the business area, but need only represent a viable solution within a practical environment to prove its feasibility.

2.5 Conclusion

The problem associated with residential recycling boils down to the fact that a waste recycler has to go through the effort of getting hold of the recyclable materials produced by consumers in a state that it can

be further recycled (Think 2wice, 2011). It has become a talking point that one must encourage people to recycle, but as long as education on environmental issues, government and municipality policies are neglected, the success of recycling hangs in the balance. People are either not aware of current recycling initiatives in their area, do not know how to sort recyclables from non-recyclables, or do not know of depots where they can deposit their recyclable materials. Residents would rather not drive too far to a drop-off depot as this uses up limited and valuable time due to busy lifestyles.

WTP is another important factor, considering whether an individual will feel more obliged to participate in recycling if he/she is paying a levy, and what amount of levy will *"force"* the individual to participate, i.e. the proverbial *stick* motivation. Some residents pay for recycling services because they really do want to contribute positively to the state of the environment by recycling their waste. The only reason for them paying for the service is probably because they do not know how else to recycle and no opportunity for recycling is available, i.e. the proverbial *carrot*.

From the study already conducted it can be seen that recycling is beginning to take shape within communities, but needs to be directed in ensuring that it is available to all. Recycling is everyone's duty, from government to the common man on the street.

Chapter 3

Data collection

The cornerstone of reliable business models is data that can be verified as accurate. Various sources have been consulted to determine all the data needed for the compiling of the business models. Some resistance were found with the consultation of small business on their recycling initiatives and experience in the recycling industry and were therefor reluctant to share data.

3.1 Blue Gill Waste Profile Study (BGWPS)

An empirical study has been conducted in BGE to evaluate the waste profile of a community of the chosen demographic. BGE is considered as a medium to high income residential community. This study was conducted to obtain data and gain insight into the amount and efficiency of community driven recycling initiatives. As no real study of its sort was found in literature, the data are regarded as a cornerstone input into the business models.

3.1.1 Introduction to BGE

BGE is a residential estate located in Ekurhuleni, Gauteng province. The estate consists out of 365 residential properties, or households and is divided by a parkland and small dam separating the estate into Blue Gill Main, and Blue Gill Waterfront Estate as indicated on the map in Figure 3.1. BGE has a recycling initiative whereby residents deposit their recyclable materials into the *Eco-park* bin, located central to the estate and near the estate's offices. Recycling in the estate is done on the residents' own initiative and no profit is gained towards the HOA or the residents. Residents in BGE have been participating in the recycling activities with good recycling yields. The only profit made is by the waste collection company, Interwaste, who sort and sell the recyclables.

To gain a better understanding of the nature of recycling within BGE, a waste profile study was conducted to evaluate the potential recycling capabilities of residents in an estate were the majority of households are already committed and educated towards recycling.

3.1.2 Data collection and method

The waste profile study analysed the amount of household recyclable material generated; plastic, paper, cardboard, cans and glass within BGE. Municipal waste, such as food scraps and non recyclables were also analysed to build a complete picture of the BGE's waste stream. Garden clippings were excluded from the weighing scope.

From May 2011 to June 2011, collection of the data was done in two phases namely 1) a general questionnaire and 2) a 4 week voluntary waste profile study.

All residents were asked to complete a questionnaire on their participation and habits regarding recycling, see Figures A.1 and A.2 in the Appendices. Specific questions were asked to determine the

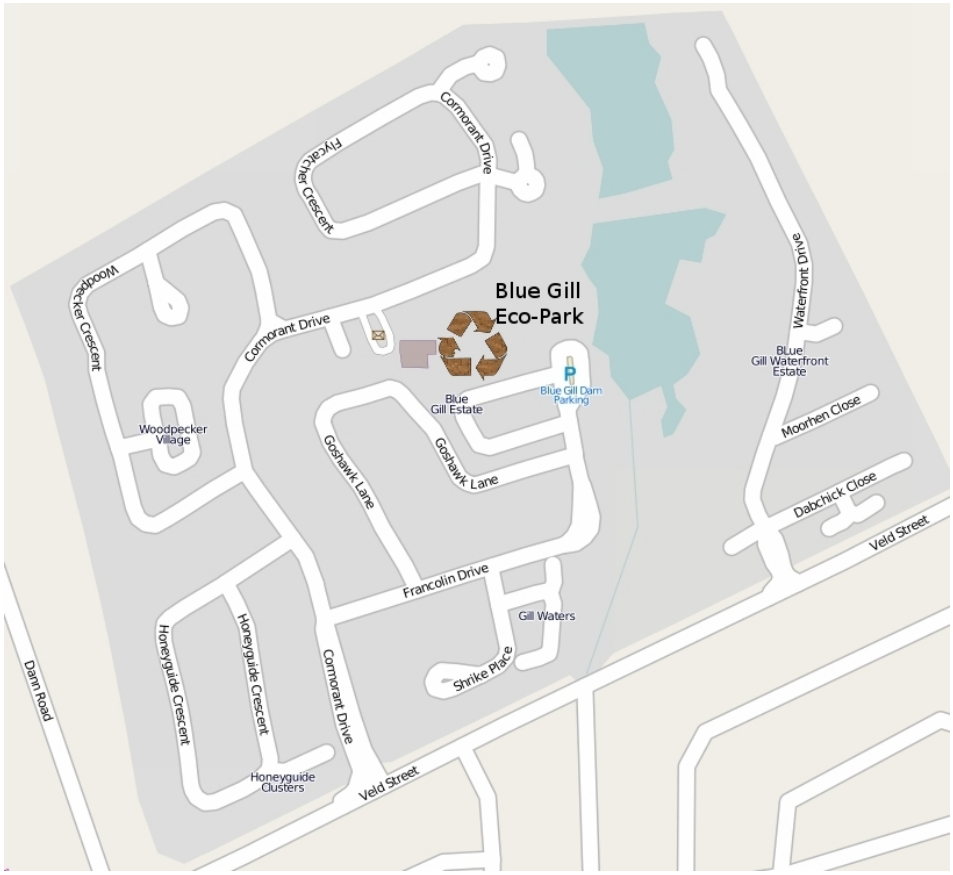

Figure 3.1: BGE Layout plan, with identified *Eco-park* bin, (OpenStreetMap, 2011)

physical size of the house, number of bedrooms, the number of occupants and their age distribution as well as the household's attitude and motivation towards recycling. Studying the motivation as to why anyone would want to recycle can be a complex task. Some questions and comments within the general questionnaire were aimed at obtaining a broad view of the BGE's specific recycling motivations.

Residents had to indicate if they were interested to participate in the waste profile study. The study would involve the weighing of participating household's sorted recyclable materials and municipal waste collection streams. The participating households' recyclable stream would be diverted temporarily from the *Eco-Park* bin, see Figure 3.2. As a service to the households, the recyclable materials were collected and deposited in the *Eco-park* bin after weighing has taken place. For 4 weeks the waste and recycling streams were weighed at the participating households the day prior to the municipal waste collection services. Garden clippings and waste were not included in the study.

The waste management company Interwaste, provides the weekly collection service of the *Eco-Park* bin's waste. Interwaste separates the recyclables further and sells the waste for a profit. Data on the total monthly weight of recyclables collected from BGE by Interwaste has also been collected and compared with the collected data from BGE. The cost of initial funding and collection of the recyclables from the *Eco-Park* has been obtained from the various stakeholders.

3.1.3 BGE Financial data

Data collected on initial investment and operational cost are displayed in Table 3.1. Most of the investment was carried by Buyisa-e-bag and Interwaste. Interwaste sponsored the modified container bin,

Figure 3.2: BGE *Eco-Park* recycling bin

Figure 3.3: Weighing of waste for the BGWPS

Figure 3.2, while Buyisa-e-bag provided the funds for paving the area surrounding the *Eco-Park* bin (Otto, 2011). General maintenance on the *Eco-Park* bin is done by Interwaste, while the BGE's HOA provides the labour for cleaning and changing of bags as they fill up (Grobbelaar, 2011).

3.1.4 Results

A total of 49 households responded to the general questionnaire, 33 of these indicated that they consider themselves as regular recyclers, Table 3.2. The other 17 household who do not recycle claim that recycling is too complicated, that they do not have time due to long working hours or that they stay to far from

Table 3.1: Investment and operational cost of BGE eco-park

	Value	Unit	Cost [R]
Capital investment, paving etc.			200 000.00[a]
Container and branding			38 000.00[b]
Total			238 000.00
Operating cost			
Eco-park bin	R500	R/anum	41.67[b]
Transportation (per delivery)	30km	R10/km	600.00[b]
Blue Gill labour cost*(hours/week)	20 hours	R8/hour	160.00[c]
Total monthly cost			801.67

* General garden labourers
[a] Buyisa-e-bag
[b] Interwaste
[c] Blue Gill estate

the *Eco-Park* bin. Most residents recycle on a weekly basis in BGE, Table 3.3, most of which is done when the residents take a walk down to the dam for recreational purposes. All but a few stated that they would like to partake in a composting initiative, either privately in their own gardens or as another BGE community initiative. Most of the residents stated that the ability to recycle in the estate is a huge advantage and benefit. Such statements indicate that residents are proud and fully willing to support the recycling initiative and that a *green* label has been placed on the estate because thereof.

Table 3.2: Number of residents participating

	Number of residents
Total number of households	365
Households partake in general questionnaire	49
Households currently recycling	33
Households currently not recycling	16
Households participating in BGWPS	24

The average number of residents in a household is claimed to be 2.75, with a percentage distribution between the ages 0-3 years of 1.8%, 3-25 years and 25 and older of 35.5% and 62.72% respectfully, Table 3.4. Knowing the distribution of the different age groups within the study area helps to understand the type of waste generated. For instance, children between the ages of 0-3 have a lot of non-recyclable materials which need to be deposited through the muncicpal stream, e.g. nappies. The age group 3-25 years seems to generate more waste resulting in more material to recycle while 25 and older residents spend most of their time at work thus consuming part of their daily recyclables at work and less at home.

The waste profile study's main goal was to determine the recycling efficiencies per household and the composition of the household waste recycled. The study stated that an average recycling efficiency per household of 56.61% were obtained for the 4 weeks, see Table A.1. The per capita recycling efficiency supports the result with an average efficiency of 56.86% per capita for the same 4 weeks, Table A.2.

The zero points are situations were residents did not recycle, or did not have the specific material out for collection on the day. These zero points can also be an indication of what recyclable materials are not recycled that often. For example, some packaging materials keep products for longer duration of time and take much longer to reach the material's useful life time. Some materials are also reused for other purposes, thus extending their useful life time. The frequency of the zero points event indicates

Table 3.3: BGE Recycling frequency

	Frequency
Once a week	16
Twice a week	3
Every 2 weeks	4
Once a month	3
Other	7

Table 3.4: Age distribution of residents participating

Age distribution	**Blue Gill**	**Waterfront residents**
0-3 years	4.44%	0.00%
3-25 years	26.67%	15.15%
25 and above	8.89%	16.67%

Missing percentage are forms not correctly filled in

the material type which is recycled less than other materials. In Table 3.5 it is clear that cans, glass and paper are the least frequent recyclable material and are mainly stockpiled within households before being recycled.

Table 3.5: Zero point waste collection

Material	**Number of occurrences**	**Percentage**
Plastic	4	4.35%
Can	26	28.26%
Glass	22	23.91%
Paper	19	20.65%
Cardboard	9	9.78%
Municipal	12	13.04%
Total	92	100.00%

The total monthly recyclables collected from BGE by Interwaste from the *Eco-Park* bin are compared with the results of the Community Waste Generation Model (CWGM), still to be described in Section 3.2. From this comparison as summarised in the following Table 3.6, BGE's current household participation is between 35% and 40%. If the household participation can be increased to 60% a total weight of 6896.80 kg can be potentially generated by BGE.

3.1.5 Distribution fitting and the POS model

Matching the data acquired from BGE, specifically the weight of recyclable materials, to a specific statistical distribution would give the capability to simulate a household and use the output for further analysis and business model projections. Each recyclable material's weight was matched to a continuous distribution, Log-Normal distributions and Weibull, Table 3.7. The actual data can be matched to the matching statistical distribution and can be used to generate at random the same distribution of data. *Easy-Fit* freeware distribution matching software in Microsoft Excel, was used to estimate the distributions (Mathwave, 2011).

Table 3.6: BGE Total monthly recyclables collected in comparison with CWGM

	Actual	**CWGM**		
Number of households	365	350		
Participation [Kg]		35%	40%	60%
Feb 2011	3480	-	-	-
Mar 2011	4580	-	-	-
Apr 2011	4730	-	-	-
Average weight [Kg]	4263.33	4023.1	4597.84	6896.8

The only data that were excluded from the distributions were the upper outliers and zero points. This was done to ensure a uniform statistical distribution, as some materials are recycled at irregular intervals, Table 3.5.

A random distribution generator was build for each of the recyclables materials' distribution using the GNU mathematical program Octave (Eaton, 2011). The Point Of Source Model (POSM) simulates the POS waste separation of recyclable material. The randomly generated distributions were compared to the actual results obtained from the waste profile study. As an example, the actual distribution of glass is compared to the randomly generated POSM in Figure B.4b. The random generated distribution matches the actual measured distribution. To evaluate the accuracy of the random generated distribution, a Quantile-Quantile (QQ) plot was used to test the conformance of the distribution, Figure B.4a. The closer the data points are to the conformance line in the QQ plot, the more accurate are the match of the distribution. The distribution of all the other recyclable materials can be viewed in Appendix B.

Table 3.7: Statistical distribution per recyclable material

Material	**Distribution**	**Average (AVG)**	**Standard Deviation (STEDV)**	**Alpha**	**Beta**
Plastic	Log-Normal	0.276	0.638		
Cardboard	Log-Normal	0.492	0.735		
Cans	Log-Normal	-0.435	0.740		
Glass	Log-Normal	0.774	0.976		
Paper	Weibull			1.137	2.949

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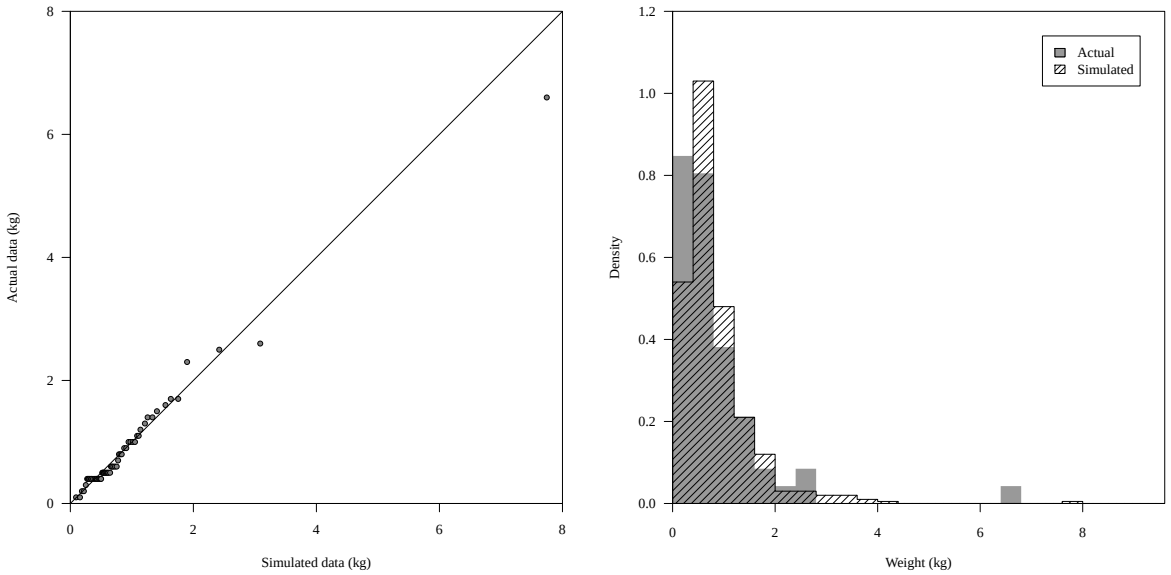
3.2 Community Waste Generation Model (CWGM)

The POSM was used to generate the random data for each household within the CWGM. Monte Carlo simulation was used in the creation of multiple household instances or area of interest from the POSM. Each area of interest is iterated to obtain the most probable weight of recyclables generated. These weights, in kg per recyclable material, can then be used in any of the preceding models to simulate a baseline community. Variables within the POSM can be adjusted with each simulation run to enable a desired scope of results. Variables include the amount of households in a community, household participation probability, zero point waste participation frequency and the price obtained for recyclable material. The entire community is then simulated 200 times to obtain an average weight of recyclable material generated.

The CWGM's main goal is to simulate a community of a specific size's waste generating ability and provide a basis of data input to the business models, Figure 3.4.



(a) QQ-Plot (b) Histogram

Figure 3.4: Comparing actual versus simulated weight of cans

3.3 Recyclable material prices

Table C.1 contains the prices companies offer for recyclable materials as sourced from different recycling companies within the Gauteng area (du Plessis, 2011; Otto, 2011; Remade Recyclers Pretoria, 2011). These companies all attempt to keep their prices stable. Nampak's prices have been stable for the past 4 to 6 months (du Plessis, 2011). Table C.1 calculates a single price for plastics based on a 2 week evaluation of a single household's separated plastic material stream. Paper are assumed to be distributed evenly. The material prices are the market average for each recyclable material type at different companies.

The revenue obtained from each model is dependent on the price that large recycling companies are willing to pay for post–consumer recyclable materials. Companies also fix and adjust their prices according to the quality and packaging of the recyclable material. The higher the quality, the higher the price. If the recyclable material is already bailed, it would obtain a higher price. Recyclable material prices are subject to economic and manufacturing demand. If oil prices rise, the demand and price for recyclable plastic also rise.

These average recyclable material prices from Table C.1 area used within the calculations for business models in Chapters 4.

3.4 Conclusion

The data collected within the BGWPS, representing general residents' views and actual qualitative data, can be considered as an appropriate representation of the recycling situation within BGE. As seen from the data analysis an average of 4263.33kg/month are currently being recycled which in turn represent a household participation rate of 30% to 40% as described in Table 3.6. This illustrates that residents are not reaching their recycling potential.

As each recyclable material type has its own distribution it can be predicted what amount of recyclable materials can be generated by a certain community at a certain household participation rate.

Knowing the potential of the community at hand is important. The use of the POSM is used to generate random households for input into the CWGM utilised within the business models.

From the financial data, investment cost, operational and revenue cost, together with waste profile data, the number of residents that is required to implement a profitable recycling initiative within a community can be determined. The specific waste collection initiative that would best suite the stakeholders involved and promote the optimum recycling in a specific residential community are addressed in Chapters 4.

The use of the business models will enable businesses, SWMS and Non-Profit Association (NPO) and profit companies, to determine the feasibility of and develop such an initiative in their community. The system would finally contribute towards the quality of the environment, enhance the collection of recyclable materials from households, minimise the load on municipal waste services and create new work opportunities.

The optimal level of business model operation within a community for each WCS will be investigated in Chapters 4 based on certain assumptions regarding the capital investment and operational cost.

Chapter 4

Development of WCS business models

4.1 Developing the business models

The CWGM were used to generate random households to simulate a community. Parameters on the community size in question were used to determine the size of the CWGM. For each amount of households the CWGM simulates, the potential recyclable materials which can be sourced, are generated. Different business models were developed to address the requirements for a drop-off or pick-up collection recycling facility within a community. Developing the business models from the CWGM data generated was done in a structured way to provide direct comparisons capabilities as seen in Figure 4.1.

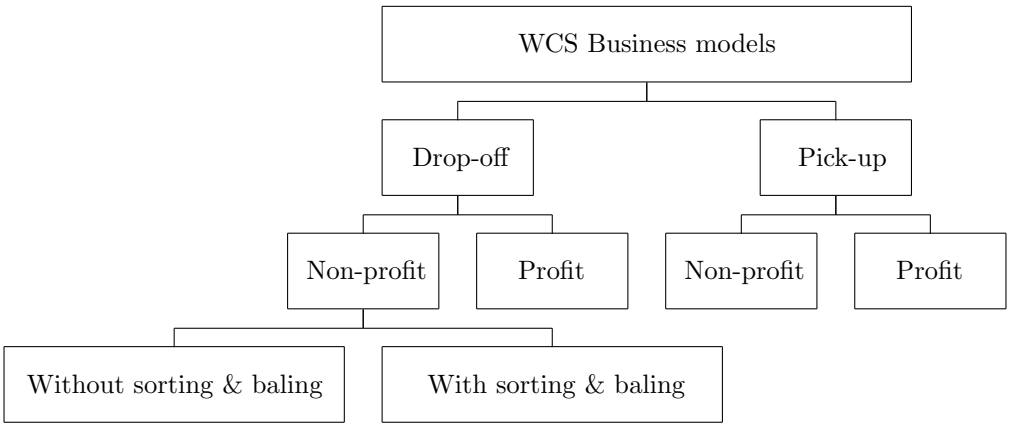


Figure 4.1: WCS Business model layout diagram

Firstly the models need to be differentiated by the way in which revenue is being generated. Revenue can be generated through either a non-profit or profit driven business aim. The non-profit models would involve an existing non-profit organisation, such as a HOA who would control and manage the recycling initiative. A profit driven organisation would aim to increase the revenue, thus exceeding break-even cost. The business models differentiate clearly between non-profit and profit driven models in the sections to follow.

4.1.1 Drop-off WCS

There are mainly two WCS under consideration within the business models, namely waste collection done by the placement of drop-off bins at central locations and pick-up collections done at households within a community.

A drop-off WCS operates on the principle that the individual will deposit his recyclable materials at a centrally located facility near his place of residents, work or daily activities. Drop-off facilities are maintained on a timely basis when the recyclable materials are collected and general clean up and maintenance is performed on the bin and surroundings. The waste is collected from the drop-off bins located in the community and transported to the various recycling companies purchasing the recyclable materials.

Drop-off facilities require the least amount of effort to establish and maintain, as only a basic capital investment is required.

Public participation and discipline are needed for any recycling initiative to be successful, especially with drop-off recycling facilities where the individual has to do the extra effort to deliver his recyclables to the drop-off facility. Some communities use the positive moral motivation to stimulate recycling initiative to support charity organisations. As seen within the BGWPS, a high level of public participation is possible, driven only by the positive attitude towards the environment. A further motivation to consider is that the residents may recycle because the facility is known to the residents, conveniently located and safe to use.

4.1.2 Pick-up WCS

The most common waste collection strategy is that of municipal collections, where the municipality collects waste from households on a scheduled basis, mostly weekly. The collection of recyclable materials in a similar way may appeal towards households more than that of a drop-off strategy. Developing pick-up recycling WCS that assist households in establishing a recycling routine, without adding the burden on households to deposit recyclable waste at a centralised collection point, will make drop-off recycling the more attractive option and gain an increase in participation rates.

A pick-up WCS entails that the household separates its recyclables from non-recyclable materials. The recyclables — cleaned, compacted and dried — are placed mixed in a single bag/container on the pavement on an agreed-to day to be collected by the pick-up service. All the recyclables are transported to a centralised facility in a commercial/industrial area to be sorted by recycling material type and bailed if possible for convenient storage and transportation to recycling companies.

Developing the household's culture of recycling needs to be a priority in maximising household participation within the community. Obtaining high household participation rates are important as the collection points of these recyclable materials need to be as close together as possible to minimise the overall transportation cost and time spent on collection. Informing the community in a well formulated, highly visible and understandable marketing campaign should encourage household participation. As pick-up recycling is more visible, the value of *word of mouth* and *follow by example* are much higher than in the case of a drop-off system.

Some commercial pick-up collection services already operating in communities, charge a levy for their services, to improve their business profitability and to encourage the households to recycle on a regular basis, i.e being forced by the proverbial *stick*.

Household participation can be as high as 95% within well established recycling communities, where some AVG communities achieve 50% to 88% efficiency (Pietersen, 2011).

4.1.3 Sorting and baling within WCS

The choice between investment in separating and compacting the material also needs to be investigation. The purchasing of baling equipment to compact the waste will increase the ease of transportation, reduced storage space, ensure increased selling price of the materials at the recycling companies and offer the potential of job creation.

Recyclable waste collected from households with pick-up WCS are mixed in nature and would obtain a low price on the market if sold un-separated. Separating and further baling the recycling materials increases the profit opportunity, compared to drop-off collection bins where the recyclable materials are already separated by the households into their respective waste streams. As the participation and therefor the bulk of recyclable material collected by pick-up collections are high, the need will arise to bale the recyclable material to ease storage and transportation costs.

Vertical baling machines from AKURA Manufacturing and Engineering Company PTY (Ltd) (2011) were used within the business models. The vertical baling machines are ideally suited for small and medium baling operations, baling plastic, paper and cardboard. The initial purchase and operational costs are included within every business models financial summary.

(a) B3 (b) B5 W

Figure 4.2: Vertical balers available from AKURA

4.1.4 Business Partnerships with WCS

Sponsorships and partnerships can be developed in non-profit and profit driven business models — for example in the case of BGE — where larger recycling companies would invest to improve their relationship with the communities or gain from the recyclables collected for their own revenue stream. Some partnerships undertaken with NPOs may involve that the partner would collect the recyclable materials from the NPO's intermediate collection points, such as drop-off, sorting and baling facilities. The partner would purchase the recyclable waste from the NPO at a reduced purchase price or at no compensation for the collection service. Possible funding and subsidies from local municipalities towards recycling companies may help achieve more profitable and sustainable recycling initiatives.

4.1.5 WCS Business feasibility parameters

For every business case there is a specific area of operations which would result in a excess or a loss. The variables involved which influence WCS are the following:

The feasible parameters under which these business models would operate, would be dependant upon the following:

1. Number of households within the participating community
2. Percentage of household participating within the community
3. Variable costs; labour, transportation and baling consumables cost
4. Fixed costs; maintenance, marketing and facility lease cost
5. Capital cost; period and interest rate paid
6. Overhead costs to support the business

4.2 Non-profit drop-off WCS business models

An NPO, such as a residential estate's HOA is financed from levies paid by the residents for the services rendered. These services range from beautification of the communal spaces such as parks, maintenance of engineering services, security and access control. HOAs are not set out to make a profit but need to supplement income to support their operations and reduce the financial burden on the residents.

The NPO develops a drop-off recycling initiative and sells the recyclable materials collected from within the community to recycling companies. The HOA has the choice to sort and bale recyclable materials. Compacting the material by means of baling improves the storing and transportation ability of the recyclable materials. Plastics and paper are sorted by hand at the drop-off facility before baling into their respective categories agreed to by the industry. Recycling companies pay more for sorted and baled recyclables as for un-baled recyclables (du Plessis, 2011; Remade Recyclers Pretoria, 2011). The selling price of baled recyclable materials are variable and more easily open to negotiations with the recycling company.

Labour is shared with already existing services such as garden and maintenance services. Expanding the process to include baling would require larger initial capital investment and require more labour hours to sort the recyclable material and to operate the baling machinery.

4.2.1 Business model assumptions

The following business assumptions were made irrespective of whether the recyclable material are sorted and baled:

1. The CWGM is an accurate representation of a community's potential recyclable material generation.
2. Land parcel on which the facility is established is available at no cost.
3. Maintenance cost on infrastructure are fixed at R1500 per year, R125 per month.
4. Promotion of the recycling initiative within the community is fixed at R1500 per year, R125 per month
5. Transportation cost is as estimated in Table 4.1. Assume that an existing utility vehicle is used.
6. Interest on capital investment is taken at a fixed rate of 4%.

For each model, a table was generated to determine the best operating environment for the specific business case. Tables D.1 and D.2, display the excess revenue or loss, generated by the drop-off initiatives. From the tables the break-even point for each variable permutation was determined. It demonstrates the change in break-even as household participation rate and the amount of households vary. It is evident where such initiatives become feasible as a monthly break-even is realised.

Within Sections 4.2.2 and 4.2.3 each initiative is explained in further detail specifically towards their operational and feasibility parameters.

Table 4.1: Transportation cost

	Value	Unit	Cost [R/ton]
Driver cost[a]	5000.00	R/month	100
Fuel cost[b]	1,17	R/km	58.82
Vehicle maintenance	60	R/ton	60
Total			218.82

[a] Assumed that a single vehicle is already available
[b] Fuel is calculated on an assumption that a ton of recyclables are transported an average of 50km

4.2.2 Non-profit drop-off without sorting and baling

Assumptions particular to recyclable material drop-off facility without sorting and baling:

1. Prices for recyclable material are as stated in Section 3.3 and Table C.1.
2. Capital cost is described in Table 4.2.
3. Labour cost are based on minimum wages for domestic workers in populated city areas working 5 dedicated hours per ton of recyclable waste (Department of Labour, 2011).

Table 4.2: Capital cost, non-profit drop-off without sorting and baling

	Cost [R]
Paving and landscaping	100 000
Drop-off bin	35 000
Total	135 000

Realistically, as seen in the BGWPS, a household participation rate of between 35% and 40% can be achieved, Table 3.6. The break-even points shown in Table 4.3 were taken from Table D.1. At 40% household participation a community of 450 households will be able to meet the feasibility requirements as well as the capital repayment.

Table 4.3: Non-profit drop-off break-even points without further sorting and baling

Participation rate [%]	20	30	35	40	45	50	55	60
Households required	950	650	550	450	450	400	350	350

In evaluating the financial statements it is evident that the initial capital investment places the most strain on the cash flow. Within an NPO it is necessary to break even every month. After the loan has been repaid the excess revenue can be re-invested into the community, such as the lowering of community's levies to the HOA.

The most suitable pay-back period of capital invested are influenced by the monthly operational cost. Referring to Table 4.4, a conservative 40% estimation was taken towards household participation rate. For instance, a 450 household community recycling at a 40% household participation, with no sorting or baling, will have to invest all revenue obtained from the selling of recyclable materials into paying for the capital infrastructure for a period of 56 months to break-even, but only 34 months when the same

community achieve a 60% household participation. The pay-back period would be longer at a household particpation of 40% as the monthly instalment needs to be lower than the excess revenue obtained after other fixed and variable costs have been deducted.

The extent of the capital investment depends on the existing infrastructure available for the use of the recycling initiative. If adequate facilities, such as paving in an area suitable for recycling are already available, the capital investment would be less. In the business case without sorting and baling, an amount of R100 000 can be deducted and thus the remainder of R35000 for the drop-off bin can be repaid in as little as 13 months if a 40% household participation is achieved. Any increase in household participation recycling can be re-invested into the recycling initiative or contributed to further promotion of the project or community.

Table 4.4: Non-profit drop-off summary of business model

			40% Household participation		**60% Household participation**	
Households			450		450	
Participation rate			40%		60%	
Income						
Recyclable materials	**Value**	**Unit**	**Weight [Kg]**	**Revenue [R]**	**Weight [Kg]**	**Revenue [R]**
Plastic	1.34	R/kg	895.47	1199.00	1343.21	1798.49
Paper	1.03	R/kg	1568.81	1612.39	2353.22	2418.58
Cardboard	0.65	R/kg	1184.49	769.92	1776.74	1154.88
Cans	0.63	R/kg	447.97	283.72	671.96	425.58
Glass	0.44	R/kg	1962.35	856.89	2943.53	1285.34
Total			6059.10	4721.92	9088.65	7082.87
Expences						
Capital investment						
Paving and landscaping				100 000.00		100000.00
Recycling bin (5 Waste streams)				35 000.00		35000.00
Total capital invested				135 000.00		135000.00
Loan details						
Interest rate				4%		4%
Loan period				56		34
Monthly annuity				-2 646.71		-4 206.44
Fixed cost						
Maintenance	125	R/month		125.00		125.00
Marketing cost	125	R/month		125.00		125.00
Total fixed cost				250.00		250.00
Variable cost						
Labour	40	R/ton		280.00		400.00
Transportation	218.82	R/ton		1531.74		2188.20
Total variable cost				1811.74		2588.20
Profit/(Loss) before capital repayment				2660.18		4244.67
Profit/(Loss) per month				13.46		38.23

4.2.3 Non-profit drop-off with sorting and baling

Assumptions particular to recyclable material drop-off facility with sorting and baling:

1. Prices for recyclable material are as stated in Section 3.3, Table C.1. The model relies on a 10%/Kg increase per recyclable material purchase price by recycling companies.
2. Capital cost is described in Table 4.5. The cost of the baler was provided by AKURA Manufacturing and Engineering Company PTY (Ltd) (2011). The baler will be operated in an enclosure which will be secured.
3. Baler Operational cost includes bale strapping, electricity and general maintenance at R70/ton.
4. Labour cost are based on minimum wages for domestic workers in populated city areas working 8 dedicated hours per day at R8/hour, 40 hour week, (Department of Labour, 2011).

Table 4.5: Capital cost, non-profit drop-off with sorting and baling

Item	Cost [R]
Paving and landscaping	100 000
Enclosure	50 000
Drop-off bin	35 000
Baler machine	50 160
Total	253 160

In the case of the model that includes the sorting and baling, the addition of further capital investment, operational costs and employment of labour will influence the profit margin negatively. A larger community of 950 households would be needed to break-even at a conservative 40% household participation rate as depicted in Tables D.2 and 4.6.

Table 4.6: Non-profit drop-off break-even points with further sorting and baling

Participation rate [%]	20	30	35	40	45	50	55	60
Households required	-	1300	1100	950	850	750	700	650

Table 4.7 indicates the payback period for a community of 950 households recycling at a household participation of 40% and 60%. The pay-back period at 40% is 52 months whereas the same loan could be repaid in 30 months should the recycling household particpation rate increase from 40% to 60%. If the payback of capital remains at 52 months, excess revenue of R3481 would be collected every month. This can be re-invested into the recycling intitative or contributed to further promotion of the project.

Table 4.7: Non-profit drop-off summary of business model

			40% Household participation		**60% Household participation**	
Households			950		950	
Participation rate			40%		60%	
Income						
Recyclable materials	**Value**	**Unit**	**Weight [Kg]**	**Revenue [R]**	**Weight [Kg]**	**Revenue [R]**
Plastic	1.47	R/kg	2061.47	2760.22	3092.21	4140.33
Paper	1.13	R/kg	3659.13	3760.77	5488.69	5641.15
Cardboard	0.72	R/kg	2734.96	1777.73	4102.45	2666.59
Cans	0.69	R/kg	1071.77	678.79	1607.65	1018.18
Glass	0.48	R/kg	4486.67	1959.19	6730.00	2938.79
Total			14014.00	10936.69	21021.00	16405.04
Expenses						
Capital investment						
Paving and environment preparation				100000.00		100000.00
Enclosure				50000.00		50000.00
Recycling bin (5 Waste streams)				35000.00		35000.00
Baler machine				50160.00		50160.00
Total capital invested				235160.00		235160.00
Loan details						
Interest rate				4.00%		4.00%
Loan period				52		52
Monthly annuity				-4933.07		-4933.07
Fixed cost						
Maintenance	125.00	R/month		125.00		125.00
Marketing cost	125.00	R/month		125.00		125.00
Labour	40.00	R/ton		1386.66		1386.66
Total fixed cost				1636.66		1636.66
Variable cost						
Transportation	218.82	R/ton		3282.30		4814.04
Baling cost	70.00	R/ton		1050.00		1540.00
Total variable cost				4332.30		6354.04
Excess/(Loss) before capital repayment				4967.74		8414.34
Excess/(Loss) per month				34.66		3481.27

4.2.4 Conclusion on non-profit drop-off initiatives

On first glace it seems as if the option of drop-off recycling without sorting and bailing will have the most probable chance of success. It is obvious that the more households are participating, the more recyclable materials will be available to sell to the recycling companies. If an increase in household participation can be achieved, a shorter pay-back period can be realised and the profit will increase. In the long term, the option including the baling machine to bale the recyclables, prove to be the more sustainable choice.

As in the BGE example, all the initial capital investment was sponsored by Buyisa-e-bag and Interwaste. Partnerships such as these should be encouraged. The partnership company, as in the case of Interwaste, may have the rights towards the recyclables per agreement and the NPO would benefit from part of the income generated by the selling of the recyclables without having the burden of investment capital debt and high operational costs and maintenance responsibilities.

Existing infrastructure such as paving and existing enclosures should be used to save on initial capital investment. The availability of capital infrastructure will differ among communities.

Promoting the recycling initiative should be regarded as the most important aspect to its success. Promoting the drop-off recycling initiative as an easy to use, safe and understandable system is key to the sustainability of recycling in the community.

If additional capital is required from the community, a special donation from home owners can be called upon to carry the initial capital investment. An advantage obtained from having direct investment from the community is that the residents would want to recycle more because of their investment, thus referring to the proverbial *carrot* and *stick* combination.

4.3 Profit drop-off WCS business model

As in an NPO, Section 4.2, a private company develops a drop-off recycling initiative and sells the recyclable materials collected from within the community to recycling companies. In this model it is assumed that the private company will take the responsibility for the sorting and baling of recyclable materials into their respective categories agreed to by the industry. The private company would invest in multiple communities to increase their overall revenue collection as profit generation is a necessity.

The support of the HOA is vital in the success of profitable recycling. Permission is needed to conduct such initiative within the community and promotion of the initiative will primarily be done through the community's or HOA's administrative network. The community will gain a *green* status branding from the project attracting potential homeowners and investors.

From initial investigation it is determined that the profit drop-off model can only be successful if several drop-off facilities are developed in multiple communities. As in the non-profit model in Section 4.2, the drop-off facility will be developed on communal properties within the respective communities. Sorting and baling of the recyclable materials will be done on an off site facility, situated in a commercial/industrial zoned area, leased by the company. The concept of an off site central facility supports the "economies of scale" principle, thus the more recyclables are processed by the facility, the lower the overall cost per kg sorted and baled material will become.

In contrast to non-profit drop-off business models, labour will be employed on a full time basis to collect waste from and maintain the multiple drop-off facilities as well as to man the sorting and baling operations of the recyclable waste at the off site facility.

Recyclable material from each drop-off facility will be transported to the company's sorting and baling facility which will increase the operational cost. The final baled waste will ultimately be transported to the recycling companies to be sold. The transportation requirements are thus much more capital intensive as a vehicle(s) has to be purchased.

4.3.1 Business model assumptions

The following business assumptions were made:

1. The CWGM is an accurate representation of a community's potential recyclable material generation.
2. Land parcels on which the drop-off facilities are created, are provided by the respective communities' HOAs at no additional cost.
3. Commercial/industrial land parcel at which the sorting and baling activities take place is leased by the company.
4. Maintenance cost on infrastructure are fixed at R1500 per year, R125 per month, per drop-off facility.
5. Promotion of the recycling initiative within each community is fixed at R1500 per year, R125 per month, per drop-off facility.
6. Overhead cost of R4500 per month, covering business costs such as water and electricity, rates and taxes etc.
7. The variable transportation cost is as previously estimated in Section 4.2, Table 4.1. The cost of a driver is estimated at R5000 per month.
8. It is assumed that at least one vehicle will be purchased.
9. Interest on capital investment is taken at a fixed rate of 9% prime rate, (South African Reserve Bank, 2011).
10. Prices for recyclable material are as stated in Section 3.3, Table C.1. The model relies on a 10%/Kg increase recyclable material purchase price by recycling companies due to material being delivered, sorted and baled.
11. Capital cost is described in Table 4.8. The cost of the baler was provided by AKURA Manufacturing and Engineering Company PTY (Ltd) (2011).
12. Baler Operational cost includes bale strapping, electricity and general maintenance at R70/ton.
13. Labour cost are based on minimum wages for domestic workers in populated city areas working 8 dedicated hours per day at R8/hour, 40 hour week (Department of Labour, 2011).
14. Each of the communities described in the model contains the same amount of households.
15. Provision is made in the calculations for a profit margin of 15%.

Table 4.8: Capital cost, profit driven drop-off business model

Item	**Cost [R]**
Paving and landscaping	15 000.00
Drop-off bin	35 000.00
Baler machine	79 800.00
Vehicle	200 000.00
Total	453 160.00

4.3.2 Financial evaluation

The financial evaluation focused on finding the break-even point for profit driven drop-off recycling. Establishing a profit driven initiative would require a large initial capital investment to ensure the business' success and continued operation. Higher operational costs further complicate the matter as transportation and full time employee cost increase due to the high tonnage of waste needed to be transported and manhandled.

Table D.3 demonstrates the change in break-even as the amount of households and the participation rate vary. It is however evident from the table that the feasible area for profit driven drop-off recycling initiatives are not within the feasible operating parameters for drop-off centers.

Low household participation rates of 35% to 40% as determined by the BGE study in Table 3.6, will require an unrealistic large community size to recycle at a single recycling drop-off facility. At an optimistic high household's participation rate of 65%, break-even point was reached if 5 communities each of a 1000 households were included.

Table 4.9: Profit drop-off break-even points

Participation rate [%]	45	50	55	60	65	70	75	80
Households required per community	1450	1300	1250	1150	1000	950	900	850

Developing a drop-off facility within a community of a 1000 households or more needs to take into account the geographic lay-out of the community to determine where the members of the households pass a particular point the most frequently and therefor the most conveniently located point for the majority of households. If the drop-off bins are not placed at the optimum location, it may result in lower household participation rates and thus less recyclable materials collected.

Capital will be repaid within 72 months as any longer investments would be unrealistic and uneconomical to support. An example of the calculation of the break-even point is represented in Table 4.10. When 5 communities each consisting of 1000 households partake at a household participation rate of 40%, a loss is realised. Once the participation rate have increased to 65%, the model shows a profit. When all the fixed and variable costs have been deducted, all expences would have been covered and a 15% profit gained.

Table 4.10: Profit driven drop-off summary of business model

Households per community			1000		1000	
Number of communities			5		5	
Participation rate			40%		65%	
Total households			5000		5000	
Income (per month)						
Recyclable materials revenue	**Value**	**Unit**	**Weight [Kg]**	**Cost [R]**	**Weight [Kg]**	**Cost [R]**
Plastic	1.47	R/kg	11212.07	15012.44	18219.75	24395.38
Paper	1.13	R/kg	19026.05	19554.55	30917.55	31776.37
Cardboard	0.72	R/kg	14506.91	9429.49	23573.89	15323.02
Cans	0.69	R/kg	5579.51	3533.69	9066.77	5742.28
Glass	0.48	R/kg	23618.04	10313.29	38379.58	16759.21
Total			73942.59	57843.47	120157.54	93996.29
Profit margin	15	%		8676.59		14099.45
Capital investment						
Paving and environment preparation	15000.00	per community		75000		75000.00
Recycling bin (5 waste streams)	35000.00	per community		175000		175000.00
Baling machine				79800.00		79800.00
Vehicle				200000.00		200000.00
Total capital invested				529800.00		529800.00
Loan details						
Interest rate				9%		9%
Loan period				72.00		72.00
Monthly annuity				-9549.93		-9549.93
Fixed cost						
Building lease cost				15000.00		15000.00
Overheads				4500.00		4500.00
Maintenance	125.00	R/month		625.00		625.00
Marketing Cost	125.00	R/month		625.00		625.00
Labour	1368	R/month		19411.84		30504.32
Total Fixed Cost				40161.84		51254.32
Variable Cost						
Transportation	218.82	R/ton		11597.46		18818.52
Baling	70	R/ton				
Total variable cost				11597.46		18818.52
Profit/(Loss) before capital repayment				-2592.42		9824.00
Profit/(Loss) per month				-12142.35		274.07

4.3.3 Conclusion on profit drop-off initiative

In an attempt to create a profitable drop-off recycling initiative within a community, it was found that the break-even point is only achieved once 5 communities representing a 1000 households each are serviced by the company. Even then, the break-even point is unrealistic high and not necessary sustainable within residential communities, due to dependence on factors such as the amount of households participating, transportation costs, the buy-back price of recyclable material, geographic layout of community, etc.

Approaching more communities to participate would seem to be the logic option, but additional communities may be located so far from the other communities involved and from the sorting facility, that the cost to collect the recyclable materials may be more that the re-sale value of such materials. Locating drop-off facilities at more visible, accessible public places may improve the amount of people reached. Locations more suited would be at small to larger commercial business areas, such as shopping malls and petrol filling stations. In the case of these publicly placed drop-off facilities, lower participation rates would be realised but more potential recyclers reached.

Cost can also be cut by investing in smaller and less expensive recycling bins to be placed within the community.

An option that could be worth investigating, is to charge a participation fee from the communities' HOAs or to negotiate with the HOA to provide the drop-off facility at their cost, or to contribute to the cost thereof. Gated communitys HOA, the HOA — and therefor the individual home owners — may benefit on the property market from being known as a *green* community.

4.4 Non-profit pick-up WCS business model

HOA or any other NPO can initiate pick-up collections within their respective communities to create efficient recycling communities. The motivation is not only a moral issue, but the initiative can also supplement the income of the HOA and thereby reduce the financial burden on the members of the HOA. Pick-up collection can be much more effective than drop-off collection as residents do not have to use extra time to deposit their waste in a drop-off bin. Providing a WCS which is more convenient to the household is of high priority within pick-up collection as it can lead to higher household participation rates than with drop-off initiatives.

4.4.1 Business model assumptions

The following assumptions were made to develop a non-profit pick-up recycling initiative:

1. Pick-up collection is performed on a weekly basis.
2. The CWGM is an accurate representation of a community's potential recyclable material generation.
3. The initiative is implemented within the boundaries of a single HOA.
4. Land parcel on which the sorting and baling takes place, is made available by the HOA at no cost except for the cost of R50000 to upgrade the facility to house the baling machine.
5. Maintenance cost on infrastructure are fixed at R1500 per year, R125 per month.
6. Overhead costs is estimated at R1500 per month.
7. Promotion of the recycling initiative within the community is fixed at R1500 per year, R125 per month.
8. Transportation cost is as estimated in Table 4.1, the same as non-profit drop-off. Assume that an existing utility vehicle is used. The cost of a driver is estimated at R5000 per month.
9. Interest on capital investment is taken at a fixed rate of 4%.

10. Prices for recyclable material are as stated in Table C.1. The model relies on a 10%/kg increase per recyclable material purchase price by recycling companies due to recyclables being sorted and baled.

11. Capital cost is described in Table 4.11. The cost of the baler was provided by AKURA Manufacturing and Engineering Company PTY (Ltd) (2011). The baler will be operated within an enclosure which can be secured.

12. Baler operational cost includes bale strapping, electricity and general maintenance at R70/ton.

13. Labour cost are based on minimum wages for domestic workers and drivers in populated city areas working 8 dedicated hours per day, 40 hour week, (Department of Labour, 2011). Labour and labour costs are shared with NPO. Table 4.12 describes the breakdown of labour costs for non-profit pick-up recycling.

Table 4.11: Capital cost, non-profit pick-up

Item	**Cost[R]**
Baling machine	50160.00
Enclosure	50000.00
Total	100160.00

Table 4.12: Labour costs, non-profit pick-up

	Value	**Unit**	**Cost [R/ton]**
Driver[a]	28	R/hour	28
Labour[b]	8	R/hour	16
Total			44

[a] One driver per vehicle
[b] Two labourers per vehicle

4.4.2 Financial evaluation

Non-profit collection of recyclable materials are operational intensive. The recyclable waste will be collected from the households on a weekly or bi-weekly recyclable waste collection schedule. Increased operational cost due to price hikes in fuel and labour can have a negative impact on the operational cost of the model. Executing pick-up waste collections should be well planned before being implemented to minimise the risk of spending more money on the collection of a household's recyclable waste than what the waste is worth. The route by which waste are collected should be optimised in terms of fuel and time. The route would constantly need to be adjusted as new households join the initiative until optimum household participation rates are achieved.

The break-even points are illustrated in Table 4.13, as derived from Table D.4. As household participation rates increase, the resulting number of households within the community decreases. With a community size of 500 households a household participation rate of only 45% is necessary while a community of 300 households can effectively maintain the initiative at a participation rate of 80%.

Even though non-profit pick-up collections do not have high capital investment cost, it is more labour and operational intensive than drop-off strategies, making the investment there of risky. Increasing the

rate at which capital is being repaid should only be done if the revenue stream is sufficient and reliable enough to cover the increased cost.

Table 4.13: Non-profit pick-up break-even points

Participation rate [%]	30	35	40	45	50	55	60	65	70	75	80
Households required	700	600	550	500	450	400	350	350	300	300	300

4.4.3 Conclusion on non-profit pick-up initiative

It is important to stay within the feasible operating parameters of the business model to ensure the sustainability of the project. Seasonal variation in recycling quantities will occur but would just need to be absorbed during months when the community is recycling more.

Due to the high transportation and labour cost involved in the collection of recyclable materials, pick-up collection initiatives can be easily sustained within smaller communities, providing that a high community participation rate is achievable and traveling distance between households are as short as possible. As most HOAs have a utility vehicle of some sort, recyclables can even be collected by one HOA employee, making pick-up collections feasible for even smaller communities who really wants to participate in recycling.

Pick-up collections are appealing due to their higher participation rates among households, providing for more waste collected and thus higher revenue obtained from the operation. Even a 5% increase in household particpation can lead to a significant increase in excess revenue. Once pick-up collection has been established and all outstanding capital has been repaid, excess revenue can effectively supplement the NPO's operations.

Table 4.14: Non-profit pick-up summary of business model

Households			450		300	
Participation rate			50%		80%	
Income						
Recyclable materials	**Value**	**Unit**	**Weight [Kg]**	**Revenue [R]**	**Weight [Kg]**	**Revenue [R]**
Plastic	1.47	R/kg	1231.27	1648.61	1295.73	1734.92
Paper	1.13	R/kg	2157.10	2217.02	2263.67	2326.55
Cardboard	0.72	R/kg	1628.55	1058.56	1654.60	1075.49
Cans	0.69	R/kg	615.96	390.11	660.85	418.54
Glass	0.48	R/kg	2698.22	1178.23	2810.15	1227.11
Total			8331.09	6492.52	8685.00	6782.61
Expenses						
Capital investment						
Baling machine				50160.00		50160.00
Enclosure				50000.00		50000.00
Total capital invested				100160.00		100160.00
Loan details						
Interest rate				4%		4%
Loan period				72.00		72.00
Monthly annuity				-1567.02		-1567.02
Fixed cost						
Maintenance	125	R/month		125.00		125.00
Marketing cost	125	R/month		125.00		125.00
Overheads	1500	R/month		1500.00		1500.00
Total fixed cost				1750.00		1750.00
Variable cost						
Labour	44	R/500ton-h		748.00		792.00
Transportation	218	R/ton		1312.92		1312.92
Baling cost	70	R/ton		630.00		630.00
Total variable cost				2690.92		2734.92
Excess/(Loss) before capital repayment				2051.60		2297.69
Excess/(Loss) per month				484.58		730.67

4.5 Profit pick-up WCS business model

Households would react to a marketing campaign and contact the profit pick-up company to inform them that they would like to participate in the pick-up initiative. Each week the participating household would place the recyclable materials mixed on the kerb and it would then be collected. This strategy entails a more formalised process of recyclable collections than that of the non-profit pick-up strategy.

Results from the non-profit pick-up model indicate that for larger pick-up WCSs multiple communities' waste need to be collected if profit are to be generated. This being so, the need arises that a central located facility for sorting and baling of materials must be provided. Large or multiple communities will therefore be serviced from this single facility supporting the concept of *"economies of scale"*. As in Table 4.18, a single community's break-even point is multiplied by the amount of communities participating to represent the total amount of households within all communities in the pick-up strategy.

Labour are employed full time as much more households within communities will be serviced. Pick-up teams will mainly consist of a driver and 2 labourers tasked to pick up and transport the recyclable material from the households participating on the specific households collection date scheduled to be transported to the sorting and baling facility.

Profit driven waste collection companies are currently emerging at an impressive rate. Most of these private recycling collectors charge a monthly fee for the collection of recyclables from the households. The monthly fee is mostly to cover the collection and operational costs of the company. Developing a profit driven initiative which only rely on revenue gained from the selling of the recyclable materials collected, is the aim of this business model.

4.5.1 Business model assumptions

The following assumptions were made to develop profit pick-up recycling initiative:

1. Pick-up collection is performed on a weekly basis.
2. The CWGM is an accurate representation of a community's potential recyclable material generation.
3. The initiative is implemented within the boundaries of a single HOA or multiple communities.
4. Maintenance cost on infrastructure are fixed at R15000 per year, R1250 per month.
5. Promotion of the recycling initiative within the community is fixed at R12000 per year, R1000 per month.
6. Transportation cost is as estimated in Table 4.16. The cost of a driver is estimated at R5000 per month.
7. Interest on capital investment is taken at a fixed rate of 9%.
8. Prices for recyclable material are the same as stated in Table C.1. The model relies on a 10%/kg increase per recyclable material purchase price by recycling companies due to material already sorted and baled.
9. Capital cost is described in Table 4.15. The cost of the baler was provided by AKURA Manufacturing and Engineering Company PTY (Ltd) (2011). The baler will be operated within an enclosure which can be secured.
10. Baler Operational cost includes bale strapping, electricity and general maintenance at R70/ton.
11. Labour cost are based on minimum wages for domestic workers in populated city areas working 8 dedicated hours per day, 40 hour week, (Department of Labour, 2011). Labour are being shared between the collection, sorting and baling of recyclable materials activities.
12. Provision is made in the calculations for a profit margin of 15%.

Table 4.15: Capital cost, profit pick-up

Item	**Cost[R]**
Baling machine	79800.00
Vehicle	200000.00
Total	279800.00

Table 4.16: Transportation costs, Profit pick-up

	Value	**Unit**	**Cost[R]**
Fixed costs			
Driver[a]	5000.00	R/month	-
Driver helper[b]	1400.00	R/month/10tons	-
Variable cost			
Vehicle maintenance	60	R60/ton	60
Fuel[c]	1.17	R/km	58.50
Total			118.50

[a] Driver is paid a fixed salary per month
[b] Labour to assist the driver in efficient loading of recyclables
[c] Fuel is calculated on an assumption that a ton of recyclables are transported an average of 50km

4.5.2 Financial evaluation

The break-even points were determined in the profit break-even Table D.5 and summarised in Table 4.17. As indicated in the literature study, Section 2.3, typical pick-up waste recycling participation rates ranges between 50% and 85% when properly marketed and continually promoted.

On the assumption that at least 3 communities are targeted, each with identical number of households and participation rates, the business models presented in the summary Table 4.18 represent two break-even points with all their associated costs. One at 650 households with a participation rate of 60% and another with 450 households at a 80% participation rate. Each of these business models repay the capital invested in 72 months and obtain an excess of R1635 and R45 respectively over and above the 15% profit each month of R5055 and R4674. This demonstrates that profit pick-up collections can be considered as having a wide area of feasibility provided that multiple communities are served.

Table 4.17: Profit pick-up break-even points

Participation rate [%]	40	45	50	55	60	65	70	75	80	85	90	95
Households required	950	850	750	700	650	600	550	500	450	450	450	400

Table 4.18: Profit driven pick-up summary of business model

Households			650		450	
Participation rate			60%		80%	
Number of communities			3		3	
Total number of households			1950		1350	
Income						
Recyclable materials	**Value**	**Unit**	**Weight [Kg]**	**Revenue [R]**	**Weight [Kg]**	**Revenue [R]**
Plastic	1.47	R/kg	6301.40	8437.27	5910.07	7913.31
Paper	1.13	R/kg	11187.63	11498.40	10354.07	10641.68
Cardboard	0.72	R/kg	8554.90	5560.69	7817.58	5081.43
Cans	0.69	R/kg	3241.45	2052.92	2956.61	1872.52
Glass	0.48	R/kg	14086.53	6151.17	12951.44	5655.50
Total			43371.91	33700.44	39989.77	31164.45
Profit	15	%		5055.07		4674.67
Expenses						
Capital investment						
Baling machine				79800.00		79800.00
Vehicle				200000.00		200000.00
Total capital invested				279800.00		279800.00
Loan details						
Interest rate				9%		9%
Loan period				72.00		72.00
Monthly annuity				-5043.55		-5043.55
Fixed cost						
Maintenance	1250	R/month		1250.00		1250.00
Marketing cost	1000	R/month		1000.00		1000.00
Overheads				4500.00		4500.00
Labour				7800.00		7800.00
Total fixed cost				14550.00		14550.00
Variable cost						
Transportation	118.5	R/ton		4266.00		3910.50
Baling cost	70	R/ton		3150.00		2940.00
Total variable cost				7416.00		6850.50
Profit/(Loss) before capital repayment				6679.37		5089.28
Profit/(Loss) per month				1635.83		45.73

4.5.3 Conclusion on profit pick-up initiative

A profit pick-up WCS is more suitable for larger scaled recycling projects, where large communities can be targeted for a pick-up initiative. Establishing a sustainable flow of recyclable materials from these communities are crucial. Continued promotion of the WCS will increase household participation rates to maximise revenue and increase the density of participating households. This would reduce traveling distance and time between participating households and increase the profit obtained from the community. Once capital has been fully repaid, the revenue and the percentage profit will increase.

A profit driven pick-up company can also include drop-off facilities in smaller communities were pick-up facilities may not be feasible to extend their profit generation activities.

Further capital investment within the business models to increase the scale of operations would require a large capital investment accompanied with a transition period before full advantages of investment are realised.

The participation density of the specific community should be considered as a higher profit is obtained when more pick-up's are done within a particular community, irrespective of community size. Higher participation density do not need to be associated with larger communities, but rather with the distances between households participating.

Chapter 5

Closing comments and conclusion

5.1 Closing comments

Society has long past the stage of having a choice to recycle waste, or not. Even if there were no legislation in place to enforce recycling, man is indebted to minimize his environmental footprint. Governmental organisations are approving bylaws to encourage and in some cases, to enforce recycling on communities and businesses, as is currently being implemented in Cape Town's residential *think 2wice* recycling strategy. Initiatives also need to be supported from a governmental level in terms of funding and legislative requirements.

Considering the Waste act of 2008, the responsibility of developing initiatives that support recycling, lies primary with the local municipalities. If the municipality can make funding and subsidies available to recycling companies, these companies could achieve more profitable and sustainable recycling initiatives.

Passing legislation to extend the manufacturers responsibility to ensure the recycling of a portion of their packaging material used, as being successfully implemented in Germany, could increase the overall demand for recycling materials and thus increase the price paid. An increase in recyclable material buying prices would have a positive effect on the profitability and growth of recycling initiatives.

The public' perception of recycling need to be considered, as recycling may not be important to enough people to make the business models feasible. In many instances, the community will need to be educated in their role and duty towards the waste management hierarchy. The specific recycling strategy chosen for a specific community, needs to cater for the exact needs of that community. Aspects such as geographical layout, community income, profile, culture, attitude towards recycling and the availability of alternative recycling services should be taken into account when deciding on which recycling strategy to implement. The project, together with the business models, explored the possibilities available to provide communities with the possibility to recycle.

One of the keystones for the launching of a successful WCS is a well structured promotion initiative. Households need to be fully informed and educated as to the 'what', 'why', 'how' and 'when' of the WCS. This was not the scope of this study, but the importance of the strategy can not be underestimated. Advertisement through systems already in place in communities that have HOAs, such as monthly newsletter and advertisement boards, could be valuable and cost efficient, but a more aggressive initial campaign might be worthwhile to obtain high household participation rates from day one. Continuing feedback to the community on successes (and failures) should also be maintained, but mainly on a positive encouragement basis. The value of *"word of mouth"* and *"follow by example"* should not be underestimated as a promotional tool.

Good and bad habits are learned 'at home'. This makes the recycling of materials consumed by households, the cornerstone of a future environmentally responsible society. School children are also being educated in reducing their carbon footprint, and may well be the trigger that makes a household enter the recycling arena.

The BGWPS determined the waste profile of households in a medium to high income gated commu-

nity, Section 3.1. These results were used to generate the business models. The BGE study has proved that, on average, 9.32kg at an efficiency rate of 56.61% recyclable materials from the total household stream are generated by the average household in the chosen community per week. The obvious question to be asked is whether this would generate enough recyclable waste to cover the cost of collecting the recyclables and in the long run divert enough recyclable waste from landfills. Waste routed to landfills needs to be minimised in line with the government's NWMS to reduce the amount of waste to landfills by 2012 by 50% and 100% by 2022 (Department of Environmental Affairs and Tourism, 2005).

5.2 Conclusion

The potential of household recycling collection could be exploited by NPO such as HOAs as well as companies wanting to make a profit out of the sale of recyclable waste. The two basic options for WCS investigated in this study, were drop-off systems and pick-up systems. Both of these could be undertaken with a non-profit break-even goal, or to generate profit. If the initiative in the community is aimed at only covering cost, institutions such as HOAs are ideally structured to undertake the exercise of starting recycling within their respective communities. Existing transportation, labour and facilities such as paving could be shared to reduce capital and operational costs. Sponsorships and partnerships with waste collection companies could ease the cost and work toward the advantage of all the parties involved.

The probability of any of the initiatives being sustainable will increase if an ongoing high rate of household participation can be maintained.

It was found that if a recycling initiative is launched on a non-profit scenario, the drop-off model will be the most likely to succeed. A baling machine need only be introduced once the bulk of recyclable material have increased to the point where the handling, storing and transportation become problematic. A HOA typically found in the modern residential estates will be well equipped to run such an initiative independently. Multiple non-profitable drop-off facilities, each managed by the community itself would be more appealing to provide maximum convenience and manage-ability to the participating households.

A pick-up scenario, with sorting and baling facilities at a centralised location, servicing multiple communities, is recommended for a private initiative aiming at generating a profit even though non-profit pick-up collection initiatives would also be feasible if implemented within a single community. The initial capital cost of the WCS that is initiated by a private company is significantly higher than that of a WCS initiated by a non-profit HOA, primary because the private company will have to invest in transportation, labour, baling machinery and the leasing of a warehouse where the sorting, baling and storage of the waste will take place. A much larger community, or multiple communities within reasonable distance from the sorting facility will need to be secured and participating. As an example the model has indicated that a community of 650 households at a household participation rate of 60% could generate a profit.

Table 5.1 summarises the feasible solution areas which were obtained from the business models in Chapter 4. Each of these initiatives can be implemented in the areas described within each of their respective WCS.

Table 5.1: Households required per initiative at respective feasible household participation rates

WCS in question	Participation rate	**Non-profit**	**Profit**
Drop-off recycling initiative	30% to 45%	250 to 1000[a]	900[b]
Pick-up recycling initiative	50% to 80%	250 and up[c]	400 and up[c]

[a] Limited due to geographical practicality
[b] Profit drop-off, impractical within residential areas
[c] Scalable to larger community sizes

5.3 Further study areas

Any further research in the field is vital. Even though residential recyclables are not as much in comparison with the potential of recyclable materials collected from commercial industries, it is ever important to help in the creation of a sustainable environment and education of future generations. Gradually including more elements into the study and business plans, broadening the scope and improving of already existing initiatives would be beneficial towards all the communities it would serve.

The following list describes further areas which can be included and/or expanded on:

1. Including composting as a waste stream addition in recycling initiatives will further reduce the tonnage of waste that have to be transported to landfill sites. Organic waste is just as dangerous towards our environment due to gasses being expelled when organic material decomposes and composting can be of great value to households and communities.

2. Determining of potential savings made by the municipality's waste collection services if a community is actively recycling.

3. Use of the same business models, but within other settings, such as high residential, industrial, commercial uses, places where the public gather such as shopping malls, filling stations, parks and public events.

4. Develop financial household incentives to participate in the promotion of recycling activities.

Appendix A

Blue Gill Waste Profile Study (BGWPS)

A.1 Data

Table A.1: BGWPS, household recycling efficiency

	Percentage of waste stream						
Overall[a]	**Week 1**	**Week 2**	**Week 3**	**Week 4**	**AVG**	**STEDV**	**Range**
Plastic	8.26%	10.10%	10.84%	12.08%	10.32%	1.60%	3.82%
Cans	3.67%	3.03%	5.25%	3.16%	3.78%	1.02%	2.22%
Glass	15.46%	15.30%	18.03%	14.90%	15.92%	1.42%	3.13%
Paper	10.47%	19.35%	10.02%	13.88%	13.43%	4.31%	9.33%
Cardboard	11.53%	14.09%	16.91%	10.13%	13.16%	2.99%	6.78%
Municipal waste	50.62%	38.14%	38.96%	45.86%	43.39%	5.93%	12.48%
Recycling efficiency	49.38%	61.86%	61.04%	54.14%	56.61%	5.93%	12.48%

[a] Flaw of averages has been avoided, each households per capita recycling efficiency has been calculated individually

Table A.2: Per capita recycling efficiency

	Week 1		Week 2		Week 3		Week 4		Total	
Per capita [kg]	**AVG**	**STEDV**	**AVG**	**STEDV**	**AVG**	**STEDV**	**AVG**	**STEDV**	**AVG**	**STEDV**
Plastic[b]	0.530	0.292	0.621	0.688	0.490	0.362	0.591	0.771	0.558	0.058
Cans[b]	0.263	0.237	0.197	0.272	0.282	0.672	0.152	0.178	0.224	0.060
Glass[b]	1.160	1.650	0.985	1.365	0.731	0.767	0.625	0.847	0.875	0.242
Paper[b]	0.856	0.923	1.202	1.700	0.450	0.487	0.716	0.782	0.806	0.313
Cardboard[b]	0.740	0.711	0.885	1.072	0.738	0.869	0.444	0.399	0.702	0.185
Total recyclables	3.552	0.573	3.891	0.559	2.693	0.206	2.531	0.292	3.167	0.570
Municipal waste[b]	3.546	3.180	2.145	1.671	1.824	1.391	2.094	1.486	2.402	0.775
Per capita recycling efficiency[a]	50.04%	-	64.46%	-	59.62%	-	54.72%	-	56.86%	

[a] Flaw of averages has been avoided
[b] Non conforming outliers has been removed

Table A.3: BGWPS, weighing data summary

Recyclable materials:	**Paper**	**Cardboard**	**Plastic**	**Cans**	**Glass**	**Total recyclables**	**Municipal waste**	**Total**
Amount weighed in 4 weeks [kg]	139.5	51.8	219.9	186.91	181.9	780.01	606.4	1386.41
Average household waste per week [kg]	1.73	0.62	2.64	2.15	2.18	9.32	7.19	16.54
Standard deviation of household waste per week [kg]	0.99	0.53	2.02	1.81	1.15	6.50	4.71	11.24

A.2 Waste profile study questionnaire

BLUE GILL HOMEOWNERS ASSOCIATION

Blue Gill Estate Waste Profile Study

Good day Resident

I am Hugo de Vos, a final year student at the University of Pretoria currently busy with data collection for my final year project in Industrial Engineering. I am studying the effects community driven recycling has on municipal services and to improve waste management and recycling opportunities in communities by using Industrial Engineering optimisation principles. I am doing a study in Blue Gill Estate Eco-Park because it is a one of a kind with waste management and recycling.

The project is fully supported by the Directors of the Blue Gill Home Owners Association as part of their drive to continuously increase the recycling tonnages in Blue Gill.

I am requesting your cooperation, the Blue Gill residents, to assist in the voluntary data collection phase of my project. The first phase will be a general questionnaire followed by voluntary participation in weighing of your recyclable and municipal disposable waste streams by me, the student.

1. General questionnaire *(to be completed by all Blue Gill Homeowners)*

Please answer the following questions to contribute to the study and return to staff at one of the security gates by no later than Friday 27 May 2011 (Mark or fill in the appropriate answer)

Are you currently recycling your household waste?	Yes		No		
If you do recycle, how often do you deliver to the collection bins on average?					
If you do not recycle, please indicate possible reason for non-participation.					
On which side of Blue Gill do you stay?	Blue Gill		Blue Gill - Waterfront		
Number of people residing on the property between ages of	0-3 years	3-25 years		25 and above	
House type	Group housing		Single house		
Street address					
Number of bedrooms					
Would you like to participate in a composting initiative* in Blue Gill Estate?					
General comments and suggestions:					

*Testing the possibility of establishing a system whereby organic waste can be composted.

COMMUNITY CENTRE 38 CORMORANT DRIVE BLUE GILL VILLAGE KEMPTON PARK
PO BOX 10762 ASTON MANOR 1630 SOUTH AFRICA Tel +27 (0)11 391 4756 Fax +27 (0)11 391 4756
OFFICE HOURS: 07h30 to 12h00

Figure A.1: Resident questionnaire, page 1

2. Profiling of residence waste streams. *(to be completed by Homeowners wishing to participate in weighing)*

If you are interested in participating in the weighing of your household waste stream please return both parts of the form to the staff at one of the security gates no by no later than Friday 27 May 2011 *and/or contact me by email, phone or SMS before the said date.*

Please continue with the separation of your recyclable material on a weekly basis, but do not deposit your recyclables into the Blue Gill Eco-Park collection bin. I will come on a weekly basis (dates provided below) to weigh the recyclable material and disposable municipal waste stream. Once weighed, I will personally deposit the recyclable material into the Eco-Park collection bin.

Process:

1. Recycle as normal
2. Place recyclable material separated by type into different plastic bags (same classification as the collection bin in the Eco-Park, bags will be provided to participating residents for recyclable material)
3. On the weighing date, place your recycled waste bags as well as your municipal collection bags on the kerb (as you would on a municipal collection day, just a day earlier)
4. I will come around and weigh the bags in the evening between 17:30 – 20:00
5. I will personally take the recycled bags and place them in the Blue Gill collection bins after weighing has taken place
6. I will return your disposable waste to your property once weighed for it to be collected by the Municipality the following day

Please be assured that your privacy will be respected throughout the weighing and collection of your recyclable material.

Collection dates:

Municipal Collection date	Weighing date	Weighing time period	Comments
Tuesday - 31 May 2011	Monday – 30 May 2011	17:30 – 20:00	First date
Tuesday - 7 June 2011	Monday - 6 June 2011	17:30 – 20:00	Second date
Tuesday - 14 June 2011	Monday - 13 June 2011	17:30 – 20:00	Third date
Wednesday - 22 June 2011	Tuesday - 21 June 2011	17:30 – 20:00	Fourth date
Wednesday – 29 June 2011	Tuesday – 28 June 2011	17:30 – 20:00	Reserved day

Your details: (only if participating in the weighing of your household waste)

Name and Surname:	
Address in Blue Gill Estate:	
Home Telephone Number:	
A Cell Number (contactable after hours):	
E-mail address:	

(Personal information will be used for the purposes of this research project only and will be not be disclosed to any external parties.)

I thank you for your cooperation in helping in obtaining the data to improve the quality and quantity of our recycling efforts.

Contact Details

Hugo de Vos

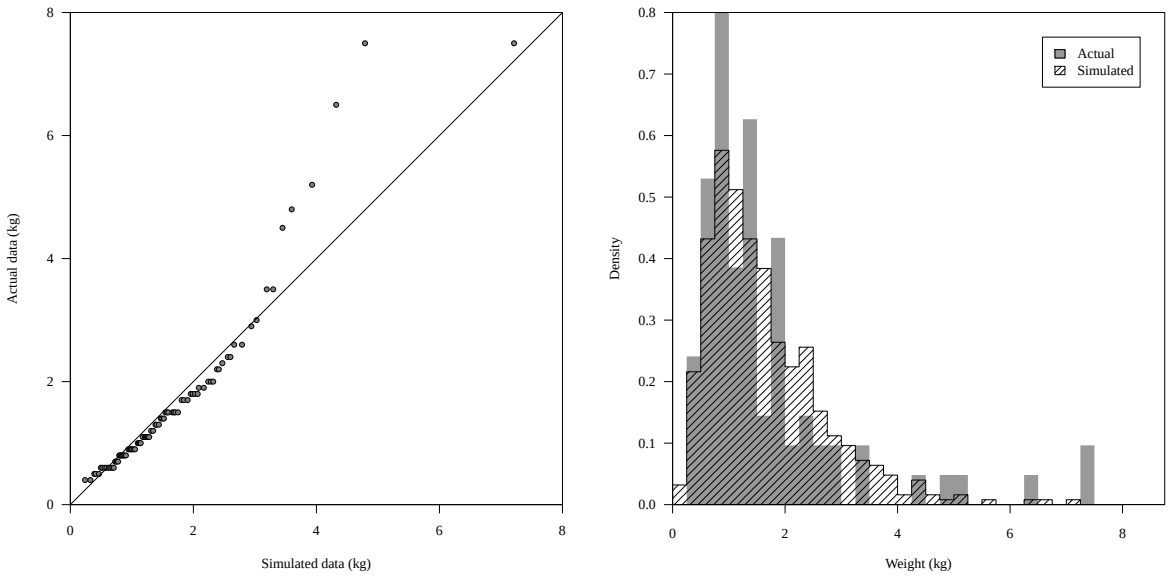
Cell: 084 517 7417 E-mail: hugow.devos@gmail.com

Figure A.2: Resident questionnaire, page 2

Appendix B

Recyclable material distributions

B.1 Plastic

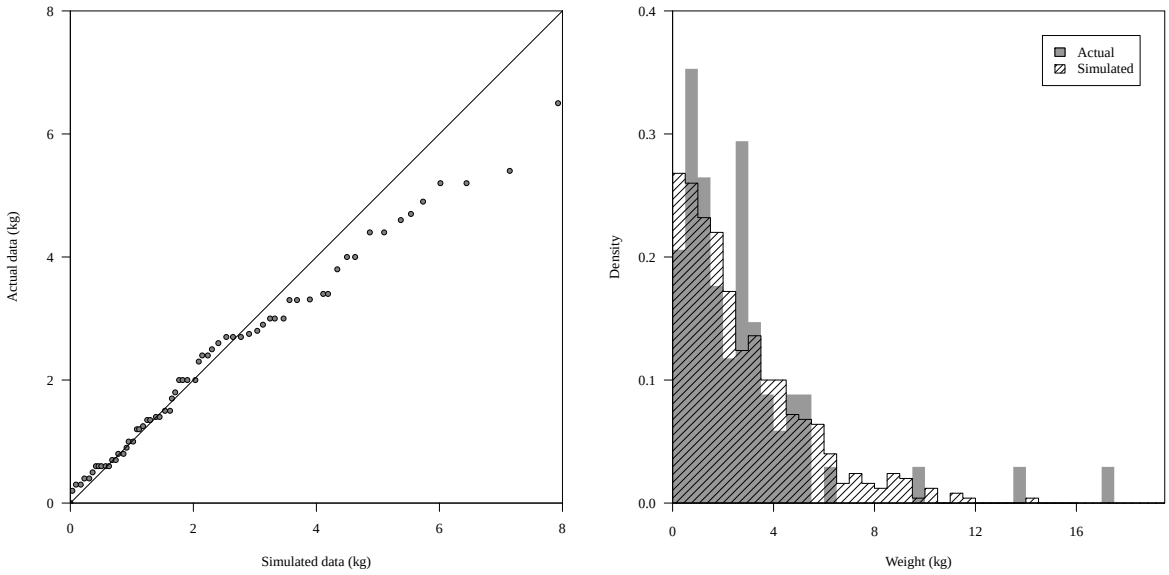


(a) QQ-Plot

(b) Histogram

Figure B.1: Comparing actual versus simulated weight of plastic

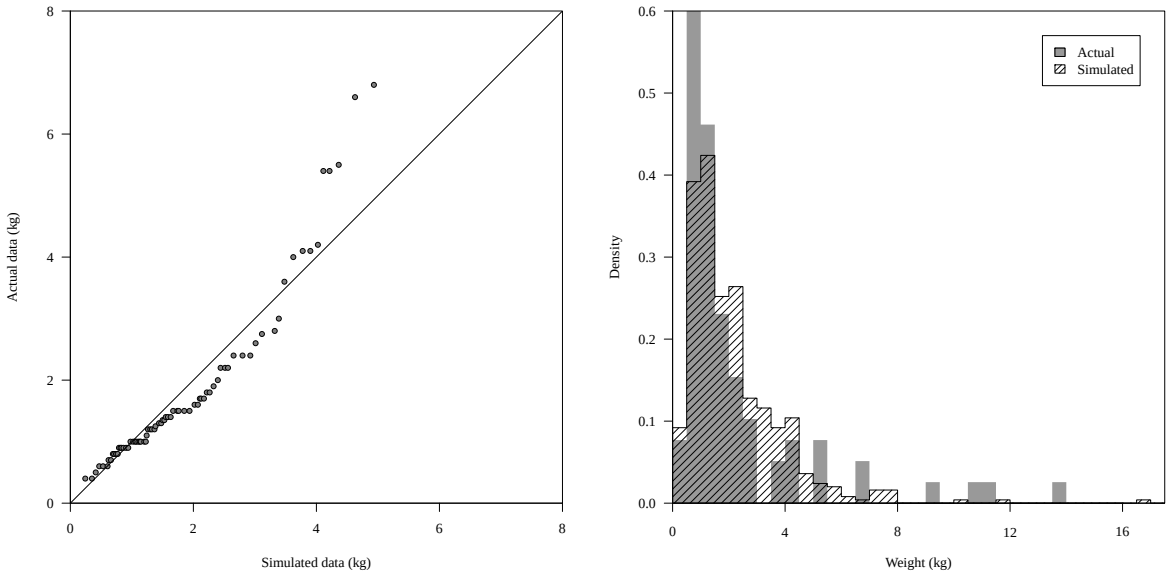
B.2 Paper



(a) QQ-Plot (b) Histogram

Figure B.2: Comparing actual versus simulated weight of paper

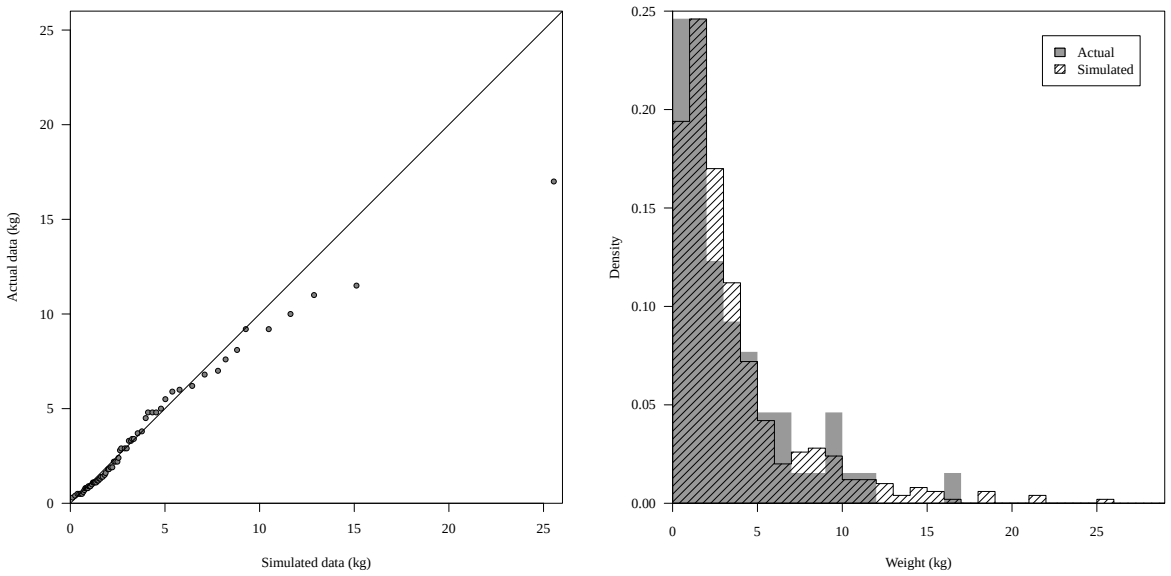
B.3 Cardboard



(a) QQ-Plot (b) Histogram

Figure B.3: Comparing actual versus simulated weight of cardboard

B.4 Glass



(a) QQ-Plot (b) Histogram

Figure B.4: Comparing actual versus simulated weight of glass

Appendix C

Data Collection

Table C.1: Recyclable material price calculations

			Remade [R]	**Nampack [R]**	**Silverton recycling [R]**	**Other [R]**	**AVG Price[c] [R]**	**Distribution**	**sub-total**	**Cost per material [R]**
Plastic[a]	1	PET	1.80	0.70	3.6	3.65	2.43	0.23	0.56	
	2	PE-HD	0.80	0.50	0.80		0.70	0.13	0.09	
	3	PVC	0.60	0.40	1.80		0.93	0.23	0.21	
	4	PE-LD	1.70	0.90	1.40		1.33	0.16	0.21	
	5	PP	1.60	0.70	0.60		0.96	0.13	0.13	
	6	PS	0.90	0.70	1.80		1.13	0.09	0.10	
	7	Other	0.90	0.70	1.80		1.13	0.00	0.00	1.33
Paper[b]	White paper		2.00	2.00			2.00	0.33	0.66	
	Coloured and other		0.45	0.65			0.55	0.33	0.18	
	Newspapers		0.45	0.35	0.8		0.53	0.33	0.17	1.02
Cardboard	K4		0.65	0.65			0.65			0.65
Cans	Mixed		0.60	0.30		1.00	0.63			0.63
Glass	Mixed		0.40	0.33		0.58	0.43			0.43

[a] Plastic price is estimated on the distribution obtained in a general household's 2 week plastic separation
[b] Paper is estimated to be distributed in thirds
[c] Note, Averages are taken to find a general price per recyclable material

Appendix D

WCS Business model break-even tables

Table D.1: Break-even table, non-profit drop-off recycling without sorting and baling

	Household participation rate										
House-holds	0.30	0.35	0.40	0.45	0.50	0.55	0.60	0.65	0.70	0.75	0.80
50	-2839.36	-2786.67	-2733.97	-2681.28	-2628.58	-2575.88	-2523.19	-2470.49	-2636.62	-2623.92	-2571.23
100	-2657.93	-2578.53	-2459.13	-2339.72	-2220.32	-2100.91	-1981.51	-2080.93	-2001.52	-1882.12	-1762.72
150	-2298.94	-2113.03	-2145.95	-2000.05	-1814.14	-1628.24	-1661.16	-1515.25	-1329.35	-1143.45	-1176.36
200	-2080.58	-1861.82	-1603.05	-1563.11	-1344.34	-1085.58	-1045.63	-826.87	-568.11	-528.16	-309.40
250	-1757.75	-1657.33	-1378.10	-1277.68	-998.44	-679.20	-578.79	-299.55	-199.13	80.11	399.34
300	-1579.70	-1234.32	-1067.75	-722.37	-555.81	-210.42	-43.86	301.52	468.08	813.47	980.03
350	-1455.68	-1046.49	-816.13	-406.94	-176.57	232.62	462.99	653.36	1062.55	1292.92	1702.10
400	-1071.60	-817.22	-344.01	-49.63	204.75	677.95	972.33	1226.72	1699.92	1994.30	2248.68
450	-868.19	-536.77	13.47	384.89	716.31	1047.73	1597.97	1969.39	2300.81	2632.23	3182.47
500	-555.63	-125.44	264.74	654.92	1045.10	1435.28	2044.28	2474.46	2864.65	3254.83	3645.01
550	-365.67	92.64	550.95	1009.25	1467.56	1925.87	2603.00	3101.31	3559.62	4017.93	4476.24
600	-236.00	287.06	810.11	1333.17	1856.23	2379.29	2902.35	3425.41	3948.47	4471.53	4994.58
650	178.89	771.10	1363.31	1955.52	2328.90	2881.11	3473.32	4065.53	4657.73	5249.94	5842.15
700	274.38	925.64	1576.90	2228.16	2879.42	3311.86	3923.12	4574.37	5225.63	5876.89	6528.15
750	663.89	1380.06	1877.42	2553.60	3269.77	3985.95	4483.31	5159.48	5875.66	6591.84	7089.19
800	834.24	1621.95	2190.83	2938.54	3726.24	4295.13	5042.84	5830.54	6399.43	7147.13	7934.84
850	1239.72	1876.19	2691.47	3327.94	4143.23	4779.69	5594.98	6450.27	7086.73	7902.02	8538.48
900	1353.71	2224.46	2916.40	3787.15	4479.09	5349.84	6041.77	6912.53	7604.46	8475.22	9167.15
950	1534.28	2478.27	3243.43	4187.42	4952.58	5677.75	6621.74	7386.90	8330.89	9096.05	9821.22
1000	1925.25	2762.25	3559.24	4575.05	5412.05	6209.04	7224.86	8061.85	8858.85	9874.66	10711.66

Table D.2: Break-even table, non-profit drop-off recycling with sorting and baling

	Household participation rate									
House-holds	0.35	0.40	0.45	0.50	0.55	0.60	0.65	0.70	0.75	0.80
350	-4503.54	-4298.25	-3804.14	-3598.86	-3104.75	-2899.46	-2694.17	-2200.07	-1994.78	-1500.67
400	-4299.45	-3734.93	-3459.23	-3183.52	-2619.00	-2343.30	-2067.60	-1503.07	-1227.37	-951.66
450	-3995.08	-3345.82	-2985.37	-2624.93	-2264.48	-1615.22	-1254.78	-894.33	-533.88	115.37
500	-3542.62	-3117.54	-2692.46	-2267.38	-1842.29	-1128.39	-703.31	-278.23	146.85	571.93
550	-3306.85	-2806.83	-2306.80	-1806.78	-1306.76	-517.91	-17.89	482.12	982.15	1482.17
600	-3097.11	-2525.86	-1954.61	-1383.37	-812.11	-240.87	330.37	901.62	1472.86	2044.11
650	-2564.66	-1917.35	-1270.04	-911.54	-264.23	383.07	1030.38	1677.69	2325.00	2972.31
700	-2398.78	-1686.51	-974.24	-261.98	161.46	873.73	1586.00	2298.26	3010.53	3722.80
750	-1898.92	-1404.06	-620.38	163.29	946.97	1441.82	2225.50	3009.18	3792.85	4287.71
800	-1636.96	-1063.42	-201.06	661.29	1234.83	2097.19	2959.54	3533.08	4395.44	5257.80
850	-1405.41	-468.71	179.16	1115.85	1763.73	2700.43	3637.12	4285.00	5221.70	5869.57
900	-978.31	-269.42	728.29	1437.18	2434.89	3143.78	4141.49	4850.38	5848.09	6556.99
950	-703.24	86.20	1164.46	1953.91	2743.36	3821.62	4611.07	5689.34	6478.78	7268.23
1000	-438.98	429.47	1586.74	2455.20	3323.66	4480.94	5349.40	6217.85	7375.13	8243.59
1050	-245.68	980.47	1917.80	2855.13	3792.47	5018.62	5955.95	6893.28	7830.62	8767.95
1100	224.75	1229.29	2233.83	3238.37	4242.90	5247.44	6540.80	7545.34	8549.88	9554.42
1150	521.78	1610.01	2698.24	3786.44	4874.70	5962.93	7051.16	8139.39	9227.62	10315.85
1200	708.43	1864.59	3020.75	4176.90	5333.06	6489.21	7645.37	8801.52	9957.68	11113.84
1250	1171.76	2394.10	3616.45	4549.97	5772.31	6994.66	8217.00	9439.35	10661.70	11884.04
1300	1414.05	2712.27	4010.48	5308.70	6318.10	7616.32	8914.54	10212.76	11510.98	12520.37
1350	1654.40	3028.21	4402.02	5487.01	6860.83	8234.64	9608.45	10693.45	12067.26	13441.08
1400	2127.30	3279.85	4721.23	6162.60	7315.15	8756.52	10197.90	11350.45	12791.82	14233.19
1450	2360.70	3876.67	5103.83	6619.80	7846.96	9362.93	10590.09	12106.06	13622.03	14849.19
1500	2619.99	4214.27	5519.73	7114.00	8419.46	10013.74	11319.19	12624.65	14218.93	15524.38

Table D.3: Break-even table, profit drop-off recycling

	Household Participation rate										
House-holds	0.30	0.35	0.40	0.45	0.50	0.55	0.60	0.65	0.70	0.75	0.80
750	-20608.35	-18530.90	-16234.63	-15543.74	-13466.29	-11388.84	-9311.39	-8620.50	-6543.05	-4465.60	-2169.33
800	-20426.16	-18014.31	-15602.46	-14796.00	-12384.15	-9972.30	-8947.01	-6753.98	-4342.14	-3316.85	-905.00
850	-18968.17	-16240.39	-15117.98	-12609.01	-11267.79	-8758.82	-7417.59	-4908.63	-2180.84	-1058.44	1450.53
900	-17849.94	-16249.40	-13481.12	-12099.41	-9331.13	-7949.41	-5181.13	-3799.41	-812.31	569.40	3337.68
950	-17619.98	-15895.91	-12785.27	-11061.19	-8169.37	-6445.30	-4721.22	-1610.58	113.50	3005.31	4729.39
1000	-17429.40	-14201.78	-12141.91	-10300.85	-6854.41	-5013.36	-2953.48	274.13	2115.19	4175.06	7402.68
1050	-16110.72	-13976.95	-11843.18	-8104.02	-5970.25	-3836.47	-1702.70	1817.64	3951.41	6085.18	8218.96
1100	-16221.19	-12415.23	-9995.83	-7576.43	-5157.04	-2956.46	-537.06	1882.34	5688.29	8107.69	10308.27
1150	-14524.68	-11968.41	-9193.32	-6637.06	-3861.97	-1305.70	1469.39	4025.66	6581.93	9357.01	11913.28
1200	-14616.78	-11771.83	-8926.87	-5863.10	-3018.15	-173.20	2671.75	5516.70	8361.66	11206.61	14051.56
1250	-13366.60	-10240.35	-7114.10	-3987.84	-861.59	878.11	3785.54	6911.80	10038.05	13164.30	16290.56
1300	-13256.04	-9807.32	-6577.43	-3128.71	101.19	3549.90	5393.24	8841.95	12071.85	15520.56	18750.46
1350	-11766.00	-8214.82	-5831.39	-2280.21	1270.96	3435.58	6986.75	10537.93	14089.10	16253.72	20023.71
1400	-11867.46	-8029.17	-4190.87	-1739.13	2099.17	5937.46	8170.38	12008.68	15846.98	18298.72	22137.01
1450	-10402.74	-7633.94	-3697.40	457.95	3007.93	7163.29	9713.27	13868.63	16418.61	20573.96	24510.50
1500	-10230.24	-5960.92	-2859.33	1409.99	4292.75	8562.07	11444.83	15714.16	18596.92	21479.68	25967.82

Table D.4: Break-even table, non-profit pick-up recycling

	Household participation rate												
House-holds	0.40	0.45	0.50	0.55	0.60	0.65	0.70	0.75	0.80	0.85	0.90	0.95	1
50	-3230.12	-3172.16	-3114.19	-3056.23	-2998.26	-2940.30	-2996.33	-2938.37	-2880.40	-2822.44	-2764.47	-2925.33	-2867.36
100	-2757.09	-2888.57	-2757.22	-2625.88	-2608.53	-2477.19	-2345.85	-2258.50	-2127.16	-2214.63	-2197.29	-2065.95	-1934.60
150	-2548.71	-2344.22	-2183.73	-2198.05	-2107.56	-1903.07	-1742.57	-1538.08	-1447.59	-1461.91	-1301.42	-1096.93	-1006.43
200	-2170.35	-1999.71	-1759.07	-1588.43	-1522.60	-1281.96	-1111.32	-826.68	-804.86	-634.22	-393.58	-108.93	-157.11
250	-1796.19	-1559.03	-1426.69	-1119.53	-882.37	-794.03	-556.87	-249.71	-231.36	75.80	312.96	401.30	752.46
300	-1546.93	-1167.01	-857.09	-695.99	-430.07	-338.97	40.95	350.87	511.97	821.90	1201.82	1292.92	1672.84
350	-1143.44	-912.15	-532.05	-81.94	35.35	415.46	646.74	1026.85	1144.14	1594.25	1755.53	2091.64	2541.75
400	-842.94	-436.42	-204.72	315.81	503.51	954.03	1141.74	1662.26	1849.96	2300.48	2488.19	3008.71	3240.41
450	-323.01	-6.56	484.70	757.15	1143.59	1634.85	1907.30	2442.56	2715.01	2987.45	3592.72	3865.16	4356.42
500	-138.73	417.17	754.25	1091.34	1647.24	2098.32	2435.40	2991.30	3328.38	3665.46	4221.37	4602.45	5158.35
550	302.80	714.82	1126.85	1757.69	2169.71	2581.74	2993.76	3624.60	4036.62	4448.65	5079.49	5491.51	5903.54
600	609.77	1093.02	1681.08	2164.33	2647.58	3130.82	3832.89	4272.14	4755.38	5238.63	5721.88	6423.94	6793.19
650	1060.28	1619.59	2064.90	2624.21	3183.52	3698.83	4476.97	4922.28	5481.59	6040.90	6556.21	7115.52	7560.83
700	1247.12	1827.38	2451.65	2961.92	3805.00	4385.27	5009.54	5519.80	6100.07	6724.34	7234.61	7858.87	8439.14
750	1774.39	2356.07	3007.74	3589.42	4285.10	4936.77	5518.45	6170.13	6865.80	7447.48	8099.15	8680.83	9376.51
800	2027.03	2687.38	3417.74	4078.10	4808.46	5468.82	6199.18	6859.53	7589.89	8250.25	8980.61	9640.97	10415.33
850	2463.73	2979.61	3784.31	4519.00	5323.70	6058.40	6863.09	7553.79	8288.49	9093.18	9609.06	10413.76	11148.45
900	2619.03	3484.74	4280.45	5032.16	5679.05	6474.77	7226.48	8092.19	8887.90	9639.61	10286.50	11082.21	11947.93
950	3105.47	3832.92	4665.18	5541.45	6373.72	7101.16	7933.43	8809.70	9641.96	10369.41	11201.67	12077.94	12910.21
1000	3474.74	4386.02	5122.48	6033.75	6945.03	7637.49	8662.77	9574.05	10266.50	11221.78	12133.06	13044.34	13850.79

Table D.5: Break-even table, profit pick-up recycling

	Household participation rate												
House-holds	0.35	0.40	0.45	0.50	0.55	0.60	0.65	0.70	0.75	0.80	0.85	0.90	0.95
300	-12533.06	-12017.56	-10936.56	-10421.06	-9340.06	-8824.56	-7953.56	-6872.57	-6357.07	-5276.07	-4760.57	-3679.57	-3164.07
350	-11845.73	-10795.75	-9891.28	-8841.30	-7936.83	-6886.86	-6192.38	-4932.41	-4237.93	-3187.96	-2283.48	-2633.51	-1939.04
400	-10798.82	-9714.78	-8840.75	-7611.22	-6527.18	-5297.65	-4423.62	-3194.09	-2110.05	-2636.02	-1406.49	-532.46	907.08
450	-9641.68	-8551.55	-7105.93	-6015.81	-4925.68	-3270.06	-2179.94	-2489.81	-1044.19	45.94	1136.06	2791.68	3881.81
500	-8697.90	-7442.95	-6188.01	-4933.06	-3322.61	-3467.66	-2002.71	-392.26	862.69	2117.64	3372.59	4983.03	6237.98
550	-7925.70	-6479.65	-5033.60	-3232.05	-3186.00	-1739.95	-293.90	1152.15	2953.70	4399.75	5845.79	7291.84	9093.39
600	-7009.86	-5026.69	-3399.02	-3381.35	-1753.68	-126.01	1501.66	3129.33	5112.50	6740.17	8367.84	9995.51	11623.18
650	-5862.12	-4040.48	-2218.85	-2007.22	-185.58	1636.05	3457.68	5279.31	6890.95	9068.08	10889.71	12711.34	13132.98
700	-5058.14	-3280.87	-2693.60	-706.33	1070.95	3058.22	5045.49	7032.76	8810.04	10797.31	12784.58	13161.85	15149.12
750	-3993.48	-1824.12	-1264.75	904.61	2863.98	5033.35	7202.71	8806.58	10975.94	13145.31	13704.68	15874.04	17833.41
800	-3154.51	-2184.51	-24.50	2345.50	4505.51	6875.51	9035.52	11050.02	11810.03	14180.03	16340.04	18710.04	20870.05
850	-1827.57	-878.00	1116.06	3675.63	6025.20	8584.77	10934.34	13138.40	14087.97	16437.54	18997.11	20991.17	23550.74
900	-2703.96	-198.81	2516.35	5021.50	7171.16	9886.31	12391.47	13141.12	15856.28	18361.43	20866.59	23226.24	25731.40
950	-1476.05	1234.52	3799.59	6510.16	8865.23	11575.80	13096.37	15451.44	18162.01	20872.58	23437.65	26148.22	27458.79
1000	-421.20	2490.85	5047.40	7959.45	10871.50	12028.05	14940.10	17706.65	20618.69	23175.24	26087.29	27243.84	30155.89
1050	598.22	3330.40	6418.08	9150.26	12237.94	13570.12	16657.80	19389.98	22477.66	25209.84	26897.52	29839.70	32927.39
1100	1232.34	4491.39	7394.94	10654.00	12157.55	15416.61	18320.16	21223.72	24482.77	27386.32	29245.38	32148.93	35052.49
1150	2726.24	5633.21	9105.68	12222.64	13939.61	17412.08	20529.05	23646.02	26908.49	28625.46	31742.43	35214.90	38331.87

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