Batch Composting of Human Excrement with Urban Waste Products

Drew Durbin
A. B. Environmental Studies, Senior Honors Thesis
Advisor: Kurt Teichert
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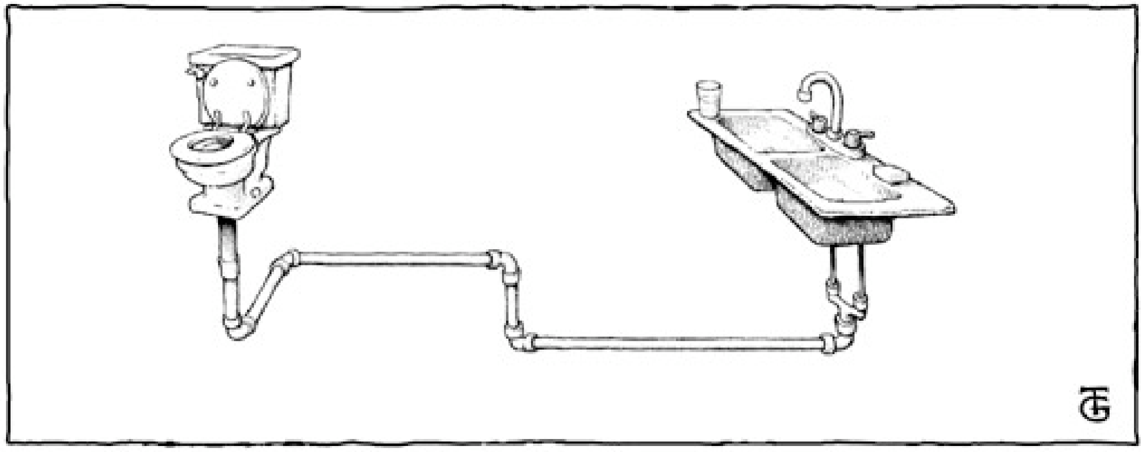

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[1] Jenkins 103

Executive Summary

Centralized wastewater treatment systems are an integral part of modern society as they efficiently destroy pathogens in human waste and prevent malodorous waste from acting as a vector for disease. However, modern wastewater treatment has a high social cost as it leads to the waste of nutrient rich excrement, water pollution, greenhouse gas emissions, production of environmentally damaging natural gas based fertilizers, and the contamination of scarce potable water. This paper theorizes that the thermophilic (high temperature), batch (large volume) composting of nitrogen-rich human waste (both solid waste and urine) with other carbon-rich urban waste products, such as newspaper, and magazines could provide an environmentally responsible alternative to modern wastewater treatment systems.

In order to determine the economic viability and environmental impact of a thermophilic, batch composting operation as an alternative to the centralized municipal waste treatment plant, this paper sets up a hypothetical composting business case study in Providence, Rhode Island. Utilizing real world water and wastewater data from a high density, medium scale urban building, the ability of the business to internalize the negative externalities of waste treatment and compete financially with the established Providence wastewater system is considered. From an operations perspective, a thermophilic urban composting venture could be a viable business solution to the wastewater treatment problem as it would gather sufficient revenue flows to cover its costs and create positive social change in the process. However, from a capital financing perspective, the project is unrealistic as the expected financial returns from the venture are not commensurate with its risk.

Since the venture has the potential to increase social welfare in a financially sustainable manner, a more thorough analysis of the necessary conditions for the business to secure start-up funding is conducted by analyzing four alternative scenarios: a political environment in which the negative externalities of natural gas based fertilizers are internalized through public policy, a political environment in which the negative environmental effects of the modern waste treatment system are internalized, a decentralized rural application where the business displaces decentralized septic waste treatment, and a municipality in which the central waste treatment plant is overburdened and in need of costly capital improvements.

On a scientific and day-to-day financial level, the thermophilic, batch composting of urban waste streams is a viable solution to the scalability challenge of composting toilets. Yet, in current political conditions, a commercial human waste composting venture is only realistic in rural scenarios and on the margin of existing municipal systems where the cost of extending the existing municipal system is prohibitive. In mainstream urban and suburban environments, a business solution alone will simply not receive the necessary funds to solve the waste treatment problem. However, with government policies to internalize the social costs of the modern wastewater treatment system and guarantee loans to businesses investing in human waste composting operations, the aerobic, batch composting of human waste could provide a sustainable private solution to a major public problem.

Chapter 1: Introduction

The modern waste treatment system has broken the natural cycle for dealing with human waste. Every time someone flushes their toilet, they use valuable potable water to wash away nutrient-rich waste. Meanwhile, composting toilets are an existing technology that provide a means for restoring this natural cycle. Rather than utilizing natural gas based fertilizers to produce our food, potable water to dispose of our waste, and chemicals to treat our sewage, composting toilets allow the nutrients in human waste to be broken down by microorganisms and returned to the soil to provide additional food for humans, minimizing water waste in the process. Thus, composting toilets save water (an increasingly scarce resource), reduce wastewater pollution from municipal treatment facilities, and minimize artificial fertilizer consumption.

However, composting toilets are not a panacea for waste treatment as they face two primary practical challenges to their widespread adoption. These toilets convert waste into compost on-site in retention bins below the toilet or in remote composting units generally located in the basement. They break down waste through low temperature, aerobic composting, killing pathogens through long retention times between one and two years. These long retention times coupled with space constraints generally limit the size of remote composting toilet systems to about three toilets. Thus, composting toilets do not provide an ideal waste treatment solution for high density structures. Furthermore, although the true social cost of composting toilets is lower than that of their competitors, their higher price makes them a less appealing option for most builders and homeowners. While composting toilets offer a sustainable option for waste treatment, they have failed to gain a significant market share a result of scalability challenges and high upfront costs relative to traditional toilet systems.

This paper addresses the simple, but vexing question that lies at the heart of any potential solution to the environmental challenge of wastewater: how can the technical and economic challenges of composting toilets be solved in order address the human waste problem. The thesis begins with an overview of the four principle methods for dealing with human waste: modern wastewater treatment, night soil application, anaerobic composting, and aerobic composting and analyzes the ability of each of these options to destroy the pathogens and capture the nutrients within human excrement. Thermophilic, or high temperature, aerobic composting is selected as the most promising method for sustainable, scalable waste management.

Next, the paper breaks down the scientific conditions necessary for aerobic composting and the alternative methods for conducting the procedure. It is determined that thermophilic, batch composting of nitrogen-rich human waste with other carbon-rich urban waste products, such as newspaper and magazines could provide an economically viable and scalable process to overcome the current short comings of composting toilets. In order to investigate the ecological impact and financial sustainability of this operation, a hypothetical composting business case study is set up utilizing wastewater data from the Marriott Courtyard in Providence, Rhode Island, and analyzed in four potential political and economic environments.

Chapter 2: Composting Background

Human waste is rich in chemical elements, such as nitrogen, phosphorous, carbon, calcium and potassium, essential for plant growth. In fact, fecal matter and urea contain all of the fundamental building blocks of commercially produced, petroleum-based fertilizers. However, unlike commercial fertilizers, raw human excrement has an unpleasant odor and acts as a vector for microorganisms that cause disease and illness. As a result, human excrement is not solely a valuable raw material that can be harnessed for agricultural applications, but also a hazardous waste product that must be managed carefully for reasons of public health and sanitation. There are four principal ways to deal with human waste: disposal of the waste through a modern sewage system, direct application of the excrement to soil, anaerobic composting to produce methane, and aerobic composting. In selecting a particular method for waste treatment, the merit of the two objectives of waste treatment, pathogen destruction and nutrient capture, must be weighed relative to the increased time and cost of focusing on either of these goals.

The Four Methods of Dealing With Human Excrement

I. Disposing Waste

With the increasing focus on public health and sanitation in the western world in the 17th and 18th centuries, the perception of human waste changed dramatically as its danger as a hazardous material began to outweigh its value as a fertilizer. In 1775, Alexander Cummings invented the S-trap toilet that utilized water to seal the outlet valve and prevent the flow of fetid air from the sewer. By the late 19th century, Thomas Crapper's plumbing company popularized S-trap flush toilets throughout Britain[2]. This led to the development of centralized wastewater treatment plants to process wastewater from toilets across municipalities. Toilets and water-carried waste systems minimized the potential for human excrement to serve as a vehicle for disease transmissions and quickly became the standard of modern waste treatment.

While modern waste treatment has led to great improvements in public health, the convenience of flushing waste away with potable water comes at a high environmental opportunity cost. First, over the course of a day, each person utilizing a modern toilet flushes away between 0.25-0.75 lbs of fecal matter and 1.75-2.25 pints of urine. On average, this is 0.30 gallons of organic matter comprised of 15% nitrogen, 5% phosphorous, and 3% potassium, the three primary macronutrients necessary for plant life[3].

Second, scarce potable water flushes away this nutrient rich waste. With only 3% of the global water supply available as freshwater, 68.7% of the world's freshwater locked up in glaciers and ice caps, and 92% of useable freshwater consumed by agriculture and industry, only 0.08% of the world's water is available for personal use in commercial and residential applications[4]. By utilizing drinkable water to flush their toilets (conventional toilets use 3.5-7 gallons/flush while low flush toilets use about 1.25 gallons/flush), people contaminate 27% of total indoor water with human excrement[5].

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[2] Reyburn 118

[3] Jenkins 35

[4] Ludwig 3

[5] Cornell Waste Management Insitute

Third, the construction of massive municipal wastewater infrastructure and the operation of the pumps and treatment plants that comprise it result in significant contributions to global carbon dioxide emissions on the order of over 15 teragrams of CO_2/year. Meanwhile, the methane and nitrous oxide emissions that occur from the anaerobic decomposition of the waste as it travels to the waste treatment plant comprise 0.5% of total US greenhouse gas emissions[6].

Finally, the wastewater effluent that flows into the sewer system must ultimately be treated in a sewage treatment plant. Although this process occurs far from the residents of most industrialized nations, the economic and social cost of this process must be considered a part of total cost of the disposal option for dealing with human waste. Waste treatment plants utilize additional chemicals and energy intensive processes to eliminate any possible health risks from the wastewater. This involves the land filling, incineration, or, occasionally, composting of the solid sewage solid skimmed from the wastewater. However, this treatment system itself is inherently imperfect as the water ultimately discharged back into the environment is concentrated with higher levels of the same macronutrients found in human waste (as well as detergents and other household waste products) that can cause eutrophication and the depletion of aquatic oxygen downstream[7]. In fact, while millions of tons of artificial phosphorous fertilizers are produced each year, municipal treatment plants are dumping 4 gigagrams of phosphate equivalent nutrients into waterways across the country[8]. Additionally, chlorine, a neurotoxin that can harm aquatic life in even small concentrations, is often added to

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[6] US Wastewater Fact Sheet
[7] Scobber 69
[8] US Wasteater Fact Sheet

wastewater as part of the purification process and can damage bodies of water near sewage outflow pipes.

Furthermore, wastewater treatment plants often serve to move the health risks from human exposure to fecal matter further downstream. In developed nations, many cities have antiquated combined sewer systems that overflow during heavy rains forcing municipalities to dump untreated or minimally treated wastewater into local bodies of water. In fact, 88% of the more than 18,000 days of pollution related closings and advisories in the US were from fecal contamination stemming from overburdened combined sewer systems[9]. In developing nations, half of all people suffer from diseases rooted in contaminated water supplies and poor sanitation, as municipal sewage treatment plants are often absent or inadequate.

II. Direct Application to Agricultural Land

The opposite method for dealing with human excrement, directly applying it to agricultural land, restores the natural cycle and the valuable nutrients to the land. However, the application of raw human waste, or “night soil” as it is known in Asia, to the land does nothing to address the danger fecal matter poses human health.

The use of “night soil” decreases the demand for synthetic fertilizers (now the largest diffuse source of water pollution in the US), while simultaneously mitigating the problem of eutrophication through decreasing the concentration of nutrient rich organic waste in the sewer system effluent. Raw human waste not only provides vital macronutrients and organic material to plants, but also increases the water retention of the

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[9] Jenkins 18

soil. This contrasts dramatically with chemical fertilizers that provide similar nutrients, but lose 25-85% of nitrogen and 15-20% of potassium and phosphorous through leaching[10]. Between 1950 and 1990, global consumption of natural gas based fertilizers rose 1000% to 140 million tons[11]. Meanwhile, the use of “night soil” in the “greenbelt” around Shanghai, China, allowed the city of over 20 million residents to grow a surplus of fruit and vegetables without the purchase or production of any chemical fertilizers[12]. In short, the direct application of “humanure” to agricultural fields provides a cost-effective way to recycle nutrients, avoid the production of artificial fertilizers, and decrease nutrient overload in local bodies of water.

While “night soil” fixes the problems of the modern water-based sewage systems, it fails to address the host of health problems that the toilet was originally introduced to combat. First, the application of raw human waste to agricultural land puts the farmers at risk to viruses and pathogenic bacteria, protozoa, and worms. Second, runoff from “night soil” laden farmland can find its way into groundwater and surface water supplies causing pollution from fecal coliform that poses a threat to humans and other organisms alike. Third, if applied as a fertilizer to food crops, “night soil” can cause the transmission of food-borne enteric disease and hookworm[13]. Thus, while “night soil” enables Shanghai to produce its own fruit and vegetable supply without the use of chemical fertilizers, the produce grown in the surrounding fields is not safe to be eaten raw unless it has a peel.

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[10] Britton 211

[11] Jenkins 21

[12] FAO Report on China

[13] Gotaas 73

III. Anaerobic Composting

Anaerobic composting is the biological degradation of organic matter by microorganisms within waste in the absence of oxygen. Unlike disposing waste or applying it directly to fields as fertilizer, the primary purpose of anaerobic composting is to produce biogas (comprised primarily of methane and carbon dioxide) for use in cooking, heating, or producing electricity. However, the process of anaerobic digestion eliminates the majority of the pathogens within the fecal matter and produces a rich fertilizer along with the gas. The obstacle to the widespread application of anaerobic composting is twofold. First, anaerobic digestion is a far more complex and costly process than flushing waste away or applying it directly to agricultural fields. Second, the effluent is more nutrient rich and pathogen free than “night soil,” but it must be treated further to completely destroy all pathogenic microorganisms[14]. Since the anaerobic digestion process adds cost without fully treating the waste, the economic logic behind the additional work and expense of anaerobic composting depends on whether there is a valuable application for the biogas.

Figure 2.1

Parasite Mortality During Anaerobic Composting

Parasite	Retention Time in Biogas Unit	Mortality Rate (%)
Roundworm eggs	150	80
Paratyphoid B bacili	44	100
Schistomsomes	37	100
Snail	32	100
Hookworm	90	100
Hookworm eggs	30	90
Flat/tape worm	70	99
Dysentary bacillus	30 hours	100

Source: FAO Report on China

Anaerobic composting involves the creation of an oxygen free environment and a feedstock with the appropriate nutrient balance. Human excrement alone will not compost. It must be mixed with carbon-rich organic material, such as waste food or

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[14] Olson, 287

agricultural products. However, once this material is added and an anaerobic environment is created in a bag or drum, the biogas produced from the humanure and food waste of a family can create substantial environmental benefits by displacing firewood use (and the accompanying deforestation) in developing nations. In Vietnam, biogas stoves save 5,500 lbs of fuel wood per family per year roughly $60-120 in annual fuel costs[15]. Furthermore, anaerobic composting is ideal for applications in developing nations where firewood is still widely used for cooking because biogas can lead to dramatic improvements in indoor air quality and, subsequently, health.

While the slurry produced through the anaerobic digestion process must be aerobically composted to destroy all pathogens, anaerobic digestion decreases fecal coliform by 99% and parasite eggs by 95% during a typical retention period[16]. Furthermore, the nitrogen within the human waste is converted into ammonia, which is more readily absorbed by plants, during the anaerobic digestion process. Thus, the sludge remaining after digestion is richer in valuable nutrients than unprocessed animal manure. However, since anaerobic composting alone does not ensure complete pathogen destruction and is not economically viable without considering the biogas production, this is not the appropriate solution for the scalability challenge of composting toilets.

Figure 2.2

Nutrient Gains Through Anaerobic Digestion in China

Site	Nutrient	Retention time in Biogas Unit (days)	Increase in Nutrient Content
Agricultural Institute of Sichuan Province	Ammonia Phosphate	30 30	19.3% 31.8%
Guangdong Province Agricultural Institute	Ammonia	30	147.2%

Source: FAO Report on China

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[15] Mak 5

[16] Haug, 14

IV. Aerobic Composting

Figure 2.3

BENEFITS OF COMPOST

ENRICHES SOIL
- Adds organic material
- Improves fertility and productivity
- Suppresses plant diseases
- Discourages insects
- Increases water retention
- Inoculates soil with beneficial microorganisms
- Reduces or eliminates fertilizer needs
- Moderates soil temperature

PREVENTS POLLUTION
- Reduces methane production in landfills
- Reduces or eliminates organic garbage
- Reduces or eliminates sewage

FIGHTS EXISTING POLLUTION
- Degrades toxic chemicals
- Binds heavy metals
- Cleans contaminated air
- Cleans stormwater runoff

RESTORES LAND
- Aids in reforestation
- Helps restore wildlife habitats
- Helps reclaim mined lands
- Helps restore damaged wetlands
- Helps prevent erosion on flood plains

DESTROYS PATHOGENS
- Can destroy human disease organisms
- Can destroy plant pathogens
- Can destroy livestock pathogens

SAVES MONEY
- Can be used to produce food
- Can eliminate waste disposal costs
- Reduces the need for water, fertilizers, and pesticides
- Can be sold at a profit
- Extends landfill life by diverting materials
- Is a less costly bioremediation technique

Source: US EPA (October 1997). *Compost-New Applications for an Age-Old Technology.* EPA530-F-97-047.
And author's experience.

Aerobic composting is the process of cultivating microorganisms within waste to break down the organic material and pathogenic organisms in the presence of oxygen. Thus, aerobic composting provides a method for dealing with human waste that harnesses the nutrients within the waste to produce a safe and viable agricultural additive.

Two things kill pathogens in compost: temperature and time. Since pathogens have short life spans in soil, compost can be produced at low temperatures if it is left to mature for over a year[17]. This is the method of composting utilized in traditional composting toilets. Alternatively, compost can be prepared thermophilically (at high temperatures) over a shorter period of time by preparing a large enough batch of compost. As they break down organic waste, microorganisms produce heat as a byproduct. In a large compost pile (one

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[17] Beeby 111

cubic yard or greater in volume), there are enough microorganisms to raise the temperature to a high enough level to kill all pathogenic bacteria[18].

While more time-consuming and expensive than disposing of waste via a water-based sewage system or direct application to agricultural fields, the aerobic composting of large batches of human excrement could provide a finished fertilizer potentially valuable enough to cover the added costs of composting. Thus, this paper focuses on aerobic composting as the most viable alternative to modern waste treatment. Of the four principle means of waste management, it is the only method that ensures complete pathogen destruction, while offering the potential to restore the natural nutrient cycle in a way that is both ecologically and socially responsible.

Figure 2.4

Comparison of Pathogen Survival in "Night Soil" Application, Anaerobic Digestion, Slow Composting, and Thermophilic Composting

Pathogen	Night Soil Application	Anaerobic Digestion	Composting Toilet (3 month retention time)	Thermophilic Composting
Enteric viruses	6 months	Over 3 months	Probably eliminated	Killed rapidly at 60 °C
Salmonellae	3 months to 1 year	Several wks	Some survive	Killed in 20 hrs. at 60 °C
Shigellae	Up to 3 months	Few days	Probably eliminated	Killed in 1 hr. at 55 °C, in10 days at 40 °C
E. Coli	Several mos.	Several weeks	Probably eliminated	Killed rapidly above 60 °C
Cholera vibrio	1 week or less	1 or 2 weeks	Probably eliminated	Killed rapidly above 55 °C
Leptospires	Up to 15 days	2 days or less	Eliminated	Killed in 10 min. at 55 °C
Entamoeba histolytica cysts	1 wk or less	3 weeks or less	Eliminated	Killed in 5 min. at 50 °C, in 1 day at 40 °C
Hookworm eggs	20 wks	Survive	May survive	Killed in 5 min. at 50 °C, or 1 hr. at 45 °C
Roundworm eggs	Several years	Many months	Survive	Killed in 2 hrs at 55 °C, 20 hrs. at 50 °C, 200 hrs at 45°C
Schistosome eggs	1 month	1 month	Eliminated	Killed in 1 hr. a 50 °C
Taenia eggs	Over 1 year	Few months	May survive	Killed in 10 min. at 59 °C, over 4 hrs. at 45 °C

Source: Faechem, 115

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[18] Brock 14

Legal Viability of Aerobic Composting of Human Waste

I. History of Legislation

Before investigating the scientific and economic questions surrounding the aerobic composting of human waste, one must first consider the legality of composting human excrement for use on agricultural lands. Ironically, the US Environmental Protection Agency (EPA) established national standards legalizing the use of composted human waste on agricultural lands in 1993 for the benefit of centralized municipal waste treatment systems. Municipalities across the country were struggling with the challenge of disposing thousands of tons of sewage sludge every year and covering the high costs that land filling and incineration imposed on local budgets[19]. The EPA established minimum standards for the application of treated sewage sludge to public lands in order to provide municipalities with a cheap, alternative means of disposing the organic byproducts of wastewater treatment.

These federal regulations, entitled the Standards for the Disposal and Utilization of Sewage Sludge, Part 503 (known as the Part 503 rule), divided treated wastewater into two classes, A and B, based on the level of pathogen destruction attained by the treatment method[20]. Class B wastes are those that are not composted thermophilically, but are subject to a treatment process that "significantly reduces pathogens," generally an extensive retention time prior to sale or distribution for public use. Class B wastes may be applied to "nonpublic contact sites," such as forests and reclamation sites, without any additional monitoring or permitting required; however, application of Class B compost to

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[19] Stauber 2

[20] Guide to Part 503 Rule: Land Application of Biosolids

"public contact sites," such as food-producing agricultural land or public parks, requires plantings or public access to be restricted for lengthy periods between one and three years. On the other hand, Class A thermophilically treated human compost can be applied to all lands without additional permitting or retention requirements as long as they also meet the federal standards for maximum concentration levels of 10 heavy metals sometimes found in municipal wastewater[21]. Although states may set more restrictive standards on the use of humanure for the purpose of protecting human health, the extensive scientific data demonstrating the pathogen destruction attained through themophilic composting has left little legislative variation in regulations applying to class A compost. As a result, thermophilic batch composting is a legally viable means for producing marketable compost from human waste.

II. Marketability of Composted Sewage Sludge

Since thermophilically composted sewage sludge can be applied to agricultural lands under Part 503 rule, the economics would seem to favor the composting of this waste for sale to farmers over the introduction of a private urban waste composting operation to perform the same function. However, there are two major reasons that the sale of composted sewage sludge, euphemistically renamed biosolids by the EPA, is not a sustainable solution to the environmental challenges posed by modern wastewater treatment.

First, while thermophilically composted biosolids are pathogen-free, they can still contain high concentrations of heavy metals introduced into municipal wastewater

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[21] Guide to Part 503 Rule: Land Application of Biosolids

streams by local industry. There is widespread controversy as to whether the government's maximum allowable standards for the ten heavy metals typically found in wastewater are in fact low enough to prevent unsafe bioaccumulation when applied to crop lands. For example, the maximum allowable concentration of cadmium in Denmark is 98% lower than that permitted by the EPA[22]. Furthermore, there have been numerous incidents of toxic concentrations of heavy metals appearing in everything from food crops grown on lands treated with biosolids to milk from cows grazed on similarly fertilized land. As a result, most food-crop farmers refuse to use biosolids on their land, and the market value of composted sewage sludge has fallen to zero in most regions. To make matters worse, the US Fifth Circuit Court of Appeals has mandated the EPA review its biosolids standards in light of the risks posed by the heavy metals[23].

Second, even if class A biosolids were a safe alternative to artificial fertilizers, they still would not single handedly internalize the high external costs of western wastewater treatment. The composting of biosolids does nothing to address the wasted potable water, high greenhouse gas emission, and nutrient loaded "treated" water outflow of modern wastewater treatment. However, the legalization of the application of human excrement compost to public lands for cost minimization reasons incidentally opened the door for truly sustainable upstream thermophilic composting operations.

Preparation of Human Waste for Composting

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[22] Woodbury 3

[23] Stauber 10

This section of the paper establishes the scientific preconditions necessary for aerobic composting. From this groundwork, the ingredients for the batch composting of urban waste streams in the business case study emerge.

I. Moisture

Compost piles require moisture because the microorganisms within the waste need water to sustain life. Thus, fecal matter mixed with paper products alone will not compost, but must be mixed with urine and, sometimes, additional water. An initial moisture content of 65% by mass is advisable because moisture is consumed by the microorganisms and lost to the air by evaporation throughout the composting process[24]. Moisture loss can be as rapid as 20-30% within the first week as the microorganisms in the waste proliferate and the temperature of the pile begins to rise from the excess heat produced by their life processes[25].

Fecal matter itself has a moisture content of 66-80; however, the paper products required to achieve the proper nutrient balance add mass with negligible water content. As a result, urea (moisture content of 93-96%) and water are required to keep the pile sufficiently moist to induce successful composting[26]. Furthermore, moisture not only sustains the microorganisms but also acts as a built-in control for the temperature of a pile. The water in the pile acts as a heat sink regulating the temperature of the pile during the thermophilic phase of composting when there is potential for the pile to overheat and even burst into flames.

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[24] Jenkins 45

[25] Brock 40

[26] Jenkins 121

II. Oxygen

In order to conduct aerobic composting, the organic material must be prepared so that oxygen can reach all corners of the composting heap. There are four widely applied methods for aerating compost. The simplest is the balanced addition of bulky materials to the human excrement. This serves not only to balance the carbon to nitrogen ratio, but form tiny air spaces of trapped oxygen. Backyard composters often take the additional step of poking holes in composting and driving PVC pipes through the pile to ensure avenues for oxygen to travel through the heap. Commercial composters often take the more expensive and thorough route of turning the compost or cycling air through the pile using fans. Both methods aerate the pile, but introduce other issues such as organic matter and moisture losses[27].

Aerating compost keeps the compost pile from acquiring a putrid smell due to the production of hydrogen sulfide and butric, acetic, and valeic acids through anaerobic digestion[28]. If proper aeration is achieved, the microorganisms will simply produce odorless heat and carbon dioxide as a byproduct of their respiration.

III. Nutrient Balance

Carbon is the building block of life for microorganisms, but nitrogen is essential for the building of proteins and subsequently genetic material. As a result, compost must

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[27] Rodale 137

[28] Winbald 39

have a carbon to nitrogen ratio within the range of 20:1 to 35:1 by mass to sustain life. The ideal ratio is 30:1 because microorganisms utilize nearly all of the nitrogen in the compost at this level. In the case of lower C:N ratios, the excess nitrogen is lost to the air in the form of ammonia gas[29]. The problems with losing nitrogen to the air are that ammonia has a very strong odor and the nitrogen lost is a valuable plant nutrient that will not be a part of the finished compost. If the pile contains too much carbon-rich material, the microorganism population within the pile will stop growing once the available nitrogen is consumed. This will prevent the complete composting of the pile and the achievement of thermophilic conditions in batch composts. Thus, the finished product will not be free of pathogens or as nutrient rich as a compost containing the proper C:N balance.

Figure 2.5

Carbon: Nitrogen Ratios of Urban Waste Products

Material	C:N Ratio
Cardboard	400-563 : 1
Fruit	40 : 1
Raw Garbage	15-25 : 1
Humanure	5-10 : 1
Newspaper	398-852 : 1
Paper	100-800 : 1
Telephone Books	772 : 1
Urine	15-18 : 1
Vegetables	20-30 : 1

Source: Jenkins, 34

Humanure contains a C:N ratio in the range of 5-10 parts to 1, while urine's ratio is even lower at 0.8 parts to 1. As a result, human excrement alone is far too nitrogen rich to compost. Fortunately, almost every other organic material, particularly plant products, have very high carbon content. With newspaper, paper, and cardboard all containing C:N ratios over 100, the addition of these waste products in the proper

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[29] Jenkins 59

proportions to human waste should make the achieving of an ideal ratio easy even in an urban area[30].

IV. Temperature

The amount of available nutrients and, subsequently, the multiplication of bacteria, protozoa, and worms themselves determine the temperature of the pile. As long as appropriate moisture content is maintained, there is no risk of the pile overheating.

The Three Stages of Batch Composting

This section establishes the underpinnings for the operations and business timeline of a thermophilic composting operation through analysis of the process of aerobic composting.

I. Mesophilic Phase

When a pile of organic refuse contains enough moisture, oxygen, and the proper balance of carbon and nitrogen, it will begin to compost with mesophilic bacteria (contained within the organic matter, such as e-coli from our intestinal tract) utilizing the nutrients within the matter (carbon and nitrogen) to produce energy for their own reproduction and growth. The bacteria produce CO_2 and heat as byproducts of their life processes[31]. If over one cubic yard of compost is collected, the mesophilic bacteria proliferate and produce enough excess heat to raise the temperature up to 44ºC (111ºF).

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[30] McKay

[31] Rodale, 179

This phase occurs rapidly, typically within 24 hours for a large batch of compost, but requires careful monitoring to ensure that the nutrient balance and moisture content maintain proper levels[32].

II. Thermophilic Phase

The transition to the thermophilic phase occurs between 44-52ºC (111-125.6º F) as thermophilic microorganisms come to dominate the pile. This is the stage during which the pathogenic organisms are killed. While most pathogens will die within 24 hours at a compost temperature above 50ºC (122ºF), a retention period of one week at 46ºC (114.8ºF) is proven to kill all pathogens, even the relatively heat tolerant round worm eggs[33]. Monitoring of the pile must continue through this phase to ensure complete pathogen destruction. A 70% reduction in the mass of the organic material occurs during this phase with only bulky organic material remaining at the end[34].

III. Cooling Phase/Curing Phase

In these final two phases the compost cools and mesophilic bacteria reenter the pile to break down the resistant materials remaining in the compost. Curing occurs over time, ensuring a return to appropriate oxygen and nitrogen balances. This retention time during the curing phase will ensure the breakdown of any remaining pathogens (in case part of the pile did not reach thermophilic conditions). Additionally, this waiting period

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[32] Jenkins 189
[33] Brock 57
[34] Jenkins 193

is important to ensure that the composting process is complete because immature compost can contain organic acids or phytotoxins that would make the compost detrimental to plant life. This phase can take anywhere from 3-6 months[35]. The final product is nutrient rich humus that makes an ideal fertilizer.

While the curing phase is essential to the production of mature compost, it requires little from a labor standpoint. The compost is simply left to sit while the microorganisms complete the breakdown of the waste over time. However, from an operations and budgetary perspective, this phase is perhaps the most important part of the composting process as the waste must occupy valuable factory space for up to 6 months, limiting the amount of new waste that can be taken in by commercial composters.

Three Methods of Aerobic Batch Composting

In the final two sections of this background chapter, the paper surveys the different technological methods for managing the compost on a macro scale. Weighing the costs and benefits of turning and the three established methods for aerobic composting (windrow, aerated static pile, and in-vessel composting), the final piece of operations for the business case study comes into focus.

I. Windrow Composting

Windrow composting is the most common composting method chosen for large-scale operations. In a windrow composting operation, the organic matter is piled in long

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[35] Hau 35

rows, called windrows, generally around 10 feet wide and 6 feet tall at the highest point[36]. The biodegradable material is stacked in rows of this size for two principal reasons. First, with well over a square yard of compost in the cross section of the row, the pile is wide and tall enough for the bacteria to rapidly proliferate and create the thermophilic conditions necessary for complete pathogen destruction. Second, the long, narrow piles enable the compost to be easily accessed by windrow turners, large rakes dragged through the compost alongside tractors, or other machines to mix the pile.

In large batch compost piles such as those existing in windrow operations, there is risk of a "dead zone" forming in the center of the compost. A "dead zone" is an area of cold and inactive compost absent of pathogen or ligin destroying microorganisms. "Dead zones" are formed by the creation of anaerobic pockets in the compost from excessive moisture buildup or insufficient fresh air penetration[37]. Windrow turners are designed to keep "dead zones" from forming in the compost by mixing the pile to ensure aeration of the entire pile.

Not only does turning ensure complete aeration and pathogen destruction throughout the pile, but it has several additional benefits that make windrow composting appealing to commercial composters. First, turning ensures continuous aerobic composting which prevents the odorous byproducts of anaerobic respiration from building up in areas of low oxygen content[38]. This is a major issue for industrial composters as odor minimization is crucial for commercial composters dealing with hundreds of cubic yards of organic waste at a given time. Second, ensuring complete aerobic respiration speeds up the composting process enabling the product to reach the

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[36] Windrow Dynamics
[37] Rynk 77
[38] Windrow Dynamics

market faster. Third, the windrow turner breaks down the compost as it turns it, producing a less bulky, finer grade finished product that farmers can sell for higher prices[39]. On the downside, constant turning adds cost to the composting operation and causes organic matter and nitrogen loss.

II. Aerated Static Pile Composting

Aerated static pile composting is the second most common method of batch processing organic waste. Instead of arranging the compost in rows and turning it to ensure even mixing and aeration, it is piled in a heap and aerated through the addition of bulking materials or perforated pipes[40]. Aerated static pile composting looks to achieve the same ends as windrow composting, marketable compost, through less expensive and labor intensive means. Since there is no turning of the organic refuse, the waste must be thoroughly mixed before it is piled in the heap for composting. Thus, homogeneous waste streams are ideal for aerated static pile composting as they can simply be left to sit in the composting facility without any labor involved in the preparation or composting phases.

Aerated static pile composting utilizes one of three methods to ensure the complete aeration of the pile and complete pathogen destruction: integration of bulking agents, passive piped air ventilation, or forced air piping. In order to ensure aeration at minimal cost, many static pile composters will simply add bulking agents, such as wood chips, straw, or newspaper, throughout the pile to ensure pathways for oxygen to pass to

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[39] Rynk 89
[40] Woodbury 13

the bottom of the pile and carbon dioxide and excess heat to escape from the center of the pile[41]. Bulking agents are larger organic materials that take longer to break down in a compost heap than most organic matter due to the presence of cellulosic ligins that take over 3 months to break down. Thus, these materials maintain their form throughout the thermophilic stage of composting enabling them to hold their bulking role through the most crucial stage of aeration[42]. Often bulking agents are supplemented with pipes to provide air through passive or active means. This network of pipes is generally set up on the floor of the composting facility with the compost piled on top of it. In forced air systems, a motorized blower blows air through the pile providing it with oxygen and keeping the pile cool to prevent overheating. Aerated static piles are often covered with a biofilter, such as finished compost, to treat processed air exiting the pile, remove particulates, and minimize odors emanating from the pile.

III. In-Vessel Composting

In-vessel composting is an adaptation of aerated static pile composting where the waste is actually placed in a large controlled bin. The bin allows for greater control and monitoring of the moisture and air content of the pile with pipes and hoses often delivering air directly to the vessel. Additionally, in-vessel composting is ideal for any composters adding worms or other organisms to the pile to aid the break down of the waste. The bins are generally covered with a biofilter to minimize malodorous air from escaping into the facility.

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[41] Jenkins 113

[42] Palisano 45

While in-vessel composting provides the benefit of greater operational control, it comes at a much higher cost. The upfront cost of the bin with its built-in piping and monitoring devices is significant. However, in-vessel composting is becoming increasingly popular for commercial composters as it allows the careful monitoring of the thermophilic stage of the composting operation. This monitoring is essential for ensuring complete pathogen destruction in short periods of time. In turn, this enables quick turnaround periods and a more time and space efficient operation. Thus, the composter makes up for the additional investment in the in-vessel system through higher revenue streams down the road.

The Costs and Benefits of Turning Compost

Ever since Sir Albert Howard espoused turning in *An Agricultural Testament*, the first book on composting and organic agriculture, in 1943, Americans have been turning the vast majority of their municipal compost[43]. In theory, turning aerates the pile, prevents odorous gases from building up, and speeds the composting process. However, as aerated static pile and in-vessel composting have demonstrated success in recent years, the benefits of turning have come under question.

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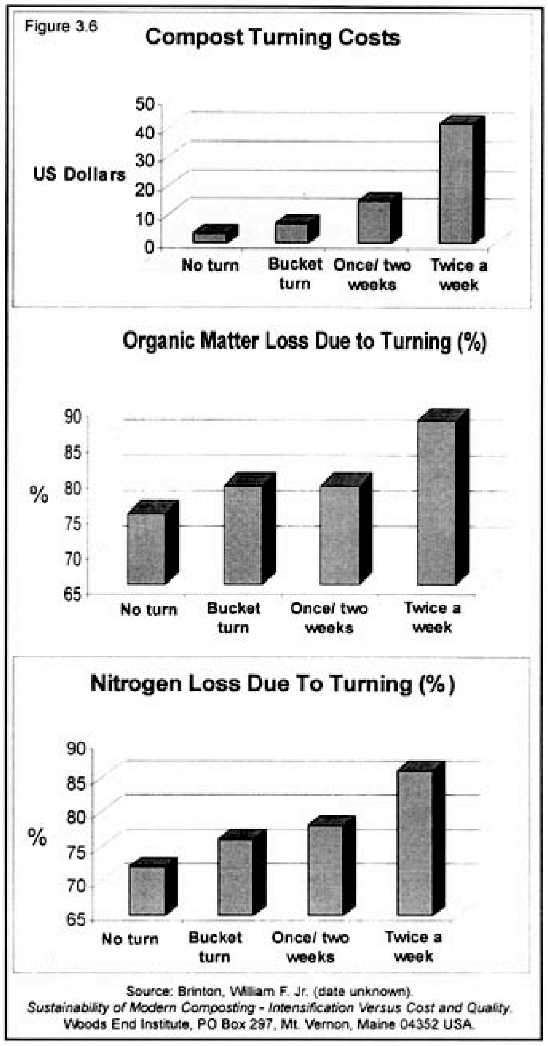
[43] Reyburn 65

Several studies have show that turning has a fleeting effect on oxygen concentrations, as it only increases the oxygen content to 10% for 1.5 hours after which it quickly drops below 5%[44]. Thus, turning has little to no added benefit in terms of aeration over static piles fed air by pipes or filled with bulking agents. At the same time, since turning does little to increase aeration and foster thermophilic microorganisms, it also does little to speed up the batch composting process. Regular turning does prevent the buildup of excessive amounts of odorous gases from the anaerobic process occurring in the heart of the compost pile by regularly releasing small amounts of these gases to the air during the turning process. However, the emissions from this turning, including Asperillus fumigatus fungi, can have hazardous health effects even in small concentrations[45]. By continually aerating the entire pile, static piles have up to 1800 times smaller concentrations of these hazardous microorganisms.

Figure 2.6



Compost Turning Costs

Organic Matter Loss Due to Turning (%)

Nitrogen Loss Due To Turning (%)

Source: Brinton, William F. Jr. (date unknown).
Sustainability of Modern Composting - Intensification Versus Cost and Quality.
Woods End Institute, PO Box 297, Mt. Vernon, Maine 04352 USA.

With the development of alternative means to aerate compost piles putting the three primary benefits of turning in doubt, turning appears destined for anachronism. To make matters clearer, turning not only causes the off-gassing of Asperillus fumigatus

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[44] Jenkins 56
[45] Britton 650

fungi, but the loss of nitrogen, organic matter, and other valuable nutrients as well. Thus, for added costs, turning compost appears to add little benefit except lower setup cost of the composting facility and a finer grade final product.

Summary

Through this introduction, the operations of the business case study begin to take shape. By collecting sufficient quantities of waste, the business will be able to conduct thermophilic aerobic composting and produce finished compost in as little as 3 months. Since cost minimization will be a priority for this commercial operation, in-vessel composting provides the ideal solution for the mesophilic and thermophilic phases of composting, while the compost can simply sit in piles in the warehouse for the remaining months before its sale as a fertilizer.

Chapter 3: Envisioning an Urban Batch Composting Operation

The modern municipal waste treatment system is a cheap, efficient, and effective means of dealing with pathogen risk posed by human feces. However, it comes with a tremendous social cost as valuable nutrients are flushed down the drain, potable water is wasted, and high concentrations of hazardous chemicals are added to our waterways. Aerobic composting of human waste to produce agricultural fertilizer is an alternative means of dealing with human excrement that both captures the nutrients in human excrement, internalizing the costs of waste treatment, and assures complete pathogen destruction, preventing feces from acting as a vector for disease.

While batch aerobic composting of agricultural waste streams has been conducted for decades, the large-scale composting of human waste is not practiced in the western world because pipe-to-plant municipal systems treat wastewater at very low costs. This paper analyzes the potential of one such alternative to municipal waste treatment, a company that conducts in-vessel, batch composting of human excrement with newspaper and other organic urban waste streams. By restoring the natural cycle for waste treatment, this company will be able to capture this nutrient rich waste stream at low cost and turn it into a value-added compost product. Through creation of a business model, economic projections, environmental impact estimates, and external cost calculations, this paper investigates the potential of such a company to provide an innovative and environmentally responsible alternative to traditional, often overburdened waste treatment facilities.

For the purpose of data collection, the Marriott Courtyard hotel is used as the case study for all water and wastewater calculations in this paper. This hotel provides the ideal baseline model, as it is a medium-sized urban structure with 222 toilets. While the business concept envisions the installation of plumbing system in new structures, the data from this existing structure served to underscore the hypothetical business' potential impact. For the purpose of the discussion of the company's manufacturing operations, it is assumed that the company will operate a composting facility to process the waste of one hotel or apartment building of the same size.

Overview of The Company

The company is a two-part commercial composting business with two principal revenue streams. First, the company will design and contract out plumbing for new medium-sized hotels and apartment buildings (approximately 200 toilets). The plumbing will separate the blackwater (pathogen containing toilet water) from greywater (water from sinks, dishwasher, and showers). The blackwater, the raw material for composting, will flow into a collection basin in the basement of the building where it will be picked up every two weeks by the company for transfer to an offsite composting factory -- thereby solving the scalability issue of composting toilet systems that currently cannot handle the volume of waste produced by a high-density building. The greywater will be diverted into a collection tank where it will be used for irrigation of the surrounding landscape in order to save the building owner even more water. Excess greywater will flow back into the municipal sewer system through an emergency diversion pipe. The low flow toilets coupled with the greywater system internalize the water waste in the current system.

The company will then enter into a contract with the apartment or hotel owner to become the building's wastewater treatment provider. Currently, water and wastewater are charged to residences on a single bill. Thus, for simplicity reasons and in order to capitalize on the water savings from the composting toilet and greywater systems (and recoup the upfront investment), the company will charge the hotel or apartment owner a set monthly amount for both water and wastewater bills, and then pay the municipality for the remaining water and wastewater services they will still provide the building (i.e. pay the building's water/wastewater bill).

The second part of the business is the production and sale of compost produced from a combination of human waste and newspaper. After collecting the nitrogen-rich sewage from the apartment buildings or hotels, it will be transported off-site to the composting factory where it will be mixed with carbon-rich newspaper purchased from a recycling company to produce high quality compost. Since microorganisms within the organic matter break down the sewage into a fertilizer over the course of a 3 month period, the composting process is time consuming, but not labor intensive. The company will then sell the finished compost to wholesalers for $45/cubic yard, the average price for high quality compost produced from animal waste[46]. Since the business is paying a low price for one composting input (the newspaper), actually profiting on the other input (the human waste), and paying very little for manual labor (the wages of the two

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[46] Alexander 2

employees plus those of the septic truck driver), the compost revenues exceed the cost of production and the business will be able to sustain operations.

Description of Product and Services

The company seeks to bring the benefits of composting to a larger market in a way that mainstream developers will adopt. The problem with many sustainable designs is that they require a larger investment up front, which developers are either unable or unwilling to make. The upfront investment pays for itself many times over in saved operating costs, but in many cases the developer is not the same as the company that will be operating the building, so they are not in the best position to make investment decisions based on life-cycle costs.

This business concept is based on a solution to this problem found by Green Bay, Wisconsin, based Solar Mining Company, formerly Packerland Solar. Solar Mining Company sells solar hot water systems to replace the traditional natural gas burning hot water heaters. The systems have a payback period relative to natural gas systems of roughly 10 years, depending on the location, but many businesses are either unaware of the benefits of solar hot water or do not wish to make the large initial investment. Solar Mining Company's solution is to offer systems to businesses at little or no additional cost and then collect the hot water savings to profit over time. They collect these savings by becoming the business' hot water utility and charging the business slightly less than what they would be paying for natural gas hot water[47]. In this way, Solar Mining Company recoups their initial investment over the lifetime of the system.

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[47] Solar Mining Company

Figure 3.1

Water/Wastewater Bill	Cost per Month
Total Water/Wastewater Bill for Courtyard Building	$4,623.49
5% of Total Water/Wastewater Bill for Average Building	$231.17
Amount Business Will Charge Building for Water/Wastewater Treatment (95% of Water/Wastewater Bill for Average Building)	$4,392.31
Total Water/Wastewater Bill for Case Study Building (Amount Business Will Have to Pay to Municipality)	$0.00
Business Revenue from Water/Wastewater Charges Per Building	$4,392.31
Business Revenue per Unit	**$19.79**

The case study business will utilize a similar approach for composting toilets. The core of the business is this: the company will install a composting toilet system for $1,000 less than a regular plumbing system. The company will then enter into a contract with the apartment or hotel owner to replace the municipality as the sewage treatment provider. The company will charge the residents slightly less than they would otherwise be paying on their water/wastewater bill (5% less than the average of similar sized buildings in the same city). Instead of spending money to treat the sewage using traditional methods, the company will truck the waste to the offsite facility where the company will turn the sewage into marketable compost. The company will recoup the initial investment through the sewage treatment fees charged and the long-term water savings the composting toilet and greywater systems create, as well as the profits from selling the compost. With this additional source of income, the company will be able to underbid traditional plumbers for the installation of the system.

In addition, in order to achieve the proper carbon to nitrogen ratio for composting the human feces, the company must add other carbon rich materials to the nitrogen rich human waste. The company will purchase paper in bulk from a local recycling company to serve this purpose. Newspaper not only will provide the carbon necessary for successful composting, but double as a bulking agent to ensure adequate aeration throughout the compost pile. While this input for the composting process will cost the company money, used paper has a very low market value so it will not comprise a large portion of total costs (see Appendix A). If the business expands to multiple factories, the company can collect paper from local office buildings itself. The company would pick up the paper for a small fee, just large enough to cover the transportation of the paper. Since recycling and trash removal services are included in the rent in many offices, the company would deal with the building owners.

Operations

In terms of operations, the business can be divided into two parts: The plumbing installation and hotel operation portion that deals with developers and hotel owners and the composting department that produces the compost and sells it to wholesalers.

I. Plumbing Installation and Hotel Operation

Although the company will market itself as a plumbing installation company, the company will subcontract the actual plumbing system installation. The company will use commercially available composting toilets and plumbing components and hire traditional plumbers, who will work with the building engineers to design a plumbing system unique to each building. The toilets the company uses will be as close to traditional toilets in appearance and operation as possible to avoid alienating customers and making adoption more difficult.

The legality of composting toilets varies from state to state; however, nearly ever state has legalized some form of composting toilet. Furthermore, there is a track record of individuals (including the operators of the Apeiron Institute outside Providence, Rhode Island) successfully appealing for liberalized greywater and composting toilet statutes. Since the business' composting toilet system is based on existing, approved technology, the business anticipates no difficulty in taking the necessary legal steps to ensure that its system is legalized in the applicable states.

The plumbing system will consist of three parts. The water supply system will be the same as in traditional buildings. The waste system, however, will be divided into two parts, in order to separate the "blackwater" from the toilets from the "greywater" from the showers, sinks and washing machines. The greywater will drain into a greywater filtration system where solid particles and soap film will separate out from the water, which will flow into a holding tank outside the building, used later for irrigation. The "blackwater" from the composting toilets will travel in straight vertical pipes into a holding tank in the basement, which will have a retrieval pipe connected to an exterior wall (see Appendix H).

As a result of the significant amount of plumbing work required to separate the blackwater and greywater, the business will initially focus operations on new buildings. With larger holding tanks or increased installation costs, the business could eventually expand into retrofits; however, these will add significant costs to the business' plumbing system and make marketing the systems more difficult and dependent on less tangible "green" image benefits.

The basement holding tank will be large enough for two weeks of sewage plus excess capacity. Every two weeks, a septic truck will collect the waste. The company will again subcontract the transportation, paying the driver per collection. The waste is then taken to the nearby offsite composting facility. As show in Appendix H, the odor of these holding tanks will be controlled by a fan aerating the sitting excrement and venting its smell into emergency connection pipe to the municipal sewer system.

II. Composting Business

The second product is high quality compost for use in gardens and agriculture. The details of how composting works have already been covered in the first chapter, and the details of operations will be discussed in the Manufacturing section.

The product itself is high nutrient compost for flowers, shrubs, trees, and agricultural crops. The compost is especially valuable for organic farms, because its nitrogen content is greater than that of many animal based fertilizers as a result of the large amount of urine utilized. Thus, it can replace the natural gas based nitrogen fertilizers that are used in conventional agriculture in order to maximize plant yield. The humanure compost will meet FDA organic standards because it is comprised of over 40% organic matter[48]. As a result, the business will price its compost at $45 per cubic yard, the average price for high end, organic fertilizer. Even for traditional farmers, the compost can replace both the fertilizer and the peat soil conditioner, so the compost can end up being cheaper when both material and labor costs are considered.

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[48] Rynk 15

Manufacturing

The manufacturing process consists of four distinct steps. First, the waste must be collected from the hotel, and then it is transferred to the large composting tank (the primary reactor) where it undergoes the first two steps of composting. Along with the waste, many times its weight in newspaper must be added to increase the C:N ratio to the requisite 20:1. After that the compost (waste and newspaper) is piled on the concrete floor for cooling/curing phase that occurs over the course of 3 months. Finally, the finished compost must be loaded for shipment to the wholesaler.

I. Collection

In order to produce compost, two things need to be collected: the waste and the newspaper. The company will hire third-party owner-operators to collect the waste. A business that specializes in waste collection for recycling will collect the newspaper and sell it to the company in bulk.

The septic truck driver will collect the waste every two weeks. He or she will start with an empty septic truck with a capacity of around 10,000 gallons. The driver will go to the first building, where he will hook up the truck's hose to the proper connector on the outside of the building, close to the street. The holding tank will be connected to this mounting point by a fixed pipe that reaches to the bottom of the tank. The driver will pump out the tank, about 8,500 gallons worth (see Appendix F).

The paper recycling company will deliver approximately 77,000 lbs of paper per week, or approximately 3% of Providence's total paper recycling (see Appendix J). If the company adds hotels or apartment buildings to its operation, the number of paper deliveries and septic truck trips per week will increase, one per building.

II. Transfer of Waste

When the septic truck gets to the facility, it will drive up to the loading dock, where there will be a hose ready to hook up. The company will have a large pump inside the facility that will quickly drain the truck, pumping the waste directly into one of the large primary reactors. Only one reactor will be needed initially, but, as the company expands, it will have to acquire an additional reactor for each two new buildings.

III. Addition of Paper

For every pound of waste delivered, roughly three pounds of newspaper need to be added to balance the carbon to nitrogen ratio. Using a front loader, the driver will move the paper from the back of the truck into the shredder. The shredder is an automatic industrial conveyor-belt fed paper shredder. It is set up to dump the shredded paper directly onto the vertical conveyor, which will deposit it in one of the paper holding tanks above each of the primary reactors. The newspaper is held there until it is needed for the next batch of compost. When the waste truck arrives and begins pumping its contents into the reactor, the paper is released at a rate corresponding to the rate of waste, to ensure that the waste and paper are consistently mixed (see Appendix G).

IV. First Stage of Composting in Primary In-Vessel Reactor

For the purposes of this company, in-vessel composting will be utilized for the first two weeks of the reaction, followed by simple static pile composting for the cooling/curing phase utilizing newspaper as the bulking agent to ensure sufficient airflow throughout the pile. Since the compost contains a homogeneous mixture and turning is expensive and nutrient depleting, the company will avoid the windrow method.

The first stage of composting is conducted in a bin reactor to ensure the complete mixing of the paper and human excrement, as well as enable the easy monitoring of the temperature, oxygen content, and pH of the pile during the sensitive first two weeks of composting. Once the organic refuse is added to the bin and the moisture content is at the appropriate level, the bacteria already present in the humanure begin to digest the waste immediately. While the compost should not be malodorous once the nutrient levels are balanced through the addition of carbon rich material, a "cap" of newspaper will be added to the top of the pile to contain any remaining smell. The first 24 hours of composting involve mesophilic bacteria. The temperature slowly rises over the first 24 hours until the pile is hot enough that thermophilic phase can begin. The vessel will have a number of perforated pipes throughout its bottom to ensure adequate airflow to foster the thrermophilic organisms and ensure that the pile temperature does not rise to too high a level to sustain the life of the nonpathogenic microorgamisms.

The thermophilic stage takes place at around 111ºF over the course of a week. The only action needed on the company's part during this stage is monitoring. The temperature will be monitored continuously to ensure that the reactor stays above a critical threshold of 114.8 ºF for the entire week to guarantee that all the pathogens are killed[49]. This extensive pathogen monitoring is the principal reason this phase of the reaction is conducted via the more expensive in-vessel method rather than the static pile method. Additionally, any remaining liquid leachate will be contained within the vessel for use in the subsequent batch of compost. By recycling the leachate, the valuable nutrients in the liquid are turned into a commercial product while averting the legal issues surrounding the disposal of this waste.

V. Second Stage of Composting on Factory Floor

After the compost has digested for two weeks under thermophilic conditions, it is ready to be moved into a pile on the factory floor for the cooling/curing stage of the composting process. The compost is emptied onto the concrete floor and pushed into place using a front loader. Since the compost has a high content of bulky materials due to the addition of the newspaper, the piles should not require additional aeration pipes[50]. In fact, with the pathogens already completely eliminated from the compost, the compost requires little attention at all for the next 3 months while the microorganisms break down the cellulosic material to create rich humus.

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[49] Jenkins 215
[50] Cornell Waste Management Institute

VI. Shipping Finished Compost

After three months curing on the factory floor, the compost is finished. All that needs to be done now is load the compost into the wholesalers' trucks to be shipped away. This will be done easily with the front loaders. After the 3 months waiting for the first shipment, new shipments go out every two weeks as the batches of compost come into the factory to begin composting in the in-vessel stage every two weeks.

Summary

By batch composting human waste with newspaper, the business can process over 40,000 lbs of organic waste per month in its 7,000 ft^2 factory. Through the collection of sufficient quantities of excrement to perform thermophilic composting and the offsite production and sale of organic compost, the business at once performs the functions of modern wastewater treatment plants and fertilizer production plants by transforming unwanted urban waste streams into nutrient rich humus.

Chapter 4: An Analysis of the Economic and Environmental Impact of the Business

While this case study may sound interesting as a theoretical exercise, the important issue is whether it is feasible in the real world. In particular, the environmental impact and economic viability of the business must be analyzed to determine whether the aerobic batch composting of urban waste streams could provide a sustainable alternative to modern municipal waste treatment.

Environmental Impact

This chapter begins with an analysis of the potential environmental impact of the business. The entire motivation for creating a scalable human composting operation is to restore the natural nutrient cycle and enable nutrient rich humanure to return to agricultural lands free of heavy metals with minimal external costs from wasted potable water, greenhouse gas emissions, or water pollution. The business makes a positive environmental impact through the reduction in water consumption, natural gas based fertilizer use, and the flow of wastewater to overburdened and polluting municipal systems.

I. Water Savings

Although the business still utilizes potable water as the medium to transport human excrement from the toilet to the blackwater holding tank, the system uses only 0.125 gallons per flush as a result of only needing to transport the water down vertical pipes to the basement of the building. Furthermore, the separation of blackwater and greywater in the hotel enables greywater recycling, which provides significant water savings beyond the scope of the pure waste treatment system. As a result, the business saves 240,000 gallons of water per month relative to a baseline 222 toilet building with conventional toilets and no greywater system[51]. Although this is a mere 0.0002% of US monthly water consumption, that amount is more significant when you consider it is the water savings from revamping the sewage system in a single urban building. If the business were scaled to service a number of high density structures, the impact on water consumption could quickly rise to a nationally statistically significant percentage.

Figure 4.1

Toilet Technology Displaced	Toilet Water Savings (gal/month)	Greywater Savings (gal/month)	Total Water Savings (gal/month)
Low Flush Toilet (1.25 gal/flush)	43,000	43,000	**86,000**
Conventional Toilet (3.5 gal/flush)	200,000	43,000	**243,000**

II. Fertilizer Savings

While compost, particularly humanure, contains significant quantity of nitrogen, the most important macronutrient for plant growth, natural gas based fertilizers contain far higher concentrations and provide a better "quick nutrient fix" to stimulate plant growth.

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[51] Faechem 29

At the same time, compost serves many other beneficial functions by serving as a soil conditioner, suppressing plant diseases, increasing water retention of the soil, and providing potassium and phosphorous. Yet, the soil amendments can be compared because compost can displace or even eliminate the need for artificial nitrogen fertilizers. However, as a result of their different properties and benefits, the grounds for comparison must be chosen carefully.

Since compost is a solid nitrogen rich product, the most similar artificial fertilizer on the market is slow release nitrogen fertilizer. Slow release fertilizers are simply traditional nitrogen rich fertilizers, such as urea and ammonia nitrate, that are pelletized, chemically altered, or coated to make them less water soluble and to minimize leaching and maximize efficient nutrient distribution over time. While compost is a clearer substitute for slow release nitrogen based artificial fertilizers, the amendments still have different nutrient compositions and, thus, must be applied to crops at different rates to achieve the same desired effects in terms of increased yield. This paper normalizes all fertilizer comparisons by putting them in terms of the amount of nitrogen nutrients are delivered to the plants. While the compost contains potassium and phosphorous not found in equivalent artificial nitrogen fertilizers, these nutrients are not factored into this analysis to provide conservative estimates of the environmental benefits of the business (See Appendix I).

In order to quantify the impact of the business in terms of fertilizer savings, one must first calculate the amount of waste processed by the composting business each month. Considering the 0.5 lb of feces and 2 lb of urine produced per person per day on average coupled with the 23 lb of newspaper necessary to balance the carbon to nitrogen ratio of waste from a single person, the 222 toilet Marriott Courtyard will produce approximately 413,000 lbs of organic composting material per month. After the 70% mass reduction that occurs over the 3 month long composting process, the business will be left with approximately 120,000 lbs of finished compost, or 268 cubic yards (see Appendix F).

Figure 4.2

Source	Fertilizer Produced (lb/month)	Weight of Nitrogen Provided to Plants (lbs/month)
Compost Production from Courtyard	123,870	**6,051**
United States Fertilizer Production	19,095,751,440	**1,131,418,834**

Next, the amount of nitrogen in each cubic yard of compost must be calculated. By summing the amount of nitrogen in the feces, urine, and newspaper composing the compost and multiplying by the appropriate factor, each cubic yard of compost was found to contain 22 lb of nitrogen (see Appendix L). Each year, the business produces approximately 73,000 lbs of nitrogen within its 3,200 cubic yards of compost. The impact this production makes in the national nitrogen fertilizer market is on the same order of magnitude as that produced by the water savings as 19 billion lbs of artificial nitrogen fertilizer are consumed each year[52]. Slow release fertilizers only account for 3.67% of total fertilizer output, and 30% of quick release artificial fertilizer are lost to leaching after application to agricultural lands[53]. Thus, only 13.5 billion lbs of this nitrogen reaches crops as useable nutrients giving the business' compost a theoretical 0.00005% market share of the nitrogen fertilizer market[54].

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[52] Helikson 13
[53] Jacobson 2
[54] Walters 21

Figure 4.3

Plant Size	Courtyard-Scale Factory (7,000 ft^2)	Providence-Scale Factory (535,000 ft^2)
Natural Gas Saved (lbs/year)	68,129	5,205,047
CO_2 Emissions Reduction (lbs/year)	1,108,464	84,686,671
Gallons of Gas Equivalent in CO_2 Emission Reduction	56,554	4,320,749

However, the environmental impact of these 73,000 lbs of nitrogen in displacing slow release nitrogen fertilizer is significant. As seen in the chart above, this represents a savings of nearly 70,000 lbs in natural gas (the feedstock from which artificial fertilizer is derived) and a reduction of over one million tons of CO_2 emissions. These emissions are not part of a carbon neutral natural cycle, such as the CO_2 emissions that result from the breakdown of organic waste (that once sequestered atmospheric CO_2) in aerobic compost, but rather stem from the mining and transport of natural gas and its transformation into ammonia by the energy-intensive Born-Haber process. Overall, the displacement of 73,000 lbs of artificial nitrogen per year by compost produced from a single Courtyard would be the equivalent of reducing gasoline consumption by 56,000 lbs per year, and this environmental impact assessment does not account for the minimal nutrient leaching from compost do to its outstanding moisture retention and the subsequent reduction in eutrophication.

III. Wastewater Savings

The final metric for assessing the environmental impact of the thermophilic composting operation is the impact it makes in terms of the reduction in wastewater load faced by the municipal waste treatment provider. If all goes according to plan, the business should divert all of the 530,000 gallons of wastewater from the cities sewers. In the short term, this wastewater reduction will have a small environmental impact as the city's pumping system and wastewater treatment plant will continue business as usual in the absence of a single building from the grid. It will only contribute to a marginal reduction in chemicals used to treat the wastewater and nutrients being discharged into the environment as "treated" wastewater.

Figure 4.4

Source	Wastewater (gallons/month)
Wastewater Averted from Courtyard	**526,898**
Wastewater Processed in Providence	**40,230,000**

However, these 530,000 gallons represent a significant 1% of the 40 million gallons of wastewater treated in Providence each month. Thus, if the business could secure the physical and financial resources to scale its operations (a substantial, yet reasonable 535,000 square feet would be needed to treat all of Providence's wastewater under the current business model), it could treat all, or a significant portion, of a city's wastewater. This would allow a minimization of centralized treatment plant capacity, wastewater collection infrastructure, and all of their associated energy emissions. Furthermore, a scaled aerobic composting facility would produce major decreases in the negative water pollution externalities created by the current system.

IV. Negative Environmental Impacts

While the business makes a postivie environmental impact directly through its reduction in water consumption and wastewater flow and indirectly through its decrease in the CO_2 emissions from fertilizer production, the business is not without its own environmentally damaging practices. In addition to the unaccounted for emissions from the embodied energy in the plumbing and factory construction materials, the business produces CO_2 through its operations as a decentralized ground transportation based waste treatment venture. The business produces CO_2 emissions from its collection of paper and waste.

Figure 4.5

CO_2 Emissions from Waste Transport (lb/yd^3)	CO_2 Emissions from Paper Collection (lb/yd^3)	Total CO_2 Emissions (lb/yd^3)	Cost of CO_2 Emissions per Lb	**Social Cost per Yd^3 of Compost**
0.18	41.54	41.72	0.006	**$0.25**

As shown in Figure 4.5, the emissions from the collection of human waste from the Courtyard are less than 1 lb per cubic yard of compost produced. This is because the septic truck only has to make trips for waste collection once every two weeks. On the other hand, the paper collection operation conducted by the recycling company is a more emissions intensive operation because it involves weekly collection from a number of houses. To make cubic yard of compost, the paper equivalent of 9 newspapers per day must be collected. In total, the monthly emissions from transporting the raw materials to the compost factory are only 11,000 lbs of CO_2, or approximately 1% of the total offset through reduced fertilizer demand. At a $12 price per ton of CO_2, these external costs amount to an insignificant \$0.25/yd^3 of compost relative to its \$45 /yd^3 sales price.

Economic Viability

In order to determine the economic viability of the business, one must answer three questions. First, does the acquisition of the inputs into the composting process (humanure and newspaper) at minimal cost allow the business to compete on a pure cost basis with existing slow release nitrogen fertilizer companies as conjectured? Second, will the business generate sufficient revenue streams to cover the added plumbing and trucking costs of this decentralized upstream waste management system? Third, will the business generate sufficient returns to generate investment in spite of its high risk as a manufacturing startup competing with an entrenched government subsidized system? Supplemented by extensive financial projections for the business case study detailed in the appendices, this chapter answers these questions and, in turn, demonstrates that the thermophilic batch composting of urban waste streams is a sustainable solution to the waste management problem, not a mere pipe dream.

I. Cost Comparison of Human Waste Compost and Slow Release Nitrogen Fertilizers

In general, compost struggles to compete on a cost per nutrient basis with artificial fertilizers. Of course, compost has numerous additional benefits, including its addition of organic matter to the soil, increase in water retention, and ability to prevent disease, that provide it with a substantial market niche. However, in order for the business to serve as a scalable waste treatment alternative, its humanure waste compost must offer the potential to capture a significant portion of artificial nitrogen fertilizers market. To do so, the business' compost must first compete with artificial fertilizers on a pure cost per nutrient basis. The business offers this potential as it acquires the primary input into its composting operation, human excrement, at a profit.

In order to compare the production cost of compost with that of artificial fertilizers, this paper once again normalizes the comparison by focusing on the nitrogen within the compost since it is the primary macronutrient of concern. The market value for wholesale slow release nitrogen fertilizers is between $0.65 and $0.80 per lb of nitrogen[55].

To determine whether the cost of producing the nitrogen within the compost falls within that range, the marginal cost of producing a cubic yard of compost must be determined. With an estimated three quarters of the business dedicated to the composting component of operations, there are significant salary costs and taxes (over $24 in total) associated with the production of a cubic yard of compost (see Appendix L). Furthermore, while the human waste is attained at a profit, the newspaper, trucking, and rent factory add costs that runs the total marginal cost up to $41 per cubic yard. The next step in the calculations is not simply to divide by the 23 lb of nitrogen found in each cubic yard of compost, but first to add the marginal value in the cubic yard of compost that is not incorporated in the value of the nitrogen itself.

Figure 4.6
Marginal Cost of Producing yd^3 of Compost
(Excludes Marketing Costs)

Truck Cost	($1.12)
Newspaper Cost	($6.73)
Factory Rent	($8.63)
Portion of Salary Dedicated to Production (75%)	($22.43)
Portion of Payroll Taxes Dedicated to Production (75%)	($1.90)
Total Marginal Cost ($/yd^3)	**($40.81)**

Figure 4.7
Marginal Value in yd^3 of Compost
(Not Including Value of Nitrogen)

Value Added to yd^3 of Compost by Phosphorous and Potassium Macronutrients	**$6.27**
Weight of Phosphorous in Compost (lb P/yd^3)	4.97
Value of Phosphorous in Compost ($/yd^3)	$5.29
Weight of Potassium in Compost (lb P/yd^3)	4.23
Value of Potassium in Compost ($/yd^3)	$0.99
Value Added by Wastewater Fee ($/yd3 of Compost)	**$16.42**
Total Value Added by Other Macronutrients and Fees	**$22.69**

Thus, the $17 in wastewater fees per cubic yard and $6 added by the wholsesale value of the potassium and phosphorous nutrients contained

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[55] Harvesting Energy with Fertilizers

within the finished compost are subtracted from the $41 in production costs to find the cost of producing the nitrogen in the compost. This value of $18 is then divided by the 23 lb of nitrogen per cubic yard to give the cost of one lb of nitrogen in the compost, $0.80. Thus, the business' compost falls within the high end of the range of market values for wholesale slow release nitrogen, and the assumption that the acquisition of one of the nutrient inputs at a profit can make the business competitive with artificial fertilizer companies in spite of their externalized costs is proved reasonable.

II. Financial Sustainability of the Business Operations

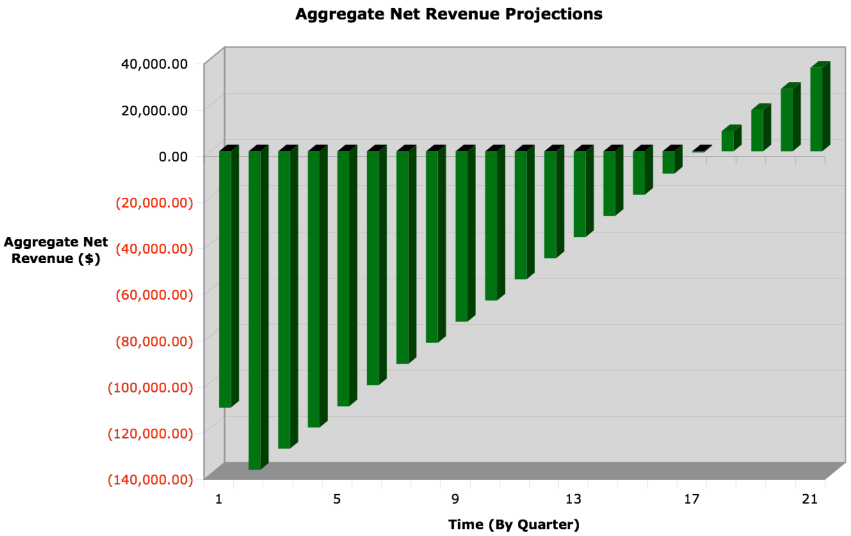
Given that the business' final product will be able to compete with the artificial fertilizers it seeks to displace, the next economic question to be addressed is whether the business can generate a profit and sustain operations in the long-term. A profitable operation is certainly no guarantee as the business replaces a subsidized pipe-to-plant municipal operation with a decentralized septic truck based business. However, as shown in the financial projections, the business is able generate profits of over $3000 per month beginning in the second quarter when the revenue from the composting operation begins to accrue.

The business has far higher upfront waste collection costs than the municipal provider because to add a building to its system it must add plumbing to the existing structure to separate the grey and the black water, a greywater treatment system, and the blackwater holding tank. Meanwhile, the municipality must simply add an average of 16 feet of pipe to bring a new building into its network at a cost of $59. Furthermore, the variable collection costs of municipal treatment are lower as well because it uses pipes and pumps to deliver the wastewater to the treatment plant while the business uses a septic truck and manual labor.

Yet, here are two primary reasons that the business is able to produce positive net revenue streams while only charging 95% of the water/wastewater bill of the municipal provider. First, the business is able to sell its finished product at $45 per cubic yard of compost; whereas, the municipality dumps effluent into waterways and pays to dispose of its sewage sludge or gives it away at cost as "composted biosolids." Second, in the composting process, unlike municipal waste treatment, the biology does the work. In other words, the microorganisms already present within the human excrement break down the organic matter while the two members of the staff simply oversee operations and the movement of the compost from the thermophilic composting vessel the floor of the factory for the cooling/curing phase. The simplicity of this operation keeps both personnel and technical costs much lower than their counterparts in complex waste treatment operations. When considering these two factors, the business is able to generate sufficient profits to stay afloat in the public service dominated waste management sector.

Furthermore, this analysis does not consider the fact that the business could likely charge apartment owners even more for wastewater treatment than it is in its current business model. Surveys have shown that the average American is willing to pay up to 15% more for "green" products. Thus, rather than charging 95% of the water/wastewater bill of an average apartment building, the business could likely charge over 100% once it successfully begins operating a few buildings and has concrete data to back up its cost internalization claims. A "green" marketing strategy will increase the net revenue projections shown in figure 4.8 and provide greater financial stability to the business in future quarters.

Figure 4.8

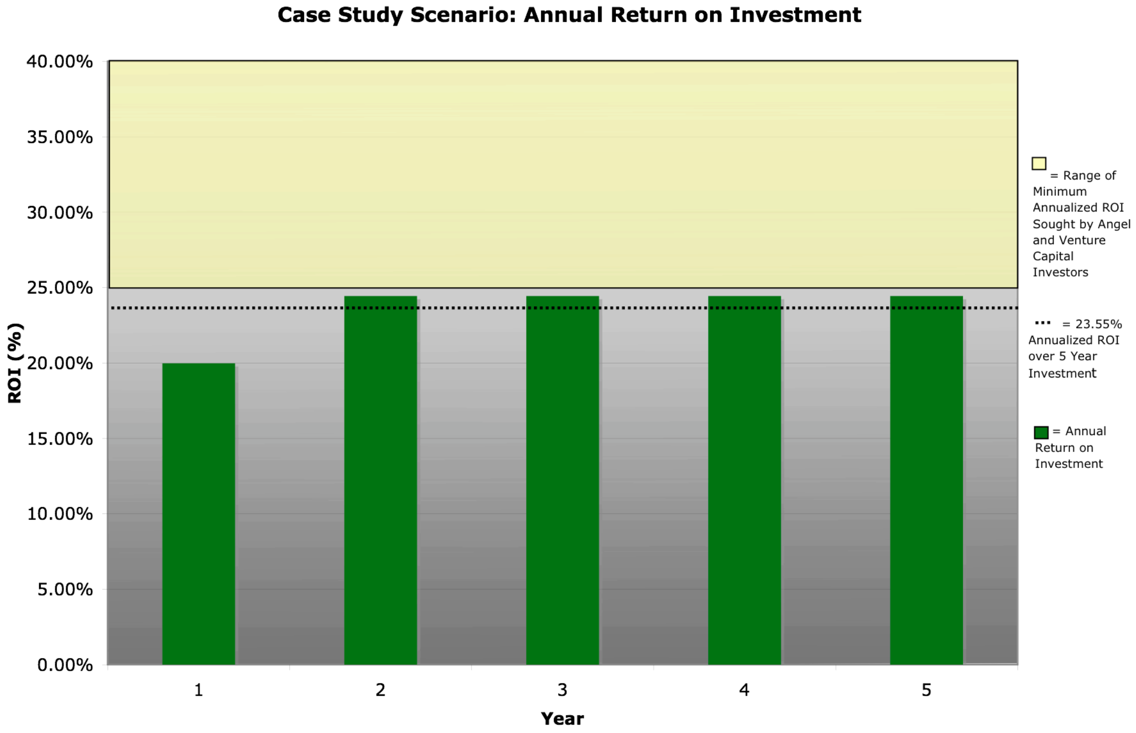


III. Capital Financing

A common misperception about businesses is that if they can generate a profit then they will make a successful venture. A prospective business will fail to generate the funds necessary for its launch as well as any additional capital financing needed to sustain operations if its returns are not commensurate with its perceived risk. In this case, the business generates a modest $36,664 in projected profit per year beginning in year 2, while requiring an initial capital infusion of $150,000 to cover startup costs, initial capital costs, and first quarter losses caused by the time lag before the receipt of the first compost revenue streams (see Appendix B).

In order to answer the question of whether the return is commensurate with the risk, the return on equity (ROE) must be analyzed through the first five years of operations. For simplicity, the financial statements assume the entire $150,000 in startup costs will be covered by private equity investment from management, angel investors, and venture capitalists. As shown in the diagram below, the business produces nearly a 20% ROE in year 1 followed by a nearly 25% ROE in years 2-5 for an annualized ROE of 23.55%.

Figure 4.9



Since angel investors and venture capitalists generally tend to look at investments over a 5 year time frame, this 23.55% ROE is the important number to consider[56]. In general, investors in startups seek a ROE of at least 25%-40% depending on the investor and type of business. The required ROE is so high because the majority of startups fail,

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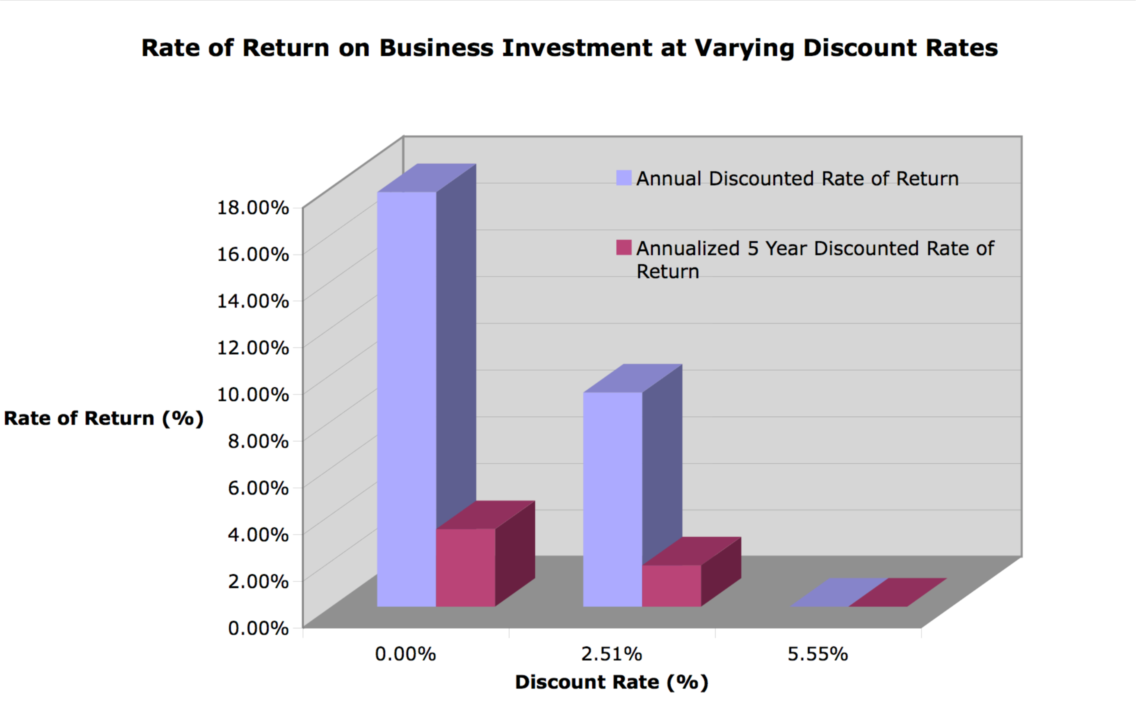
[56] Investment Philosophy

and, thus, the prospective businesses must offer tremendous growth potential and high expected returns to make an overall portfolio of startup investment successful. With a ROE of 23.55%, the aerobic batch composting operation will likely struggle to gain investment particularly because the risk of the operation is very high as it is attempting to operate into two markets simultaneous, including one dominated by a subsidized state operation. Thus, even though the business appears to offer the potential to be a sustainable and socially positive operation from a day-to-day perspective, it will struggle to generate the funds necessary to reach the point where it can generate positive net revenues.

Figure 4.10



An alternative way of considering the investment issue is to investigate why municipalities themselves have not invested in similar upstream composting operations.

Analyzing the business as an internal investment project with an initial capital outflow of \$150,000 and annual cash flows equal to the return on equity, the project generates a non-discounted 17.76% return on investment or a 3.32% five year annualized return. Discounting these future cash flows at the low current risk free rate of 2.5%, the returns diminish to 9.17% and 1.77% respectively. This 1.77% return on investment discounted at the risk free rate of return is equal to the risk premium of the business as an internal investment. In other words, this is the additional financial benefit the project offers per year over the risk free rate that could be earned by investing in 5 year US treasury bonds[57]. Clearly, a risk premium of 1.77% is not commensurate with the tremendous amount of risk inherent in funding such a project, especially when the fact that the stock of Fortune 500 firm's typically demands approximately a 5% risk premium.

Summary

The potential of the business to internalize the negative externalities of modern wastewater treatment is sufficient to warrant attempting the large-scale thermophilic composting of human waste from an environmental perspective. Furthermore, the economic analysis reveals that the business will generate enough revenue to cover its costs. However, the principal obstacle for the future of commercial urban composting is the ability of prospective companies to raise funds as their risk is not commensurate with their economic returns. Thus, the subsequent chapter investigates four possible scenarios that could lead to the financing of thermophilic composting operations and, ultimately, the attainment of their substantial social returns.

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[57] Daily Treasury Yield Curves

Chapter 5: An Analysis of the Case Study in Four Alternative Economic Environments

Following the environmental and economic analysis of Chapter 4, it is clear that the business has the potential to provide a scalable and financially sustainable solution to the waste treatment problem. In the case study scenario, the private sector alone will be reluctant to attempt a human waste composting operation because the economic returns do not align with the financial risk of the project. However, the social returns from the internalization of waste treatment are sufficiently large to warrant a more thorough analysis of the conditions necessary to provide the business with the funds to establish operations.

This chapter begins by considering the return on investment of the business in a political environment in which the externalities of artificial fertilizer production and municipal wastewater treatment are internalized by government policy. These externalities could be internalized through one of three methods: command and control, pigovian taxation, or pollution credit allocation and trading. In the case of natural gas based fertilizer, command and control would impose limits on the amount of CO_2 emissions from the fertilizer production process to achieve the socially efficient level of manufacturing. Pigovian taxation seeks to achieve the same goal through a tax on the emissions. Whereas command and control only requires knowledge of the socially efficient level of pollution, taxation only requires policy makers to be able to estimate the external cost CO_2 for which there currently are many markets for worldwide. Finally, pollution credit allocation is a more flexible, market based version of command and control that would allocate the socially efficient amount of CO_2 emissions “credits” to fertilizer production factories and allow them to trade the “credits” so the most efficient companies could reduce emissions more than their competitors and sell their emissions credits for monetary gain. Rather than look into the particular policy methods that could be utilized to internalize these negative externalities, the paper focuses on the quantification of these social costs and the effects that this have on the bottom line of the humanure composting operation.

After considering these hypothetical political scenarios, the chapter moves onto consider two possible real world situations where constraints on municipal wastewater treatment increase the opportunity cost of neglecting investment in the business. In particular, the cost effectiveness of the decentralized composting of human waste changes dramatically when competing with septic treatment and an overburdened waste treatment plant rather than an urban system with ample capacity.

Scenario 1) Fertilizer Cost Internalization

Due to the disruption of the nutrient cycle through the disposal of the natural fertilizer that is human excrement, modern society is forced to rely on fossil fuels and heavy industry to support the agricultural yields necessary to sustain human life. This industrial agricultural complex comes at a high social cost as the carbon emissions and nutrient leaching of artificial fertilizers are not internalized in their price and, thus, these fertilizers are dramatically over consumed. By utilizing the emissions data from the production and transport of natural gas, calculating the energy consumed in the Born-Haber cycle, and estimating the amount of nitrogen lost to leaching, the external cost of the artifical fertilizer nutrient equivalent of one cubic yard is conservatively estimated to be $2 (see Appendix N).

Once again, slow release nitrogen fertilizers were chosen as the closest nutrient equivalent to the business' compost, and, thus, the external costs of producing one pound of nitrogen were calculated and then multiplied by the 22 lb of nitrogen per cubic yard of compost to find the value added to the compost if the government were to correct this market failure.

First, the CO_2 equivalent emissions from the natural gas utilized in the production of anhydrous ammonia were calculated to be 9 lb of CO_2 eq/lb of N. This number was derived from finding the emissions of the natural gas production process per kilogram times the 700 kilograms of natural gas required to produce a ton of anhydrous ammonia followed by some simple dimensional analysis and the incorporation of the fact that only 82% of anhydrous ammonia is nitrogen[58]. Second, the emissions from the production of the fertilizer from the natural gas were estimated at 3 lb of CO_2 eq/lb of N by averaging the emissions records of thirteen fertilizer plants in the European Union[59]. Third, even slow release fertilizers lose about 1% of their nitrogen content to the atmosphere due to vaporization during their application to agricultural lands[60]. Incorporating the fact that nitrous oxide is 310 times more potent a greenhouse gas than carbon dioxide, this is the equivalent of an additional 3 lb of CO_2 eq/lb of N. In total, slow release nitrogen fertilizers produce 15 CO_2 eq emissions per lb of N. In order to quantify the social cost of these emission, this total was multiplied by $0.006 per lb of CO_2, the market value of

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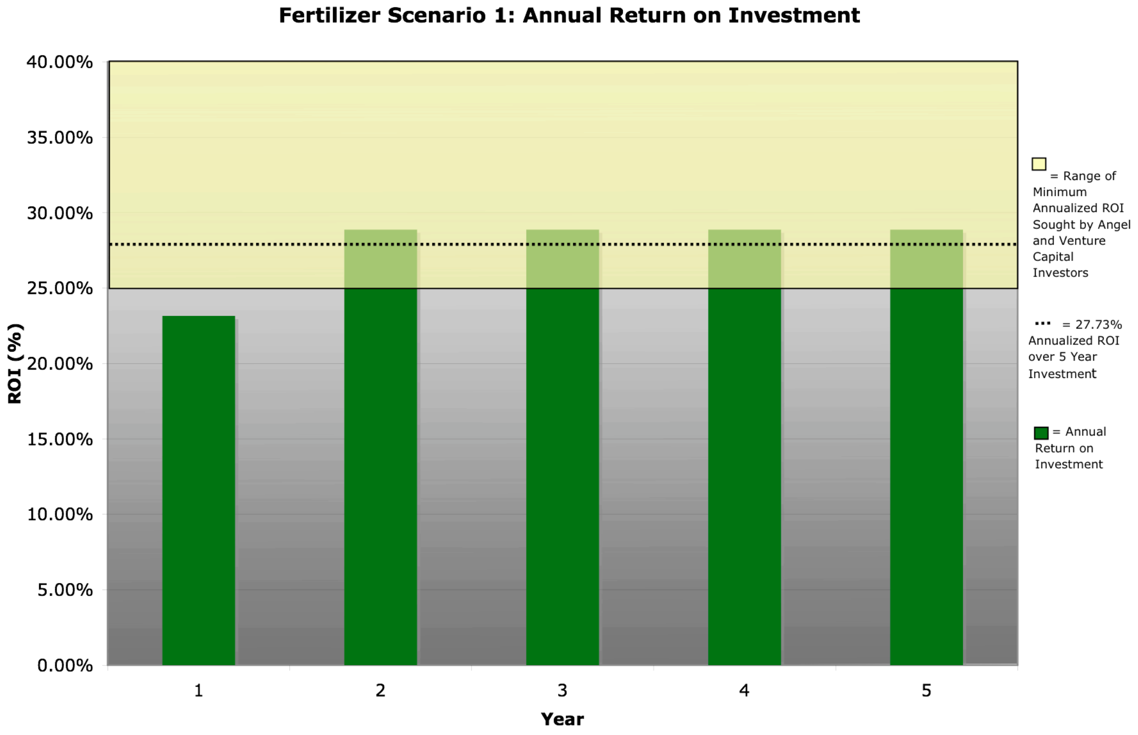
[58] Wood 11
[59] Bahmannia 18
[60] Walters 9

CO_2 determined by averaging the price per ton of CO2 on a range of international and private markets.

The total external cost of $0.09 per lb of nitrogen is a conservative estimate that accurately estimates the social cost of the emissions from the production, transport, and application of artificial fertilizers. However, since there was insufficient data to incorporate the social cost of the nitrogen that leaches from the fields into waterways across the nation, this estimate is likely far below the true value of the negative externalities. For example, consider the fact that eutrophication brought about by the leaching of artificial fertilizers used in farms in the Chesapeake Bay watershed has cost the Maryland shellfish industry millions of dollars each year alone. Add to this value to the cost of the damage to ecosystems, recreation, and fishing, and the estimate of the external cost of nitrogen fertilizer would likely increase significantly.

Figure 5.1



However, if fertilizer companies were forced to internalize solely the emission cost of their damaging environmental policies, this would still change the complexion of the soil amendment market. In response, the business would be able to increase its prices, and the effect on its finances would be dramatic as it would raise the 5-year annualized return on investment by over 4% to 27.73% per year. Since the business would be able to sell its fertilizer for over $2 more per cubic yard, the business would reap profits of over $10,000 per quarter once its composting revenue began to accrue and likely be able to attract investment from some angel investors as its return on investment would fall within the bottom of the range considered viable for startups. Furthermore, the impact of the internalization of these emissions cost underscores the dramatic potential of government policy to internalize the full external cost of artificial fertilizers including their much greater propensity to nutrient leaching than compost. If government studies were commissioned to gather accurate data on these externalities and these costs were internalized, the business would gain even greater traction as a cost saving alternative to the status quo because its social returns would transform from intangible bonus to real economic benefit.

Scenario 2) Wastewater Treatment Cost Internalization

Similar methods were used to estimate the external cost of wastewater treatment. In a world increasingly concerned about climate change, it is not surprising that the most comprehensive records of the environment damage caused by the modern wastewater treatment system fall under the category of greenhouse gas emissions. While greenhouse gas emissions are far from the primary contributor to the external costs of modern wastewater treatment, the amount of energy consumed and, subsequently, greenhouse gases emitted during the construction and operation of municipal wastewater treatment systems is remarkable. At a $12 price per ton of CO_2, the construction of an average wastewater treatment plant contributes nearly 1 cent per 100 cubic feet (ccf) of wastewater treated over the lifetime of the plant, or 45% of total CO_2 emissions[61] (see Appendix P).

Figure 5.2

Emissions from Municipal Wastewater Treatment Plants (billion g CO_2 eq/year)	Municipal Wastewater Treated (billion gallons/year)	Emissions Per Gallon of Wastewater Treated (g/gal)	Tons of CO_2 eq/ccf Wastewater Treated	Price of CO_2 eq/ton	**External Cost of Wastewater Treatment Emissions ($/ccf)**
15500	14600	1.061643836	0.000875415	12	**$0.011**

The other 55% of emissions come from the day-to-day operation of the treatment plant and running the pumps in the energy intensive wastewater collection system. Furthermore, the emissions of methane from the degradation of the organic material along its path from toilet to treatment plant contribute an additional $ 0.02 of external emissions costs per ccf of wastewater treated. These emissions are from the natural degradation of the wastewater; however, the CH_4, with 21 times the greenhouse warming potential of CO_2, is produced from anaerobic parts of the wastewater treatment process. The business does not conduct any anaerobic composting, and, thus, the increased global warming potential of these emissions must be considered in the analysis.

Figure 5.3

CH_4 Emissions (billion g/year)	Greenhouse Warming Potential	Municipal Wastewater Treated (billion gallons/year)	**External Cost of Methane and Nitrous Oxide Emissions ($/ccf)**
1210	21	14600	**$0.017**

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[61] US Wastewater Factsheet

In addition to the $0.04 of negative emissions externalities per ccf of treated wastewater, municipal treatment plants emit nutrient loaded wastewater often treated with toxic concentrations of chlorine into our nations waterways. Since there is insufficient data to allow a systematic breakdown of the social costs of water pollution caused by wastewater treatment, this paper utilized an indirect method to estimate the cost of these water pollution externalities. According to an economic paper on waste and wastewater externalities, the government of Barbados mandated a rate increase that amounted to a pigovian tax of $178 per household for the environmental upgrade to their wastewater treatment plant[62]. This tax equates to an external cost of $0.25/ccf for the Providence wastewater system.

Figure 5.4

External Cost of Wastewater Treatment Emissions ($/ccf)	External Cost of Plant Construction Emissions ($/ccf)	External Cost of Methane Emissions ($/ccf)	External Cost of Environmental Damage Caused by Municipal Wastewater Treatment Plants ($/ccf)	**Total External Cost of Municipal Wastewater Treatment ($/ccf)**
$0.011	$0.007	$0.017	$0.253	**$0.288**

Incorporating this external cost into the $3.35/ccf Providence charges for wastewater treatment raises the marginal cost of waste treatment by 7.5%. While this is sufficient to raise the 5 year annualized return on investment just over the 25% threshold, it does not make the business a significantly more attractive investment. In fact, the 7.5% rate increase is less than the coefficient of variation of wastewater treatment rates in urban areas across the country. Thus, the internalization of wastewater externalities as documented in this paper would make minimal contribution to the increased feasibility of the sustainable business operation.

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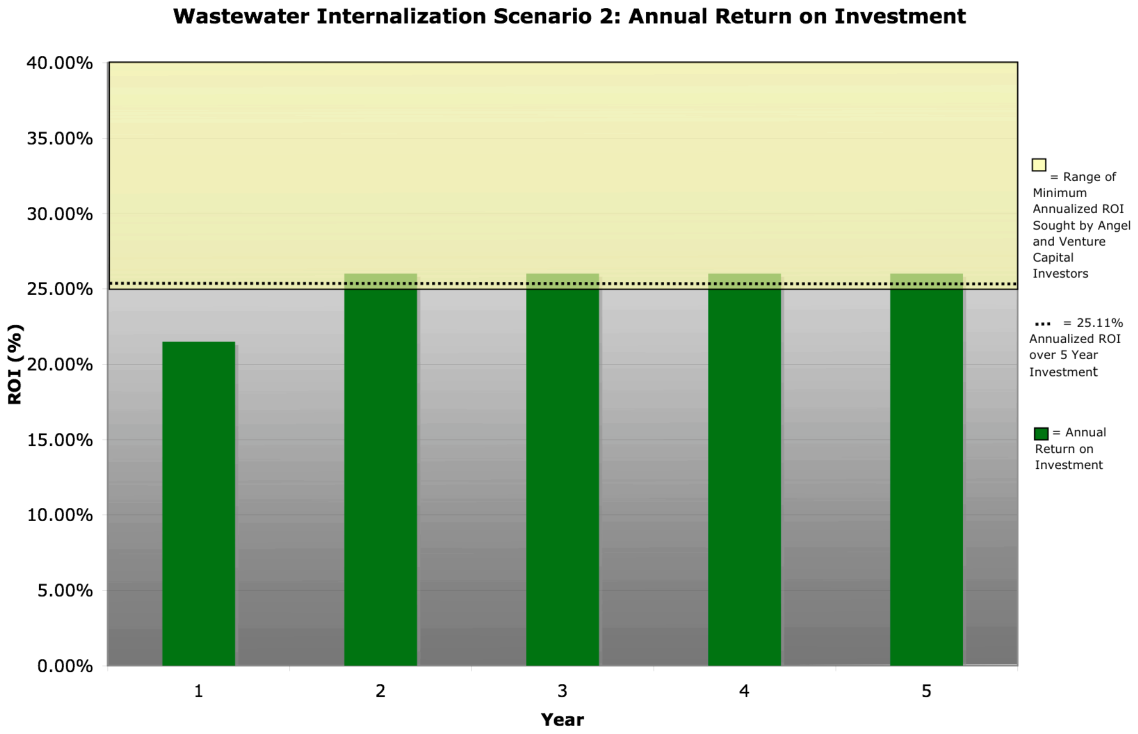
[62] Beukering 18

Figure 5.5



The primary reason for this is not that the external costs of waste treatment are insignificant, but rather that the calculations likely grossly underestimate the true social cost of water pollution from municipal plants. The estimate of water pollution externalities is based on a single government's attempt at cost internalization that focused on the environmental upgrades necessary to ensure human health and safety during use of the local waterways. Thus, this $178 tax did nothing to internalize the costs of eutrophication or chlorine pollution that might have dramatic effects on aquatic life, but indirect, yet costly, effects on humans through harm to fisheries and water recreation. Overall, while the modern waste treatment system is a convenient and cheap method for disposing of human waste, its social cost is enormous as it leads to a twofold rise in emissions and water pollution stemming both from artificial fertilizer production and leaching and wastewater system operations and pollution.

Scenario 3) Decentralized Wastewater Treatment

While government policy internalizing the social costs of waste treatment could spur the rapid proliferation of human waste composting operations by tilting the cost equation in favor of more sustainable operations, the batch composting of human waste also offers strong competition to modern waste treatment systems in scenarios where centralized treatment is already expensive due to non-environmental factors. One such situation is rural areas where there are large distances between structures that make centralized treatment impractical. As a result, more costly septic systems, which offer little environmental improvement over central system, dominate these rural areas.

By calculating the amortized cost of septic systems per two person dwelling per month, this paper normalizes the cost of rural waste treatment so it can be compared to the business' wastewater treatment revenue projections (95% of the average water/wastewater bill of the Providence Courtyard per equivalently sized unit). An appropriately sized septic unit costs a minimum of $1000 and is projected to last 20 years. However, the system must be emptied out once every two years at a cost of $250, doubling the cost of septic treatment[63]. Once the government mandated permitting and filter costs are added, septic systems cost $23 per month[64] (see Appendix R). Even without accounting for the time-value of money that would make septic systems even more expensive due to their high upfront costs, this is $3 more per unit than the revenue that the business is deriving from its wastewater fees in urban operations.

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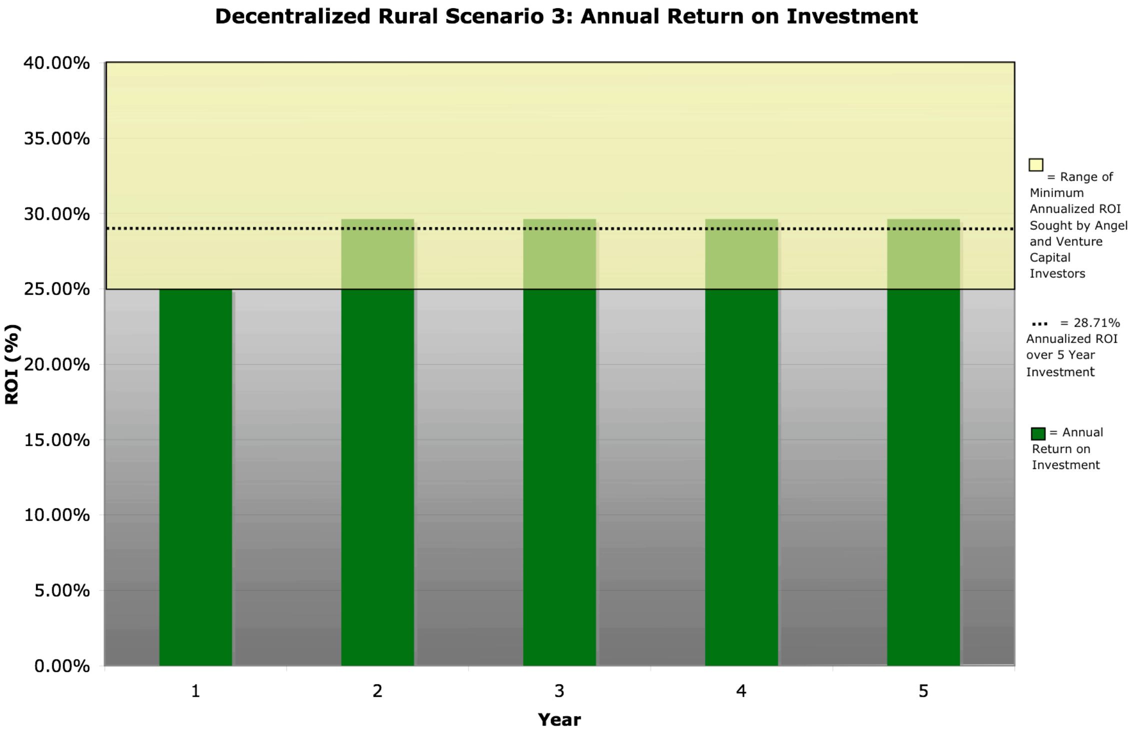
[63] Ludwig 83

[64] Water & Sewer Rate Study

Figure 5.6



If the business were to operate in a decentralized region where its increased operation costs (from the biweekly trucking of waste) relative to alternative waste treatment methods were diminished, its annualized 5 year return on investment would jump to 28.71%. Thus, a niche application of the batch composting of human waste is a fiscally realistic possibility assuming the business can find sufficiently high density rural structures to collect enough waste to conduct thermophilic composting. While not a single handed solution to the wastewater treatment problem, this application of the business could restore the natural nutrient cycle in rural areas by bringing a large amount of compost onto the market areas where the demand for compost will be highest.

Scenario 4) Margin of Existing Municipal System

Municipal wastewater treatment plants are massive engineering projects that process millions of gallons of sewage each month. Unsurprisingly, these plants take years to construct and cost tens, even hundreds, of millions of dollars. As a result, the marginal cost of adding buildings to a municipal wastewater system increases dramatically when the central treatment plant nears maximum capacity. In fact, the EPA mandates the construction of additional treatment facilities once the central plant reaches 90% of maximum capacity[65]. At this point, adding new structures to the wastewater treatment grid is not a matter of adding a few additional feet of piping, but rather investing in a multimillion dollar capital improvement project. Thus, in a city with an overburdened wastewater treatment system, the competitive advantage of the business is increased dramatically without even considering its green benefits.

I. Financing of Wastewater Treatment Plants

Municipal wastewater treatment systems are funded entirely through the monthly bills paid by residents. Rates are determined indirectly by dividing the cost of wastewater treatment by the number of ratepayers. The cost of wastewater treatment is the sum of the variable cost per volume times the projected amount of sewage treated, monthly operating expenses, and amortized debt service to cover capital costs paid for by municipal loans. Thus, wastewater treatment plants must set rates at the level necessary

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[65] Cost Accounting and Budgeting for Improved Wastewater Treatment

to cover costs because they do not receive subsidies from the municipalities in the form of property or sales tax revenues.

Since all municipalities serve districts of different size, there is a large amount of variance in the rates charged for wastewater treatment across the country. However, while municipalities do not directly subsidize wastewater treatment, they all have socially inefficient, low rates not only due to their failure to incorporate social costs, but also due to indirect federal subsidy through the Clean Water State Revolving Fund. This program allows municipalities to externalize the true cost of financing their economically risky 20 year capital improvement projects (which municipalities regularly are late on loan payments for) and results in a socially harmful amount of municipal wastewater treatment and higher barriers to entry for more sustainable private businesses.

The Clean Water State Revolving Fund was established out of the passage of the 1987 Amendments to the Clean Water Act to fund projects to improve the quality of wastewater treatment across the nation[66]. Under the program, the federal government provides states with matching grants (the states must contribute 20% of the amount of the federal grant to the fund) to provide low interest loans to wastewater treatment projects. These low rate, flexible term loans often cover a large percentage of capital improvement projects to address wastewater capacity issues and reduce the cost of financing for municipalities by as much as 20% below the market rate. According to the EPA, the Clean Water State Revolving Fund provides loans at an average rate of 2.1%, compared to the market average of 4.3%[67]. Not only do municipalities enjoy the fundraising advantage of being able to tap into the Clean Water State Revolving Fund, but the

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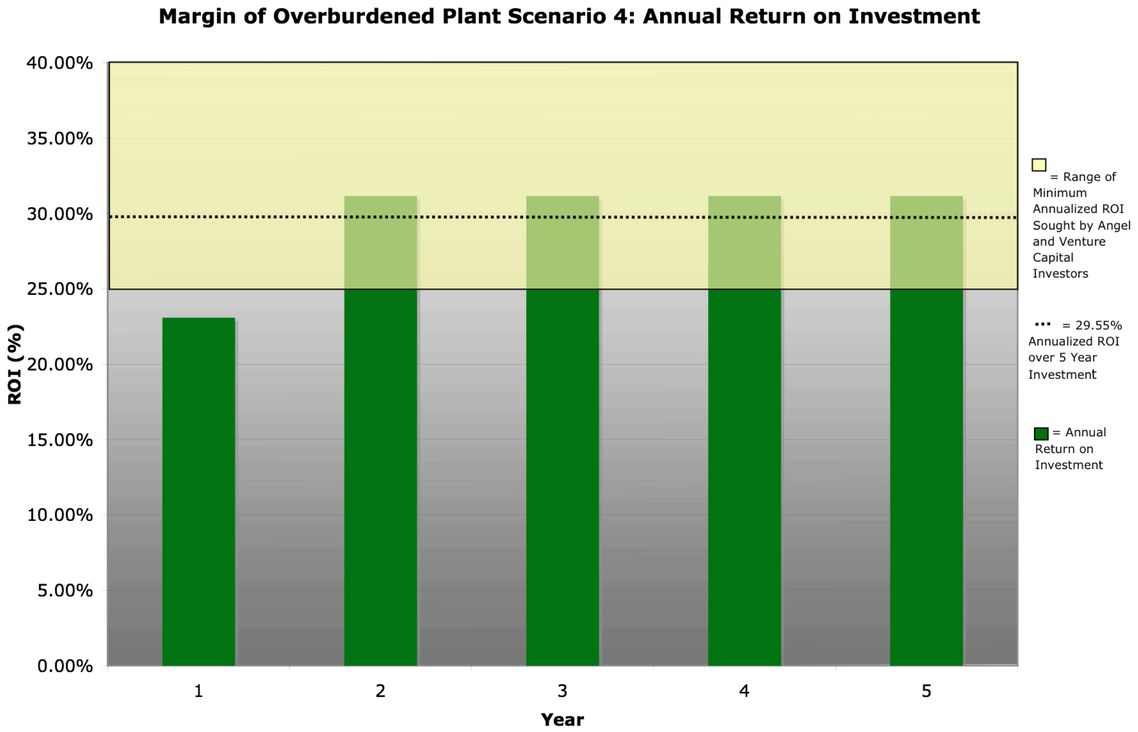
[66] Cost Accounting and Budgeting for Improved Wastewater Treatment
[67] Frequently Asked Questions About the Wastewater Treatment Plant Construction

municipal bonds they sell to cover the rest of their capital improvement costs are tax exempt. Given all of these factors, the cost of adding capacity to a waste treatment plant is less daunting than it would be if a similar project were undertaken by a private enterprise.

II. Cost of Adding Capacity to Wastewater Treatment Plants

In order to determine the economic viability of a human composting operation in an urban area facing the alternative of adding capacity to its central treatment plant, the average cost of wastewater treatment plant projects must be determined. Since municipal wastewater systems vary in size and scope, this paper bases all intercity comparisons on the percentage effect capital improvement projects have on ratepayers sewage bills. To make matters more complicated, while municipalities generally finance capital improvement projects over a standard 20 year period, these same governments often phase in these rate increases over different periods of time for policy reasons. For the purpose of normalizing the comparisons, the paper annualizes the total rate increase in ten municipalities similar in population size to Providence over the 5 year period used for the business' financial projections. Then, these average annual rate increases are averaged to give an estimate of the effect on residents' bills of a prospective project planning to add more than 10% capacity to a central wastewater treatment plant.

Figure 5.7



According to the calculations illustrated in the table above, adding capacity to a central treatment plant increase the cost of local wastewater management by 9.15% per year over 5 years. Even considering the fact that this number is depressed by the beneficial financing terms secured by municipal governments, this is still a 7% greater real increase in user rates than the typical annual rate change (see Appendix T). This increases the opportunity cost of investing in the municipal plant upgrade instead of the business and dramatically alters the perspective of those considering investment in the composting of urban waste streams. With the ability to charge significantly higher wastewater fees to customers, the business' projected return on investment jumps to nearly 30%, while the internal rate of return on the $150,000 rises to a respectable 14%. Under these circumstances, it is likely that the business will overcome its financing barrier as investors and perhaps even the local government itself will invest in this sustainable alternative to expanding the municipal system.

Summary

Under all four of the alternative political and economic scenarios, the business achieves sufficient economic returns to meet its capital financing obstacles. The return on investment is most promising in the scenario where the municipal wastewater treatment plant is overburdened and the addition of capacity would mean construction of more treatment plants. This signals that the business is a viable alternative to the municipal wastewater treatment system when they are competing on level ground (i.e. both have to add treatment *and* collection capacity). The decentralized collection plan at the heart of the business' operations makes it ideal for rural applications as well. However, the social returns of the business are great enough to make it a viable alternative to even established urban municipal systems when these environmental benefits are incorporated into the economic equation.

Chapter 6: Conclusion

A thermophilic, batch composting operation has the potential to offer a sustainable solution to the modern wastewater problem. However, as shown in the paper, a humanure composting factory is not exactly the investment equivalent of a tech startup with low costs and high projected net revenue streams. Thus, the case study scenario of starting operations in a high density urban area with an entrenched municipal wastewater system is not a realistic business model. In this conclusion, the paper builds on the analysis of the last chapter to suggest two possible paths thermophilic, batch composting of human waste can move from the fringes of scientific experiment into the mainstream as the modern wastewater treatment status quo.

I. Private Solution

While the returns of the business would not compensate private investors for the risk of the venture in the case study scenario in Providence, Rhode Island, the business offers stronger financial prospects on the margins of existing systems. In situations where the primary wastewater treatment competitor is a septic tank or an overburdened municipal system, the business offers an attractive alternative investment option. Thermophilic, batch composting operations could likely secure the necessary funds to start operations in such environments. If the financial and environmental projections turned out to be accurate, the perceived risk of the business would fall, and the company would gradually secure the additional funds needed expand into urban areas and displace unsustainable, established wastewater treatment operations.

II. Public Solution

While a private solution to the market failure in the wastewater treatment business is theoretically possible as outlined above, public involvement would greatly facilitate the development of upstream composting operations as an alternative to existing pipe-to-plant systems. In fact, the public sector is largely to blame for this market failure, as the wastewater rate structure set up by local governments does not internalize the external cost of municipal operations. Furthermore, the low interest loans provided by the Clean Water State Revolving Fund and municipal bonds further distorts fiscal incentives in favor of centralized wastewater treatment.

By correcting these market failures, the public sector could make two major steps towards ensuring a socially efficient wastewater treatment future whether it is by the thermophilic, batch composting of human waste or an alternative method. First, the federal government could take the bold step of enacting policies to internalize the external costs of wastewater treatment and artificial fertilizer production. Whether through taxation, command and control, or permit trading, this strategy would increase the economic cost of these services with the goal of reducing their consumption to socially-efficient levels. However, this is likely a politically infeasible strategy as it will involve costly studies to accurately quantify these external costs, pit narrow special interests against the diffuse public interest, and draw the public ire due to the perceived cost of tangible service price increases with the less tangible benefit of improved environmental quality.

As a result, a more realistic public strategy to provide incentives for increasing sustainability in wastewater treatment would be to lower the barriers of entry into this field through loan guarantees to businesses pursuing sustainable solutions to wastewater treatment. For example, a program to allow business such as the case study example to apply for grants or low interest loans would provide a more politically feasible carrot to encourage the private sector to correct the market failure in wastewater treatment.

In the end, the current wastewater treatment system coupled with the proliferation of artificial fertilizer accomplishes the same end goals as the composting of urban waste: complete destruction of the pathogens in human waste and the provision of nutrients to crops. However, the modern status quo comes at a tremendous social cost in the form of wasted drinking water, algae blooms, greenhouse gas emissions, and beach closings. As shown in this paper, a viable, scalable alternative exists in the form of thermophilic, batch composting. With the funding of niche humanure composting systems through private social entrepreneurs or direct government aid of alternative wastewater management programs, this theoretical solution could correct an age old market failure and increase social welfare in the process.

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Appendix A

Pro Forma Income Statement

	Month 0	Month 1	Month 2	Month 3	Month 4	Month 5
Revenue						
Water/Wastewater Fee	0.00	4,392.31	4,392.31	4,392.31	4,392.31	4,392.31
Wastewater Fee Revenue per Unit	0.00	19.79	19.79	19.79	19.79	19.79
Compost Fertilizer Revenue	0.00	0.00	0.00	0.00	12,039.06	12,039.06
Compost Revenue per Unit	0.00	0.00	0.00	0.00	54.23	54.23
Total Revenue	0.00	4,392.31	4,392.31	4,392.31	16,431.37	16,431.37
Costs						
Startup Costs						
Incorporation and Office Costs	(6,000.00)	0.00	0.00	0.00	0.00	0.00
Factory (Front Loader, Shredder, Comoposting Vessel)	(80,000.00)	0.00	0.00	0.00	0.00	0.00
Total Startup Costs	(86,000.00)	0.00	0.00	0.00	0.00	0.00
Fixed Costs						
Rent (Including Utilities)	0.00	(2,310.00)	(2,310.00)	(2,310.00)	(2,310.00)	(2,310.00)
Total Salary	0.00	(8,000.00)	(8,000.00)	(8,000.00)	(8,000.00)	(8,000.00)
Number of Employees	*0*	*2*	*2*	*2*	*2*	*2*
Employee Salary	*0.00*	*(4,000.00)*	*(4,000.00)*	*(4,000.00)*	*(4,000.00)*	*(4,000.00)*
Payroll Taxes	*0.00*	*(676.00)*	*(676.00)*	*(676.00)*	*(676.00)*	*(676.00)*
Advertising	0.00	(200.00)	(200.00)	(200.00)	(200.00)	(200.00)
Telephone, Internet, Website	0.00	(80.00)	(80.00)	(80.00)	(80.00)	(80.00)
Website	0.00	(10.00)	(10.00)	(10.00)	(10.00)	(10.00)
Total Fixed Costs	0.00	(11,276.00)	(11,276.00)	(11,276.00)	(11,276.00)	(11,276.00)
Variable Costs						
Plumbing Installation	(25,000.00)	0.00	0.00	0.00	0.00	0.00
Truck Expenses	0.00	(300.00)	(300.00)	(300.00)	(300.00)	(300.00)
Paying Recycling Company	0.00	(1,800.00)	(1,800.00)	(1,800.00)	(1,800.00)	(1,800.00)
Total Variable Costs	(25,000.00)	(2,100.00)	(2,100.00)	(2,100.00)	(2,100.00)	(2,100.00)
Net Revenue						
Total Revenue	0.00	4,392.31	4,392.31	4,392.31	16,431.37	16,431.37
Total Costs	(111,000.00)	(13,376.00)	(13,376.00)	(13,376.00)	(13,376.00)	(13,376.00)
Net Revenue	(111,000.00)	(8,983.69)	(8,983.69)	(8,983.69)	3,055.37	3,055.37
Gross Net Revenue	(111,000.00)	(119,983.69)	(128,967.37)	(137,951.06)	(134,895.68)	(131,840.31)

Appendix A

	Month 6	Month 7	Month 8	Month 9	Month 10	Month 11	Month 12
Revenue							
Water/Wastewater Fee	4,392.31	4,392.31	4,392.31	4,392.31	4,392.31	4,392.31	4,392.31
Wastewater Fee Revenue per Unit	19.79	19.79	19.79	19.79	19.79	19.79	19.79
Compost Fertilizer Revenue	12,039.06	12,039.06	12,039.06	12,039.06	12,039.06	12,039.06	12,039.06
Compost Revenue per Unit	54.23	54.23	54.23	54.23	54.23	54.23	54.23
Total Revenue	16,431.37	16,431.37	16,431.37	16,431.37	16,431.37	16,431.37	16,431.37
Costs							
Startup Costs							
Incorporation and Office Costs	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Factory	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total Startup Costs	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Fixed Costs							
Rent (Including Utilities)	(2,310.00)	(2,310.00)	(2,310.00)	(2,310.00)	(2,310.00)	(2,310.00)	(2,310.00)
Total Salary	(8,000.00)	(8,000.00)	(8,000.00)	(8,000.00)	(8,000.00)	(8,000.00)	(8,000.00)
Number of Employees	*2*	*2*	*2*	*2*	*2*	*2*	*2*
Employee Salary	*(4,000.00)*	*(4,000.00)*	*(4,000.00)*	*(4,000.00)*	*(4,000.00)*	*(4,000.00)*	*(4,000.00)*
Payroll Taxes	*(676.00)*	*(676.00)*	*(676.00)*	*(676.00)*	*(676.00)*	*(676.00)*	*(676.00)*
Advertising	(200.00)	(200.00)	(200.00)	(200.00)	(200.00)	(200.00)	(200.00)
Telephone, Internet, Website	(80.00)	(80.00)	(80.00)	(80.00)	(80.00)	(80.00)	(80.00)
Website	(10.00)	(10.00)	(10.00)	(10.00)	(10.00)	(10.00)	(10.00)
Total Fixed Costs	(11,276.00)	(11,276.00)	(11,276.00)	(11,276.00)	(11,276.00)	(11,276.00)	(11,276.00)
Variable Costs							
Plumbing Installation	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Truck Expenses	(300.00)	(300.00)	(300.00)	(300.00)	(300.00)	(300.00)	(300.00)
Paying Recycling Company	(1,800.00)	(1,800.00)	(1,800.00)	(1,800.00)	(1,800.00)	(1,800.00)	(1,800.00)
Total Variable Costs	(2,100.00)	(2,100.00)	(2,100.00)	(2,100.00)	(2,100.00)	(2,100.00)	(2,100.00)
Net Revenue							
Total Revenue	16,431.37	16,431.37	16,431.37	16,431.37	16,431.37	16,431.37	16,431.37
Total Costs	(13,376.00)	(13,376.00)	(13,376.00)	(13,376.00)	(13,376.00)	(13,376.00)	(13,376.00)
Net Revenue	3,055.37	3,055.37	3,055.37	3,055.37	3,055.37	3,055.37	3,055.37
Gross Net Revenue	(128,784.94)	(125,729.56)	(122,674.19)	(119,618.82)	(116,563.44)	(113,508.07)	(110,452.69)

Appendix A

	Year 2				Year 3		
	Year 2 Q1	**Year 2 Q2**	**Year 2 Q3**	**Year 2 Q4**	**Year 3 Q1**	**Year 3 Q2**	**Year 3 Q3**
Revenue							
Water/Wastewater Fee	13,176.94	13,176.94	13,176.94	13,176.94	13,176.94	13,176.94	13,176.94
Wastewater Fee Revenue per Unit	19.79	19.79	19.79	19.79	19.79	19.79	19.79
Compost Fertilizer Revenue	36,117.18	36,117.18	36,117.18	36,117.18	36,117.18	36,117.18	36,117.18
Revenue per Unit	54.23	54.23	54.23	54.23	54.23	54.23	54.23
Total Revenue	49,294.12	49,294.12	49,294.12	49,294.12	49,294.12	49,294.12	49,294.12
Costs							
Startup Costs							
Incorporation and Office Costs	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Factory	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total Startup Costs	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Fixed Costs							
Rent (Including Utilities)	(6,930.00)	(6,930.00)	(6,930.00)	(6,930.00)	(6,930.00)	(6,930.00)	(6,930.00)
Total Salary	(24,000.00)	(24,000.00)	(24,000.00)	(24,000.00)	(24,000.00)	(24,000.00)	(24,000.00)
Number of Employees	*2*	*2*	*2*	*2*	*2*	*2*	*2*
Employee Salary	*(12,000.00)*	*(12,000.00)*	*(12,000.00)*	*(12,000.00)*	*(12,000.00)*	*(12,000.00)*	*(12,000.00)*
Payroll Taxes	*(2,028.00)*	*(2,028.00)*	*(2,028.00)*	*(2,028.00)*	*(2,028.00)*	*(2,028.00)*	*(2,028.00)*
Advertising	(600.00)	(600.00)	(600.00)	(600.00)	(600.00)	(600.00)	(600.00)
Telephone, Internet, Website	(240.00)	(240.00)	(240.00)	(240.00)	(240.00)	(240.00)	(240.00)
Website	(30.00)	(30.00)	(30.00)	(30.00)	(30.00)	(30.00)	(30.00)
Total Fixed Costs	(33,828.00)	(33,828.00)	(33,828.00)	(33,828.00)	(33,828.00)	(33,828.00)	(33,828.00)
Variable Costs							
Plumbing Installation	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Truck Expenses	(900.00)	(900.00)	(900.00)	(900.00)	(900.00)	(900.00)	(900.00)
Paying Recycling Company	(5,400.00)	(5,400.00)	(5,400.00)	(5,400.00)	(5,400.00)	(5,400.00)	(5,400.00)
Total Variable Costs	(6,300.00)	(6,300.00)	(6,300.00)	(6,300.00)	(6,300.00)	(6,300.00)	(6,300.00)
Net Revenue							
Total Revenue	49,294.12	49,294.12	49,294.12	49,294.12	49,294.12	49,294.12	49,294.12
Total Costs	(40,128.00)	(40,128.00)	(40,128.00)	(40,128.00)	(40,128.00)	(40,128.00)	(40,128.00)
Net Revenue	9,166.12	9,166.12	9,166.12	9,166.12	9,166.12	9,166.12	9,166.12
Gross Net Revenue	(101,286.57)	(92,120.45)	(82,954.33)	(73,788.21)	(64,622.09)	(55,455.97)	(46,289.84)

Appendix A

		Year 4				Year 5	
	Year 3 Q4	**Year 4 Q1**	**Year 4 Q2**	**Year 4 Q3**	**Year 4 Q4**	**Year 5 Q1**	**Year 5 Q2**
Revenue							
Water/Wastewater Fee	13,176.94	13,176.94	13,176.94	13,176.94	13,176.94	13,176.94	13,176.94
Wastewater Fee Revenue per Unit	19.79	19.79	19.79	19.79	19.79	19.79	19.79
Compost Fertilizer Revenue	36,117.18	36,117.18	36,117.18	36,117.18	36,117.18	36,117.18	36,117.18
Compost Revenue per Unit	54.23	54.23	54.23	54.23	54.23	54.23	54.23
Total Revenue	49,294.12	49,294.12	49,294.12	49,294.12	49,294.12	49,294.12	49,294.12
Costs							
Startup Costs							
Incorporation and Office Costs	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Factory	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total Startup Costs	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Fixed Costs							
Rent (Including Utilities)	(6,930.00)	(6,930.00)	(6,930.00)	(6,930.00)	(6,930.00)	(6,930.00)	(6,930.00)
Total Salary	(24,000.00)	(24,000.00)	(24,000.00)	(24,000.00)	(24,000.00)	(24,000.00)	(24,000.00)
Number of Employees	*2*	*3*	*4*	*5*	*6*	*7*	*8*
Employee Salary	*(12,000.00)*	*(12,000.00)*	*(12,000.00)*	*(12,000.00)*	*(12,000.00)*	*(12,000.00)*	*(12,000.00)*
Payroll Taxes	*(2,028.00)*	*(2,028.00)*	*(2,028.00)*	*(2,028.00)*	*(2,028.00)*	*(2,028.00)*	*(2,028.00)*
Advertising	(600.00)	(600.00)	(600.00)	(600.00)	(600.00)	(600.00)	(600.00)
Telephone, Internet, Website	(240.00)	(240.00)	(240.00)	(240.00)	(240.00)	(240.00)	(240.00)
Website	(30.00)	(30.00)	(30.00)	(30.00)	(30.00)	(30.00)	(30.00)
Total Fixed Costs	(33,828.00)	(33,828.00)	(33,828.00)	(33,828.00)	(33,828.00)	(33,828.00)	(33,828.00)
Variable Costs							
Plumbing Installation	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Truck Expenses	(900.00)	(900.00)	(900.00)	(900.00)	(900.00)	(900.00)	(900.00)
Paying Recycling Company	(5,400.00)	(5,400.00)	(5,400.00)	(5,400.00)	(5,400.00)	(5,400.00)	(5,400.00)
Total Variable Costs	(6,300.00)	(6,300.00)	(6,300.00)	(6,300.00)	(6,300.00)	(6,300.00)	(6,300.00)
Net Revenue							
Total Revenue	49,294.12	49,294.12	49,294.12	49,294.12	49,294.12	49,294.12	49,294.12
Total Costs	(40,128.00)	(40,128.00)	(40,128.00)	(40,128.00)	(40,128.00)	(40,128.00)	(40,128.00)
Net Revenue	9,166.12	9,166.12	9,166.12	9,166.12	9,166.12	9,166.12	9,166.12
Gross Net Revenue	(37,123.72)	(27,957.60)	(18,791.48)	(9,625.36)	(459.24)	8,706.88	17,873.00

Appendix A

	Year 5 Q3	Year 5 Q4
Revenue		
Water/Wastewater Fee	13,176.94	13,176.94
Wastewater Fee Revenue per Unit	19.79	19.79
Compost Fertilizer Revenue	36,117.18	36,117.18
Compost Revenue per Unit	54.23	54.23
Total Revenue	49,294.12	49,294.12
Costs		
Startup Costs		
Incorporation and Office Costs	0.00	0.00
Factory	0.00	0.00
Total Startup Costs	0.00	0.00
Fixed Costs		
Rent (Including Utilities)	(6,930.00)	(6,930.00)
Total Salary	(24,000.00)	(24,000.00)
Number of Employees	*9*	*10*
Employee Salary	*(12,000.00)*	*(12,000.00)*
Payroll Taxes	*(2,028.00)*	*(2,028.00)*
Advertising	(600.00)	(600.00)
Telephone, Internet, Website	(240.00)	(240.00)
Website	(30.00)	(30.00)
Total Fixed Costs	(33,828.00)	(33,828.00)
Variable Costs		
Plumbing Installation	0.00	0.00
Truck Expenses	(900.00)	(900.00)
Paying Recycling Company	(5,400.00)	(5,400.00)
Total Variable Costs	(6,300.00)	(6,300.00)
Net Revenue		
Total Revenue	49,294.12	49,294.12
Total Costs	(40,128.00)	(40,128.00)
Net Revenue	9,166.12	9,166.12
Gross Net Revenue	27,039.13	36,205.25

Appendix B

Pro Forma Cash Flow Statement

	Month 0	Month 1	Month 2	Month 3	Month 4
Cash Inflow					
Income from Sales					
Cash Sales	$0.00	$2,635.39	$2,635.39	$2,635.39	$9,858.82
Collections of Accounts Receivable	$0.00	$0.00	$1,756.93	$1,756.93	$1,756.93
Total Cash from Sales	$0.00	$2,635.39	$4,392.31	$4,392.31	$11,615.75
Income from Financing					
Equity Capital Investments by Management	$50,000.00	$0.00	$0.00	$0.00	$0.00
Equity Capital Investments by Other Shareholders	$100,000.00	$0.00	$0.00	$0.00	$0.00
Debt Financing Proceeds	$0.00	$0.00	$0.00	$0.00	$0.00
Total Cash from Financing	$150,000.00	$0.00	$0.00	$0.00	$0.00
Total Cash Inflow	$150,000.00	$2,635.39	$4,392.31	$4,392.31	$11,615.75
Cash Outflow					
Expenses					
Cost of Goods	$0.00	($2,100.00)	($2,100.00)	($2,100.00)	($2,100.00)
Operating Expenses	$0.00	(11,276.00)	(11,276.00)	(11,276.00)	(11,276.00)
Debt Payments	$0.00	$0.00	$0.00	$0.00	$0.00
Property, Plant, Equipment	($111,000.00)	$0.00	$0.00	$0.00	$0.00
Distribution to Management	$0.00	$0.00	$0.00	$0.00	$0.00
Distribution to Other Shareholders	$0.00	$0.00	$0.00	$0.00	$0.00
Total Cash Outflow	($111,000.00)	($13,376.00)	($13,376.00)	($13,376.00)	($13,376.00)
Cash Balances					
Net Cash Flow	$39,000.00	($10,740.61)	($8,983.69)	($8,983.69)	($1,760.25)
Opening Cash Balance	$0.00	$39,000.00	$28,259.39	$19,275.70	$10,292.02
Cash Inflow	$150,000.00	$2,635.39	$4,392.31	$4,392.31	$11,615.75
Cash Outflow	($111,000.00)	($13,376.00)	($13,376.00)	($13,376.00)	($13,376.00)
Ending Cash Balance	$39,000.00	$28,259.39	$19,275.70	$10,292.02	$8,531.77

Appendix B

	Month 5	Month 6	Month 7	Month 8	Month 9
Cash Inflow					
Income from Sales					
Cash Sales	$9,858.82	$9,858.82	$9,858.82	$9,858.82	$9,858.82
Collections of Accounts Receivable	$6,572.55	$6,572.55	$6,572.55	$6,572.55	$6,572.55
Total Cash from Sales	$16,431.37	$16,431.37	$16,431.37	$16,431.37	$16,431.37
Income from Financing					
Equity Capital Investments by Management	$0.00	$0.00	$0.00	$0.00	$0.00
Equity Capital Investments by Other Shareholders	$0.00	$0.00	$0.00	$0.00	$0.00
Debt Financing Proceeds	$0.00	$0.00	$0.00	$0.00	$0.00
Total Cash from Financing	$0.00	$0.00	$0.00	$0.00	$0.00
Total Cash Inflow	$16,431.37	$16,431.37	$16,431.37	$16,431.37	$16,431.37
Cash Outflow					
Expenses					
Cost of Goods	($2,100.00)	($2,100.00)	($2,100.00)	($2,100.00)	($2,100.00)
Operating Expenses	(11,276.00)	(11,276.00)	(11,276.00)	(11,276.00)	(11,276.00)
Debt Payments	$0.00	$0.00	$0.00	$0.00	$0.00
Property, Plant, Equipment	$0.00	$0.00	$0.00	$0.00	$0.00
Distribution to Management	$0.00	$0.00	$0.00	$0.00	$0.00
Distribution to Other Shareholders	$0.00	$0.00	$0.00	$0.00	$0.00
Total Cash Outflow	($13,376.00)	($13,376.00)	($13,376.00)	($13,376.00)	($13,376.00)
Cash Balances					
Net Cash Flow	$3,055.37	$3,055.37	$3,055.37	$3,055.37	$3,055.37
Opening Cash Balance	$8,531.77	$11,587.14	$14,642.51	$17,697.89	$20,753.26
Cash Inflow	$16,431.37	$16,431.37	$16,431.37	$16,431.37	$16,431.37
Cash Outflow	($13,376.00)	($13,376.00)	($13,376.00)	($13,376.00)	($13,376.00)
Ending Cash Balance	$11,587.14	$14,642.51	$17,697.89	$20,753.26	$23,808.63

Appendix B

				Year 2	
	Month 10	**Month 11**	**Month 12**	**Year 2 Q1**	**Year 2 Q2**
Cash Inflow					
Income from Sales					
Cash Sales	$9,858.82	$9,858.82	$9,858.82	$29,576.47	$29,576.47
Collections of Accounts Receivable	$6,572.55	$6,572.55	$6,572.55	$19,717.65	$19,717.65
Total Cash from Sales	$16,431.37	$16,431.37	$16,431.37	$49,294.12	$49,294.12
Income from Financing					
Equity Capital Investments by Management	$0.00	$0.00	$0.00	$0.00	$0.00
Equity Capital Investments by Other Shareholders	$0.00	$0.00	$0.00	$0.00	$0.00
Debt Financing Proceeds	$0.00	$0.00	$0.00	$0.00	$0.00
Total Cash from Financing	$0.00	$0.00	$0.00	$0.00	$0.00
Total Cash Inflow	$16,431.37	$16,431.37	$16,431.37	$49,294.12	$49,294.12
Cash Outflow					
Expenses					
Cost of Goods	($2,100.00)	($2,100.00)	($2,100.00)	($6,300.00)	($6,300.00)
Operating Expenses	(11,276.00)	(11,276.00)	(11,276.00)	(33,828.00)	(33,828.00)
Debt Payments	$0.00	$0.00	$0.00	$0.00	$0.00
Property, Plant, Equipment	$0.00	$0.00	$0.00	$0.00	$0.00
Distribution to Management	$0.00	$0.00	($9,991.59)	$0.00	$0.00
Distribution to Other Shareholders	$0.00	$0.00	($19,983.17)	$0.00	$0.00
Total Cash Outflow	($13,376.00)	($13,376.00)	($43,350.76)	($40,128.00)	($40,128.00)
Cash Balances					
Net Cash Flow	$3,055.37	$3,055.37	($26,919.38)	$9,166.12	$9,166.12
Opening Cash Balance	$23,808.63	$26,864.01	$29,919.38	$3,000.00	$12,166.12
Cash Inflow	$16,431.37	$16,431.37	$16,431.37	$49,294.12	$49,294.12
Cash Outflow	($13,376.00)	($13,376.00)	($43,350.76)	($40,128.00)	($40,128.00)
Ending Cash Balance	$26,864.01	$29,919.38	$3,000.00	$12,166.12	$21,332.24

Appendix B

			Year 3		
	Year 2 Q3	**Year 2 Q4**	**Year 3 Q1**	**Year 3 Q2**	**Year 3 Q3**
Cash Inflow					
Income from Sales					
Cash Sales	$29,576.47	$29,576.47	$29,576.47	$29,576.47	$29,576.47
Collections of Accounts Receivable	$19,717.65	$19,717.65	$19,717.65	$19,717.65	$19,717.65
Total Cash from Sales	$49,294.12	$49,294.12	$49,294.12	$49,294.12	$49,294.12
Income from Financing					
Equity Capital Investments by Management	$0.00	$0.00	$0.00	$0.00	$0.00
Equity Capital Investments by Other Shareholders	$0.00	$0.00	$0.00	$0.00	$0.00
Debt Financing Proceeds	$0.00	$0.00	$0.00	$0.00	$0.00
Total Cash from Financing	$0.00	$0.00	$0.00	$0.00	$0.00
Total Cash Inflow	$49,294.12	$49,294.12	$49,294.12	$49,294.12	$49,294.12
Cash Outflow					
Expenses					
Cost of Goods	($6,300.00)	($6,300.00)	($6,300.00)	($6,300.00)	($6,300.00)
Operating Expenses	(33,828.00)	(33,828.00)	(33,828.00)	(33,828.00)	(33,828.00)
Debt Payments	$0.00	$0.00	$0.00	$0.00	$0.00
Property, Plant, Equipment	$0.00	$0.00	$0.00	$0.00	$0.00
Distribution to Management	$0.00	($12,221.50)	$0.00	$0.00	$0.00
Distribution to Other Shareholders	$0.00	($24,442.99)	$0.00	$0.00	$0.00
Total Cash Outflow	($40,128.00)	($76,792.49)	($40,128.00)	($40,128.00)	($40,128.00)
Cash Balances					
Net Cash Flow	$9,166.12	($27,498.36)	$9,166.12	$9,166.12	$9,166.12
Opening Cash Balance	$21,332.24	$30,498.36	$3,000.00	$12,166.12	$21,332.24
Cash Inflow	$49,294.12	$49,294.12	$49,294.12	$49,294.12	$49,294.12
Cash Outflow	($40,128.00)	($76,792.49)	($40,128.00)	($40,128.00)	($40,128.00)
Ending Cash Balance	$30,498.36	$3,000.00	$12,166.12	$21,332.24	$30,498.36

Appendix B

		Year 4			
	Year 3 Q4	**Year 4 Q1**	**Year 4 Q2**	**Year 4 Q3**	**Year 4 Q4**
Cash Inflow					
Income from Sales					
Cash Sales	$29,576.47	$29,576.47	$29,576.47	$29,576.47	$29,576.47
Collections of Accounts Receivable	$19,717.65	$19,717.65	$19,717.65	$19,717.65	$19,717.65
Total Cash from Sales	$49,294.12	$49,294.12	$49,294.12	$49,294.12	$49,294.12
Income from Financing					
Equity Capital Investments by Management	$0.00	$0.00	$0.00	$0.00	$0.00
Equity Capital Investments by Other Shareholders	$0.00	$0.00	$0.00	$0.00	$0.00
Debt Financing Proceeds	$0.00	$0.00	$0.00	$0.00	$0.00
Total Cash from Financing	$0.00	$0.00	$0.00	$0.00	$0.00
Total Cash Inflow	$49,294.12	$49,294.12	$49,294.12	$49,294.12	$49,294.12
Cash Outflow					
Expenses					
Cost of Goods	($6,300.00)	($6,300.00)	($6,300.00)	($6,300.00)	($6,300.00)
Operating Expenses	(33,828.00)	(33,828.00)	(33,828.00)	(33,828.00)	(33,828.00)
Debt Payments	$0.00	$0.00	$0.00	$0.00	$0.00
Property, Plant, Equipment	$0.00	$0.00	$0.00	$0.00	$0.00
Distribution to Management	($12,221.50)	$0.00	$0.00	$0.00	($12,221.50)
Distribution to Other Shareholders	($24,442.99)	$0.00	$0.00	$0.00	($24,442.99)
Total Cash Outflow	($76,792.49)	($40,128.00)	($40,128.00)	($40,128.00)	($76,792.49)
Cash Balances					
Net Cash Flow	($27,498.36)	$9,166.12	$9,166.12	$9,166.12	($27,498.36)
Opening Cash Balance	$30,498.36	$3,000.00	$12,166.12	$21,332.24	$30,498.36
Cash Inflow	$49,294.12	$49,294.12	$49,294.12	$49,294.12	$49,294.12
Cash Outflow	($76,792.49)	($40,128.00)	($40,128.00)	($40,128.00)	($76,792.49)
Ending Cash Balance	$3,000.00	$12,166.12	$21,332.24	$30,498.36	$3,000.00

Appendix B

	Year 5 Year 5 Q1	Year 5 Q2	Year 5 Q3	Year 5 Q4
Cash Inflow				
Income from Sales				
Cash Sales	$29,576.47	$29,576.47	$29,576.47	$29,576.47
Collections of Accounts Receivable	$19,717.65	$19,717.65	$19,717.65	$19,717.65
Total Cash from Sales	$49,294.12	$49,294.12	$49,294.12	$49,294.12
Income from Financing				
Equity Capital Investments by Management	$0.00	$0.00	$0.00	$0.00
Equity Capital Investments by Other Shareholders	$0.00	$0.00	$0.00	$0.00
Debt Financing Proceeds	$0.00	$0.00	$0.00	$0.00
Total Cash from Financing	$0.00	$0.00	$0.00	$0.00
Total Cash Inflow	$49,294.12	$49,294.12	$49,294.12	$49,294.12
Cash Outflow				
Expenses				
Cost of Goods	($6,300.00)	($6,300.00)	($6,300.00)	($6,300.00)
Operating Expenses	(33,828.00)	(33,828.00)	(33,828.00)	(33,828.00)
Debt Payments	$0.00	$0.00	$0.00	$0.00
Property, Plant, Equipment	$0.00	$0.00	$0.00	$0.00
Distribution to Management	$0.00	$0.00	$0.00	($12,221.50)
Distribution to Other Shareholders	$0.00	$0.00	$0.00	($24,442.99)
Total Cash Outflow	($40,128.00)	($40,128.00)	($40,128.00)	($76,792.49)
Cash Balances				
Net Cash Flow	$9,166.12	$9,166.12	$9,166.12	($27,498.36)
Opening Cash Balance	$3,000.00	$12,166.12	$21,332.24	$30,498.36
Cash Inflow	$49,294.12	$49,294.12	$49,294.12	$49,294.12
Cash Outflow	($40,128.00)	($40,128.00)	($40,128.00)	($76,792.49)
Ending Cash Balance	$12,166.12	$21,332.24	$30,498.36	$3,000.00

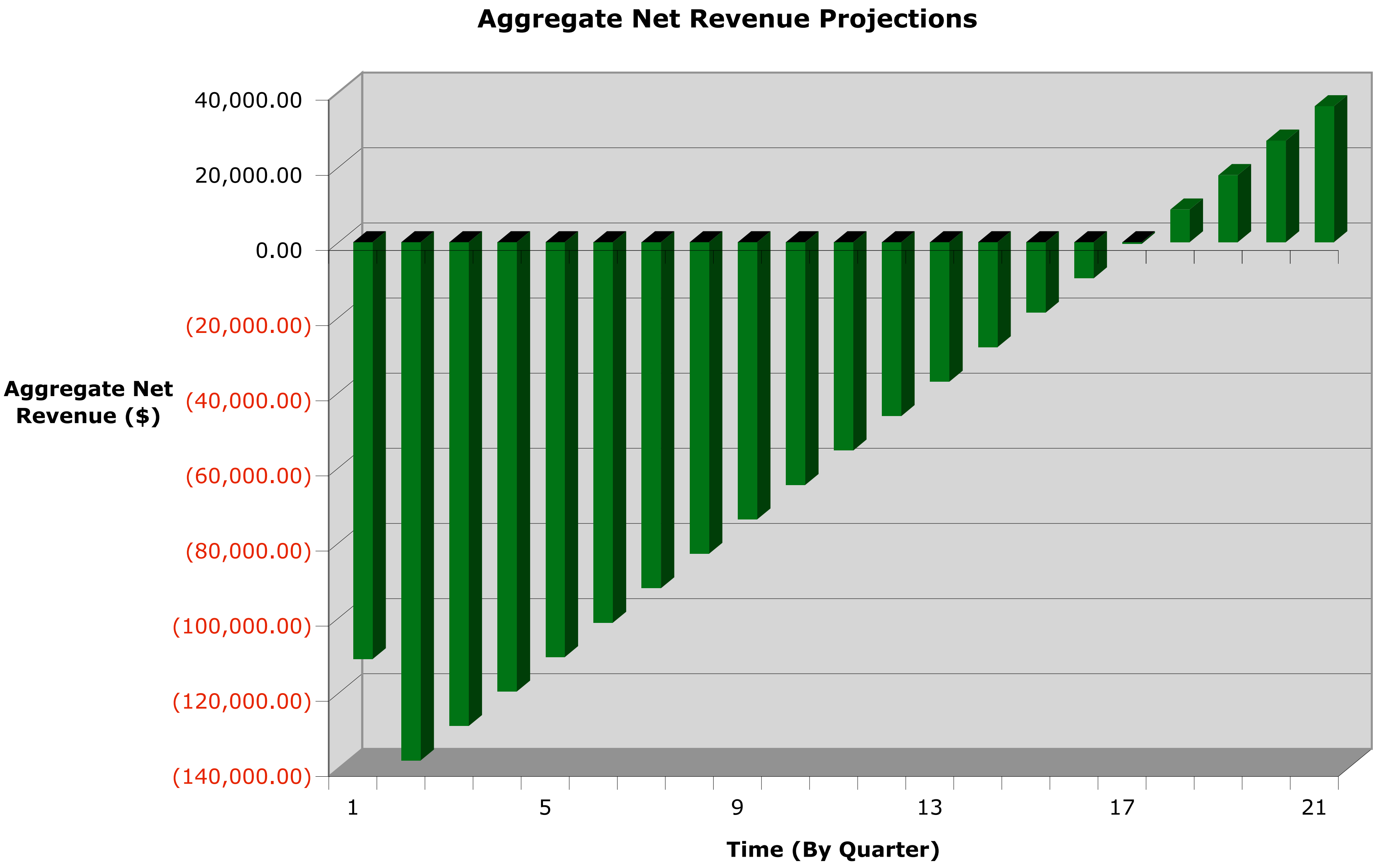
Appendix C

Balance Sheet

For Case Study, Inc.
For Period Ending in Year 1

Assets	**Year 1**
Current Assets	
Cash	$3,000.00
Accounts Receivable	$6,572.55
Inventory	$0.00
Total Current Assets	$9,572.55
Property, Plant, Equipment	
Equipment	
Front Loader	$10,000.00
Shredder	$20,000.00
In-Vessel Composting Reactor	$50,000.00
Less Depreciation	($3,750.00)
Total Property, Plant, and Equipment	$76,250.00
Total Assets	**$85,822.55**
Liabilities and Owners' Equity	**Year 1**
Liabilities	
Current Liabilities	$0.00
Accounts Payable	$0.00
Long-Term Liabilities	$76,250.00
Total Liabilities	$76,250.00
Owners' Equity	
Contributed Capital	$150,000.00
Dividends	($30,000.00)
Accumulated Retained Earnings	($110,452.69)
Total Owner's Equity	$9,547.31
Total Liabilities and Owners' Equity	**$85,797.31**

Appendix D



Aggregate Net Revenue Projections
40,000.00
20,000.00
0.00
(20,000.00)
(40,000.00)
(60,000.00)
(80,000.00)
(100,000.00)
(120,000.00)
(140,000.00)
Aggregate Net Revenue ($)
1
5
9
13
17
21
Time (By Quarter)

Appendix E

Monthly Wastewater Fee Calculations

Explanation of Method

In order to calculate the revenue the business gains from its water/wastewater bill that is 95% of that of the municipality, one must first measure the difference in the average annual bill at the Providence Courtyard and the hypothetical bill after retrofit to the new plumbing system.

	Existing Marriott Courtyard	**My Building**
Blackwater Consumption		
Water Consumption (gallons/flush)	1.6	0.125
Avg Flushes per day/person	5	5
People per Room	2	2
Toilet Water Use per day/room	*16*	*1.25*
Toilet Water Use (gallons/month)	**108,040**	**8,441**

Greywater Water Consumption		
Other Indoor Water Use (gallons per room/day)	71	71
Other Indoor Water Use (gallons/month)	***477,402***	***477,402***

Calculating the Water Bill

Total Water Consumption (gallons/month)	**585442**	**485842**
Price of Water ($/748.052 gallons)	$1.88	$1.88
State Water Fund Surcharge ($/748.052 gallons)	$0.22	$0.22
Variable Water Cost	$1,643.83	$1,364.17
Service Charge on 2” Meter (flat monthly rate)	$8.89	$8.89
State Tax on Water Sale	15.92%	15.92%
Total Water Cost per Month ($/building)	***$1,915.84***	***$1,591.66***

Calculating the Wastewater Bill

Wastewater Consumption* (gallons/month)	526,898	0
Price of Wastewater ($/748.052 gallons)	$3.35	$3.35
Service Charge on 2” Meter (flat monthly rate)	$167.75	$0.00
Environmental Pretreatment Fee (flat monthly rate)	$181.00	$0.00
Total Wastewater Cost ($/Month)	***$2,707.65***	$0.00

*Gallons of Wastewater Consumption on Providence Bill is Based on 90% of Metered Water Consumption

Appendix E

Calculating the Revenue per Unit

Water/Wastewater Bill	**Cost per Month**
Total Water/Wastewater Bill for Courtyard Building	$4,623.49
5% of Total Water/Wastewater Bill for Average Building	$231.17
Amount Business Will Charge Building for Water/Wastewater Treatment (95% of Water/Wastewater Bill for Average Building)	$4,392.31
Total Water/Wastewater Bill for Case Study Building (Amount Business Will Have to Pay to Municipality)	$0.00
Business Revenue from Water/Wastewater Charges Per Building	$4,392.31
Business Revenue per Unit	**$19.79**

Appendix F

Compost Volume Calculations

Values per Person	Per Day	Per Week	Per 2 Weeks	Per Month
Weight of Feces	**0.50 lb**	3.50 lb	7.00 lb	15.21 lb
Weight of Urine	**2.00 lb**	14.00 lb	28.00 lb	60.83 lb
Volume of Feces	**0.06 gal**	0.42 gal	0.84 gal	1.83 gal
Volume of Urine	**0.24 gal**	1.68 gal	3.36 gal	7.30 gal
Volume of Water	0.63 gal	4.38 gal	8.75 gal	19.01 gal
Weight of Newspaper	23 lb	160.07 lb	320.15 lb	695.56 lb

C/N Ratio
20

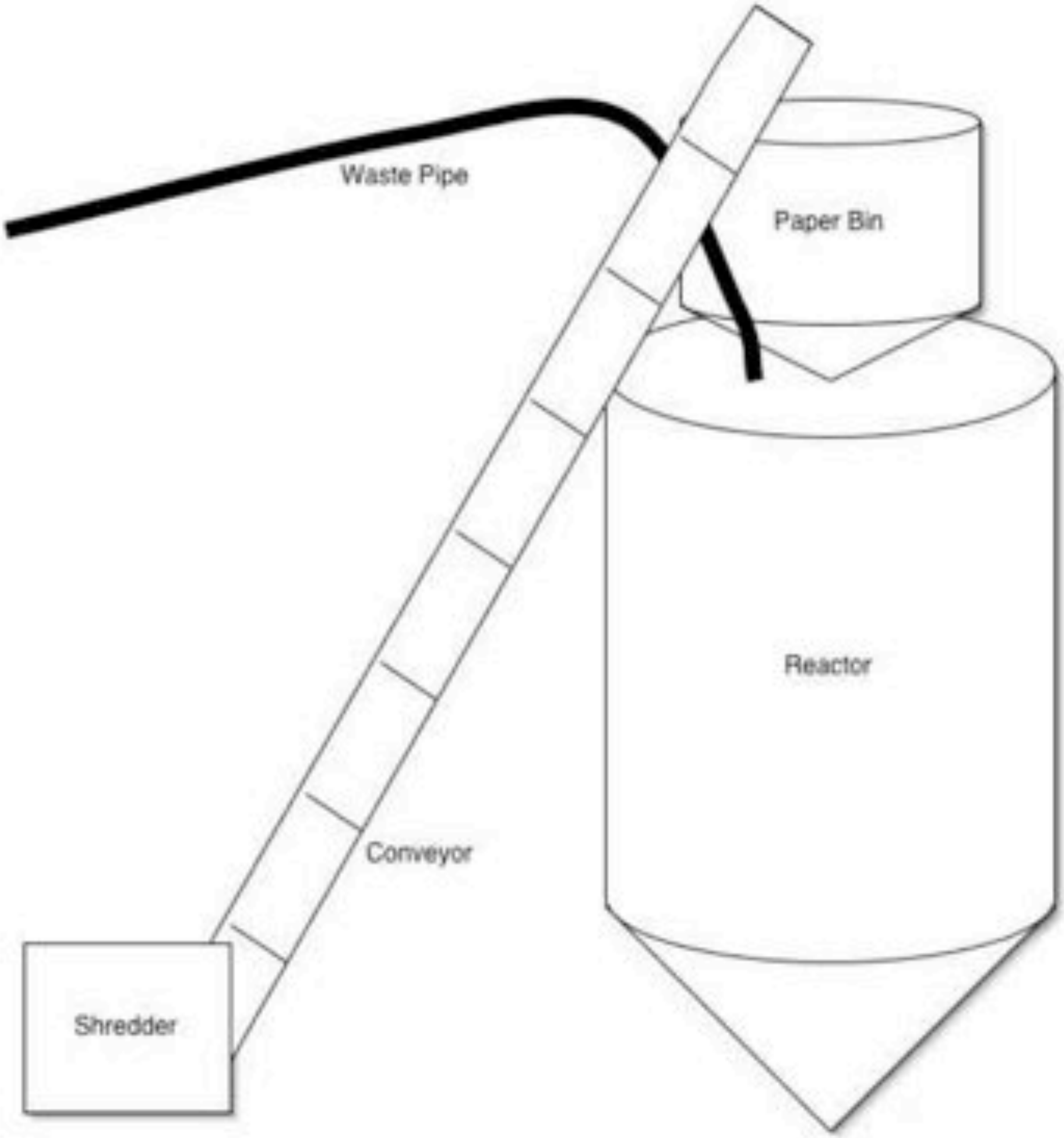
People/ Toilet
2

Building Totals	100 Toilets	200 Toilets	222 Toilets	300 Toilets	400 Toilets	500 Toilets
Volume Feces / month	365 gal	730 gal	811 gal	1095 gal	1461 gal	1826 gal
Volume Urine / month	1461 gal	2921 gal	3242 gal	4382 gal	5842 gal	7303 gal
Volume Water / month	3802 gal	7604 gal	8441 gal	11406 gal	15208 gal	19010 gal
Weight Feces / month	3042 lb	6083 lb	6753 lb	9125 lb	12167 lb	15208 lb
Weight Urine / month	12167 lb	24333 lb	27010 lb	36500 lb	48667 lb	60833 lb
Weight Water / month	31671 lb	63343 lb	70310 lb	95014 lb	126685 lb	158357 lb
Weight Paper / month	139112 lb	278223 lb	308828 lb	417335 lb	556446 lb	695558 lb
Total Weight	**185991 lb**	**371983 lb**	**412901 lb**	**557974 lb**	**743965 lb**	**929957 lb**
After 70% Mass Reduction	55797 lb	111595 lb	123870 lb	167392 lb	223190 lb	278987 lb
Finished Compost Volume	120.5 cu. yd	241.0 cu. yd	267.5 cu. yd	361.5 cu. yd	482.1 cu. yd	602.6 cu. yd
Value	**$5,423.07**	**$10,846.15**	**$12,039.22**	**$16,269.22**	**$21,692.29**	**$27,115.36**

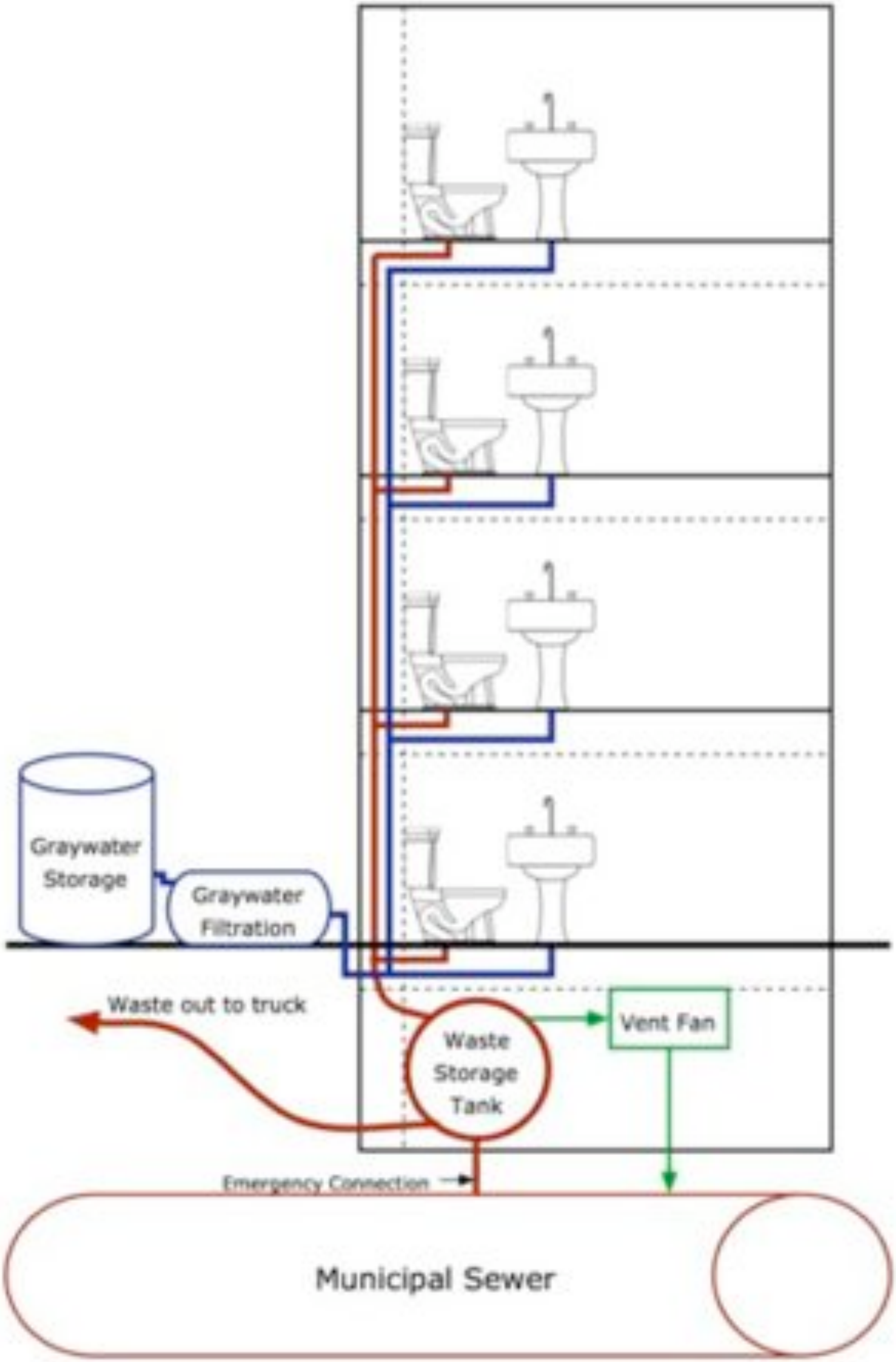
Warehouse Space Concerns	100 Toilets	200 Toilets	222 Toilets	300 Toilets	400 Toilets	500 Toilets
3 Month Total	362 cu. yd	723 cu. yd	803 cu. yd	1085 cu. yd	1446 cu. yd	1808 cu. yd
Sq. ft needed 4-high accounting for the rounded shape of the pile	2546 sq. ft	5093 sq. ft	5653 sq. ft	7639 sq. ft	10186 sq. ft	12732 sq. ft

Sub-total per 222 Toilets per two weeks (holding tank size)	**6247 gal**

Appendix G



Appendix H



Note: This diagram is a schematic and does not provide an accurate or scaled representation of the design of the plumbing system

Appendix I

Environmental Impact of the Business

Water Savings

Toilet Technology Displaced	Toilet Water Savings (gal/month)	Greywater Savings (gal/month)	Total Water Savings (gal/month)
Low Flush Toilet (1.25 gal/flush)	43,000	43,000	**86,000**
Conventional Toilet (3.5 gal/flush)	200,000	43,000	**243,000**

US Monthly Water Consumption = **127,000,000,000 gallons/month**
Water Savings as a Percentage of Total US Water Consumption = **0.00019%**

Fertilizer Savings

Source	Fertilizer Produced (lb/month)	Weight of Nitrogen Provided to Plants (lbs/month)
Compost Production from Courtyard	123,870	**6,051**
United States Fertilizer Production	19,095,751,440	**1,131,418,834**

Compost Produced as Percentage of Total US Production = **0.00053%**

Wastewater Savings

Source	Wastewater (gallons/month)
Wastewater Averted from Courtyard	**526,898**
Wastewater Processed in Providence	**40,230,000**

Percentage of Providence Wastewater Processed = **1.3%**
Area Required to Process Providence's Wastewater = **535,000 ft^2 or 9.3 football fields of factory space**

Appendix J

Calculating the Negative Environmental Effects of the Business

Price of Carbon ($/ton)	12

Explanation of Method

While the business will be more environmentally responsible than its competitors, it will not be devoid of negative externalities. This appendix seeks to estimate the environmental costs of doing business by calculating the carbon dioxide emissions totals from waste and paper collection.

Step 1) Calculating CO_2 Emissions from the Waste Transport

Miles Driven per Pickup	Waste Pickups per Month	CO_2 Emissions per Mile	Yd^3 of Compost per Month	**CO_2 Emissions (lb/yd^3)**
10	2	2.45	267.5	**0.18**

Step 2) Calculating CO_2 Emissions from the Paper Collection

Scale of Paper Collection Operation

Paper Recycled in NYC (lb/day)	Population of NYC	Recycling Rate (lb/person)	Paper Recycled in Providence at this Rate (lbs/day)	Lbs of Paper Needed by Business per Day	Percent of Total Paper Recycling
2,600,000	8,100,000	32.1%	56,255	2268	4.0%

Emissions of Paper Collection

Lbs of Paper Needed per Month	Yd^3 of Compost per Month	Lbs of Paper per Yd^3	Number of Newspapers per Day per Yd^3	Miles Traveled per Newspaper (mi/wk)	**CO_2 Emissions (lb/yd^3)**
70310	267.5	263	8.5	0.5	**41.54**

Step 3) Calculating the Social Cost of Carbon Emissions from the Business

CO_2 Emissions from Waste Transport (lb/yd^3)	CO_2 Emissions from Paper Collection (lb/yd^3)	Total CO_2 Emissions (lb/yd^3)	Cost of CO_2 Emissions per Lb	**Social Cost per Yd^3 of Compost**
0.18	41.54	41.72	0.006	**$0.25**

Appendix K

Analysis of Business' Impact on National Nitrogen Fertilizer Market

US Nitrogen Fertilizer Consumption by Fertilizer Type

Fertilizer	Anhydrous Ammonia	Ammonia Nitrate	Ammonia Sulfate	Nitrogen Solutions	Sodium Nitrate	Urea
2006 Fertilizer Consumption (tons)	4,219,538	963,710	1,218,964	10,104,319	17,219	5,369,913
Nitrogen Content by Mass	82%	34%	21%	30%	16%	46%
2006 Nitrogen Consumption (tons)	3,460,021.16	327,661.40	255,982.44	3,031,295.70	2,755.04	2,470,159.98

Breakdown of Total US Agricultural Nitrogen Consumption

Weight of Nitrogen Produced by Artificial Fertilizer Companies (lbs/year)	Percentage of Nitrogen Dedicated to Slow Release Fertilizer Market	Weight of Nitrogen in Slow Release Fertilizer (lbs/year)	Weight of Nitrogen in Non-Slow Release Fertilizers	Percent of Artificial Fertilizer Lost to Leaching	Amount of Nitrogen Delivered to Plants by Artificial Fertilizer (lbs/year)
19,095,751,440	3.67%	700,000,000	18,395,751,440	30%	13,577,026,008

Market Share Capture by Business' Compost

Volume of Compost Produced by Business (yd^3/year)	Weight of Nitrogen in Cubic Yard of Compost	Weight of Nitrogen in Compost Produced by Business (lbs/year)	Compost's Percentage of Slow Release Fertilizer Market	Compost's Percentage of Nitrogen Nutrients Provided to Plants
3210.459069	22.62	72610.88	0.01037%	0.00053%

Environmental Impact of Displacing Slow Release Nitrogen Fertilizer with My Compost

Plant Size	Courtyard-Scale Factory (7,000 ft^2)	Providence-Scale Factory (535,000 ft^2)
Natural Gas Saved (lbs/year)	68,129	5,205,047
CO_2 Emissions Reduction (lbs/year)	1,108,464	84,686,671
Gallons of Gas Equivalent in CO_2 Emission Reduction	56,554	4,320,749

Appendix L - Cost of Nitrogen in Yd^3 of Compost

Nutrient Content of Waste

	Nitrogen	Phosphorous	Potassium
Weight of Feces (lb per person/day)	0.50	0.50	0.50
Nutrient Content of Solid Waste (% by Weight)	6%	4.70%	1.75%
Weight of Nutrient in Solid Waste (lb per person/day)	**0.03**	**0.0235**	**0.00875**
Weight of Urine (lb per person/day)	2.00	2.00	2.00
Nitrogen Content of Urine (% by Mass)	19%	3.75%	3.75%
Weight of Nutrient in Urine (lb per person/day)	**0.38**	**0.08**	**0.08**
Weight of Newspaper (lb per person/day)	23	23	23
Nitrogen Content of Newspaper	0.17%	0.00%	0.00%
Weight of Nutrient in Newspaper (lb per person/day)	**0.04**	**0.00**	**0.00**
Weight of Nutrient (lb per person/day)	***0.45***	**0.10**	**0.08**

Calculating the Value of Phosphorous

Cost of Super-Phosphate ($/ton)	$418.00
Phosphate Content in Super-Phosphate (% by weight)	45%
Weight of Phosphate in Ton Super-Phosphate (lb P_2O_5)	900
Phosphorus Content in Phosphate (% by weight)	44%
Weight of Phosphorous in Ton of Super-Phosphate	393
Value of lb of Phosphorous ($/lb P)	**$1.06**

Calculating the Value of Potassium

Cost of Potassium Chloride ($/ton)	$280.00
Potassium Content in Potassium Chloride (% by weight)	60%
Weight of Potassium in Ton of Potassium Chloride (KCL)	1200
Value of lb of Potassium ($/lb K)	**$0.23**

Marginal Cost of Producing yd^3 of Compost (Excludes Marketing Costs)

Truck Cost	($1.12)
Newspaper Cost	($6.73)
Factory Rent	($8.63)
Portion of Salary Dedicated to Production (75%)	($22.43)
Portion of Payroll Taxes Dedicated to Production (75%)	($1.90)
Total Marginal Cost ($/yd^3)	**($40.81)**

Marginal Value in yd^3 of Compost (Not Including Value of Nitrogen)

Value Add to yd^3 of Compost by UP and I Macronutrients	**$6.27**
Weight of Phosphorous in Compost (lb P/yd^3)	4.97
Value of Phosphorous in Compost ($/yd^3)	$5.29
Weight of Potassium in Compost (lb P/yd^3)	4.23
Value of Potassium in Compost ($/yd^3)	$0.99
Value Added by Wastewater Fee ($/yd3 of Compost)	**$16.42**
Total Value Added by Other Macronutrients and Fees	**$22.69**

Cost of Producing the Nitrogen in the Compost

Cost of Producing Nitrogen in One Cubic Yard of Compost	($18.11)
Weight of Nitrogen in Compost (lb N/yd^3)	22.62
Cost of One lb of Nitrogen in Compost ($/lb)	**($0.80)**

Conclusion: The cost of producing N at $0.80/lb is within $0.65-$0.80/lb range for slow release N fertilizers, the primary competitor of compost.

Appendix M - The Economics of the Case Study: Will It Be Able to Raise Funds?

Analyzing the Return on Equity

In determining whether to invest in a startup, investors typically start by analyzing whether the return on their equity investment is commensurate with the risk of the investment

Equity Investment Required **$150,000.00**

	Year 1	Year 2	Year 3	Year 4	Year 5
Return to Investors	$29,974.76	$36,664.49	$36,664.49	$36,664.49	$36,664.49
Return on Equity	19.98%	24.44%	24.44%	24.44%	24.44%

Annualized Return on Equity (ROE) over Five Years	**23.55%**
Target Minimum Annualized ROE for Startups	25%-40%

Conclusion:
Since the ROE is less than that generally required for risky startup investments, the business will struggle to raise funds under the current conditions.

Analyzing the Business as an Internal Investment Project

In this model, the business is evaluated as a project with a cash outflow of -150,000 in year 0 and then positive returns in each year thereafter.

Scenario 1: No Discounting

	Year 0	Year 1	Year 2	Year 3	Year 4	Year 5
Non-Discounted Return to Investors	($150,000.00)	$29,974.76	$36,664.49	$36,664.49	$36,664.49	$36,664.49

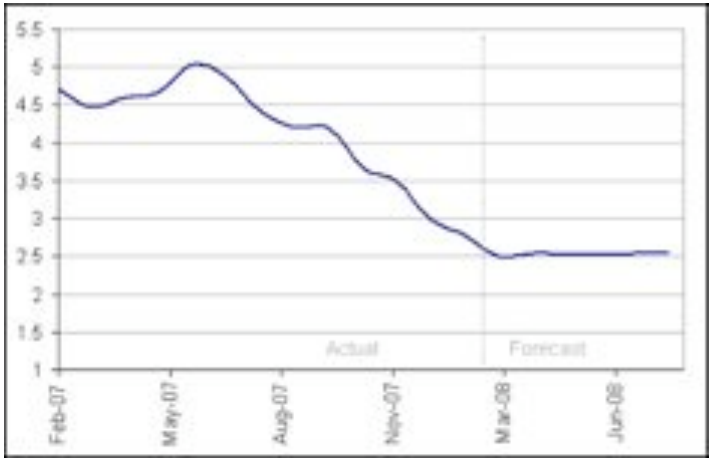
Return on Investment over Five Years	17.76%
Annualized Return over Five Years	**3.32%**

Conclusion:
Without accounting for the time value of cash, the business is a viable investment with a positive annual return on investment; however, this is an optimistic estimate that does not incorporate risk into the assessment.

Scenario 2: Discounting at the Opportunity Cost of Capital

	Mar-08	Feb-08
Five-Year Treasury Constant Maturity	2.51%	2.72%

Risk Free Rate of Return = 2.5%



Interest Rate on Five Year Treasury Bonds

	Year 0	Year 1	Year 2	Year 3	Year 4	Year 5
Discounted Cash Flows (by Risk Free Rate)	($150,000.00)	$29,240.81	$34,890.98	$34,036.66	$33,203.26	$32,390.26

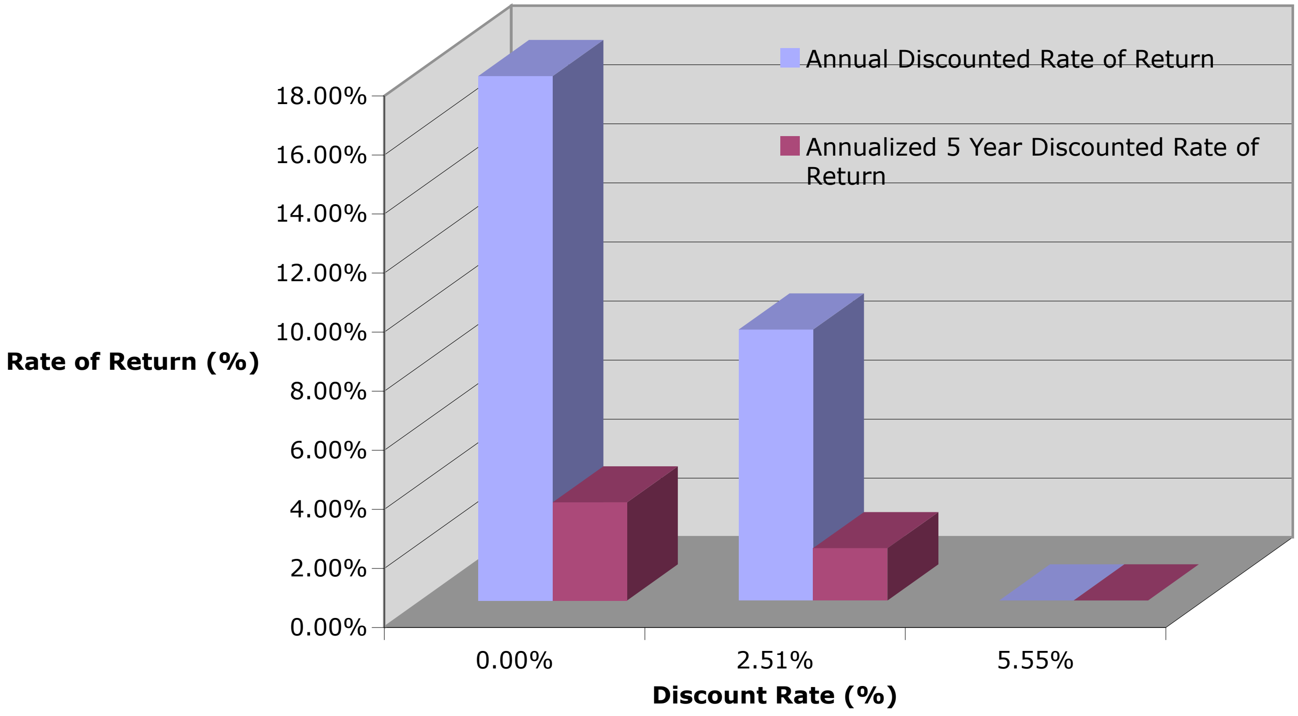
Net Present Value	$13,761.96
Discounted Return on Investment over Five Years	9.17%
Annualized Discounted Return on Investment	1.77%

Conclusion:

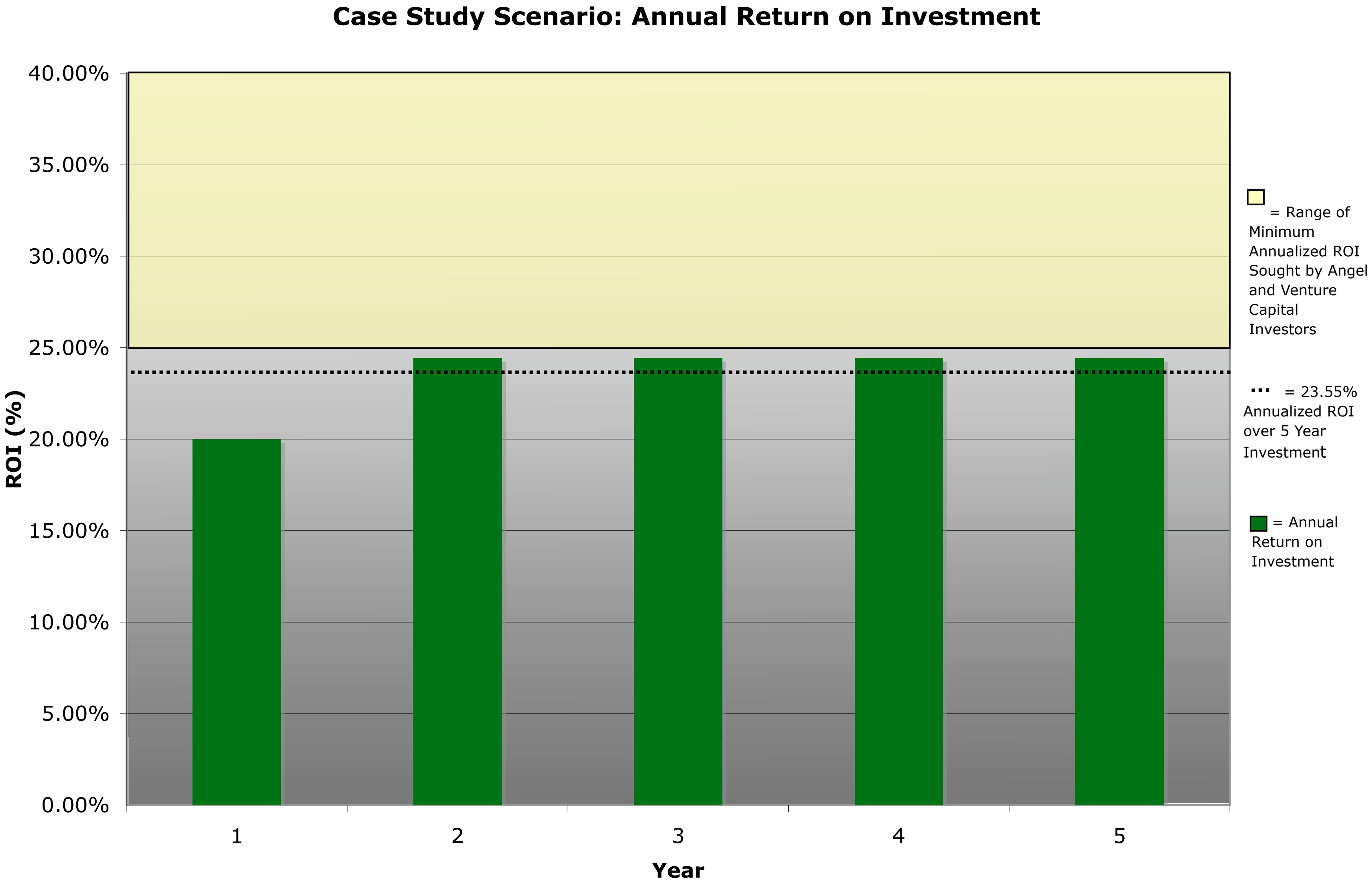
The business is still a viable investment with a positive net present value even when discounted for the opportunity cost of a risk free investment in treasury bonds. This model still does not take account for the risk of the investment. As shown below, the internal rate of return (discount rate that sets the NPV of the project to 0) of the investment is 5.55% so theoretically the project is only a good investment if the risk portion of the discount rate is less than or equal to 3.05%.

Internal Rate of Return	5.55%

Rate of Return on Business Investment at Varying Discount Rates



Appendix M



Case Study Scenario: Annual Return on Investment
40.00%
35.00%
30.00%
25.00%
20.00%
15.00%
10.00%
5.00%
0.00%
ROI (%)
1
2
3
4
5
Year
= Range of Minimum Annualized ROI Sought by Angel and Venture Capital Investors
= 23.55% Annualized ROI over 5 Year Investment
= Annual Return on Investment

Appendix N - External Cost of Producing Inorganic Fertilizers

Price of Carbon ($/ton)	12.00

Explanation of Method

Since compost and artificial fertilizers contain different nutrients to foster plant growth, one must find a common ground on which to compare their cost. As the primary macronutrient (along with carbon) required for plant growth and the most valuable nutrient in compost, nitrogen was the natural element selected. Thus, I base all of my comparisons of compost to artificial fertilizer not on the cost per cubic yard or lb, but the cost of nitrogen per lb.

	Cost of lb of N in this Product
My Compost	$0.80
Slow-Release Nitrogen Fertilizer	$0.65-$0.80

Without incorporating external costs, my compost falls within the upper bracket of slow-release nitrogen fertilizer products.

Calculating the External Cost of Producing lb of N from Natural Gas

Step 1) Finding CO_2 Equivalent Emissions from Natural Gas Production and Transport

Greenhouse Gas Emissions from the Production and Transport of Natural Gas	Emissions (g/kg of natural gas)	Greenhouse Warming Potential	CO^2 Equivalent Emissions (g/kg natural gas)
Carbon Dioxide	10620	1	10620
Methane	60	21	1256
Nitrous Oxide	0.04	310	12
Total (g CO_2 eq emissions/kg natural gas)			**11888**

Energy Content of Natural Gas (GJ/kg)	0.050
Energy Requirements for Manufacture of Anhydrous Ammonia (GJ/ton)	35
Amount of Natural Gas Required to Manufacture Ton of Anhydrous Ammonia (kg/ton)	699.44
Nitrogen Content of Anhydrous Ammonia (% by mass)	82%
Amount of Natural Gas Require to Manufacture Ton of Nitrogen (kg/ton)	852.98
Carbon Equivalent Emissions of Natural Gas Required to Produce One Ton of N (kg $C0_2$ eq)	8315.09
Carbon Equivalent Emissions Required to Produce One lb of Nitrogen (lb C02 eq)	**9.17**

Step 2) Finding CO_2 Emissions from Energy Consumed in Production of Nitrogen Fertilizer

In "A Review of Greenhouse Gas Emission Factors for Fertilizer Production", the emissions are measured from 13 nitrogen fertilizer production plants. The mean was 3 lb CO2/lb of N	**3.00**

Appendix N - External Cost of Producing Inorganic Fertilizers

Step 3) Estimating the Emissions from Nitrogen Lost to the Atmosphere as Nitrous Oxide

There is insufficient data to quantify the cost of eutrophication from the leaching of nitrogen fertilizers. However, even slow release artificial fertilizers lose approximately 1% of nitrogen to the atmosphere as nitrous oxide.

Nitrous Oxide Emissions per lb of N	Greenhouse Warming Potential	CO^2 Equivalent Emissions (lb)
0.01	310	**3.10**

Step 4) Sum the Emissions and Multiply by the Market Value of Carbon Dioxide Emissions

Emissions from Natural Gas Used to Make Fertilizer	9.17
Emissions from Energy Used to Produce Fertilizer	3.00
Emissions from Nitrogen Lost to Air During Farming	3.10
Total (lb of CO_2 eq/lb of N)	15.27

Average Market Value of lb of CO_2	$0.006
External Cost of lb of N	**$0.09**

Weight of N in Cubic Yard of Compost (lb)	22.62
External Cost of Artificial Fertilizer Cubic Yard Equivalent of Compost (lb)	**$2.07**

Appendix O

Fertilizer Scenario 1: Will Business Be Able to Raise Funds?

Analyzing the Return on Equity

In determining whether to invest in a startup, investors typically start by analyzing whether the return on their equity investment is commesurate with the riskiness of the investment

Equity Investment Required	**$150,000.00**				
	Year 1	**Year 2**	**Year 3**	**Year 4**	**Year 5**
Return to Investors	$34,737.41	$43,310.05	$43,310.05	$43,310.05	$43,310.05
Return on Equity	23.16%	28.87%	28.87%	28.87%	28.87%
Annualized Return on Equity (ROE) over Five Years	**27.73%**				
Target Minimum Annualized ROE for Startups	25%-40%				

Analyzing the Business as an Internal Investment Project

In this model, the business is evaluated as a project with a cash outflow of -150,000 in year 0 and then positive retuns in each year thereafter.

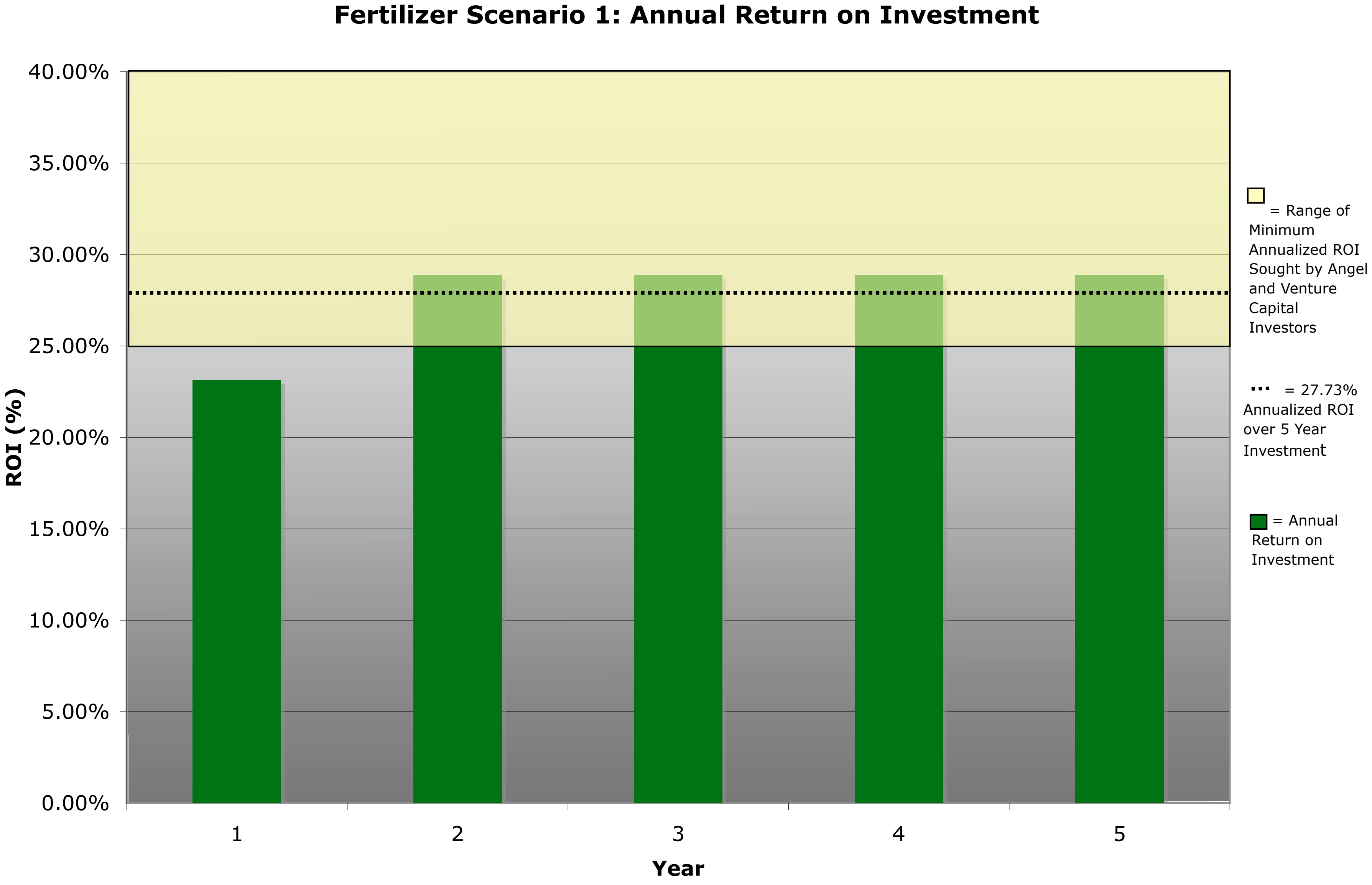
Scenario 1: No Discounting

	Year 0	**Year 1**	**Year 2**	**Year 3**	**Year 4**	**Year 5**
Non-Discounted Return to Investors	($150,000.00)	$34,737.41	$43,310.05	$43,310.05	$43,310.05	$43,310.05
Return on Investment over Five Years	38.65%					
Annualized Return over Five Years	**6.75%**					

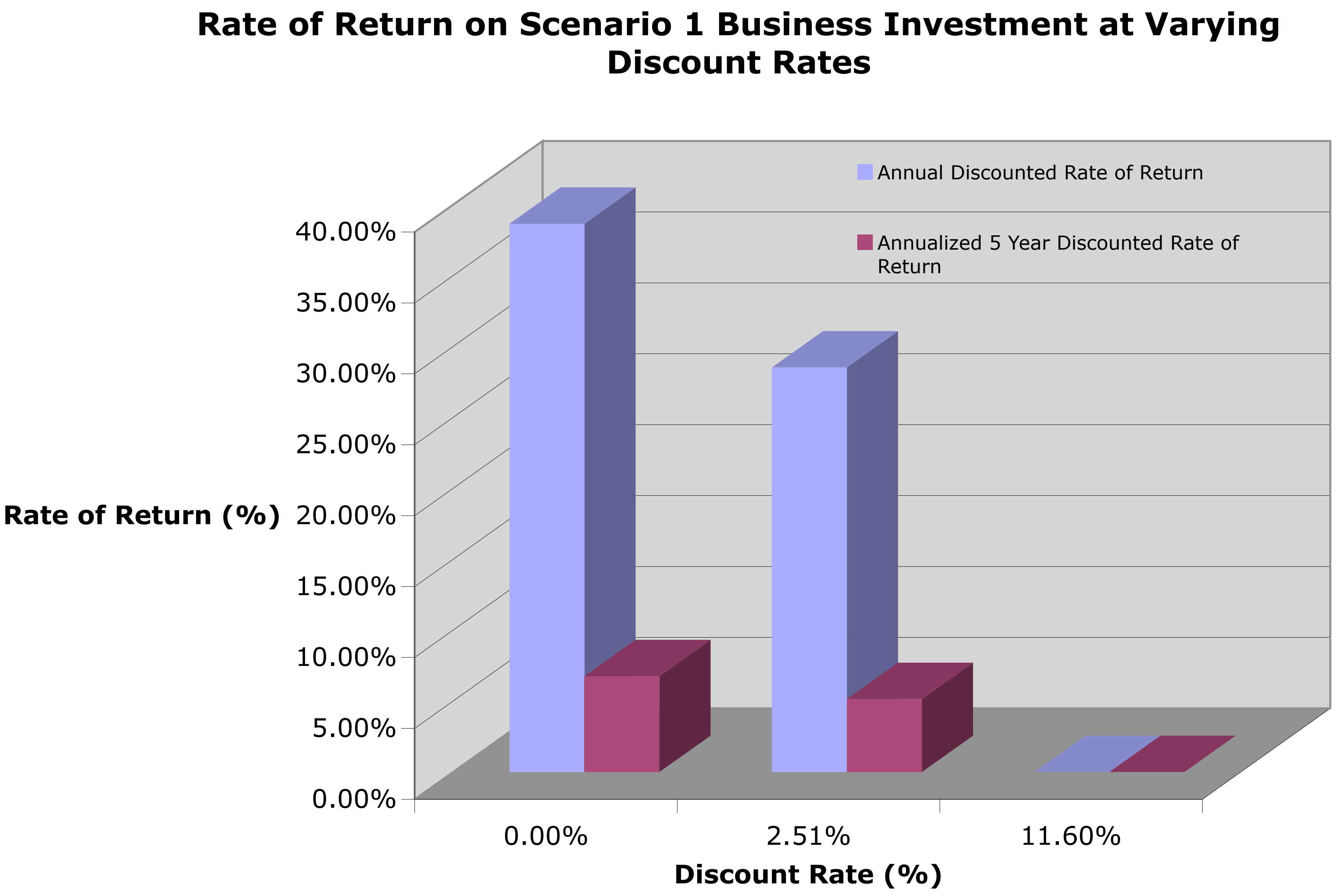
	Year 0	**Year 1**	**Year 2**	**Year 3**	**Year 4**	**Year 5**
Discounted Cash Flows (by Risk Free Rate=2.5%)	($150,000.00)	$33,886.85	$41,215.08	$40,205.92	$39,221.46	$38,261.10
Net Present Value	$42,790.41					
Discounted Return on Investment over Five Years	28.53%					
Annualized Discounted Return on Investment	5.15%					

Internal Rate of Return	11.60%

Appendix O


Fertilizer Scenario 1: Annual Return on Investment
40.00%
35.00%
30.00%
25.00%
20.00%
15.00%
10.00%
5.00%
0.00%
ROI (%)
1
2
3
4
5
Year
= Range of Minimum Annualized ROI Sought by Angel and Venture Capital Investors
= 27.73% Annualized ROI over 5 Year Investment
= Annual Return on Investment

Appendix O


Rate of Return on Scenario 1 Business Investment at Varying Discount Rates
Annual Discounted Rate of Return
Annualized 5 Year Discounted Rate of Return
Rate of Return (%)
40.00%
35.00%
30.00%
25.00%
20.00%
15.00%
10.00%
5.00%
0.00%
0.00%
2.51%
11.60%
Discount Rate (%)

Appendix P - Estimating the External Cost of Centralized Wastewater Treatment Systems

Price of Carbon ($/ton)	12

Explanation of Method

There are three primary externalities resulting from the modern centralized wastewater treatment system:

1) the CO_2 emissions from the energy consumed building the massive wastewater infrastructure, moving the wastewater, and treating it

2) The CO_2 equivalent emissions from the methane and nitrous oxide emitted during the wastewater treatment process

3) Water pollution from the release of untreated sewage water during peak capacity, "treated" wastewater with high concentrations of nitrogen and phosphorous (the two primary contributors to eutrophication), and "treated" wastewater with high concentrations of chlorine (a neurotoxin that is detrimental to living organisms).

In odor to put the external costs in a common unit for summation, I quantified the cost of each externality per 100 cubic feet (ccf).

Calculating the External Cost of Centralized Wastewater Treatment

Step 1) Calculating the CO_2 Emission of the Average Municipal Waste Treatment System (per ccf treated)

Emissions from Municipal Wastewater Treatment Plants (billion g CO_2 eq/year)	Municipal Wastewater Treated (billion gallons/year)	Emissions Per Gallon of Wastewater Treated (g/gal)	Tons of CO_2 eq/ccf Wastewater Treated	Price of CO_2 eq/ton	**External Cost of Wastewater Treatment Emissions ($/ccf)**
15500	14600	1.061643836	0.000875415	12	**$0.011**

Step 2) Calculating the CO_2 Emission from the Construction of the Treatment Pant (per ccf treated)

According to the University of Michigan Center for Sustainable Systems, the construction of an average wastewater treatment plant represents 45% of the CO2 emissions over the life of the plant.

External Cost of Wastewater Treatment Emissions ($/ccf)	Percentage of Total CO2 Emissions from Waste Treatment	Total External Cost of CO2 Emissions from Wastewater Treatment	Percentage of CO2 Emissions from Wastewater Treatment Plant Construction	**External Cost of Plant Construction Emissions ($/ccf)**
0.010504983	55%	$0.016	45%	**$0.007**

Step 3) Calculating the CO_2 eq Emissions from the CH Emitted During Anaerobic Sludge Degradation

CH_4 Emissions (billion g /year)	Greenhouse Warming Potential	Municipal Wastewater Treated (billion gallons/year)	**External Cost of Methane Emissions ($/ccf)**
1210	21	14600	**$0.017**

Appendix P - Estimating the External Cost of Centralized Wastewater Treatment Systems

Step 4) Estimation of Water Pollution Externalities

According to a study on the "External Economic Costs and Benefits of Water and Solid Waste Investments," the addition of equipment to improve the environmental effectiveness of a wastewater treatment in Barbados added a flat rate of$178/year onto resident's wastewater bills. I will use this to find a low estimate for the water pollution externalities of wastewater treatment.

Cost of Environmental Plant Upgrade ($ per household/year)	**External Cost of Environmental Damage Caused by Municipal Wastewater Treatment Plants ($/ccf)**
$178	**$0.253**

Step 5) Sum the External Costs of Waste Treatment

External Cost of Wastewater Treatment Emissions ($/ccf)	**External Cost of Plant Construction Emissions ($/ccf)**	**External Cost of Methane Emissions ($/ccf)**	**External Cost of Environmental Damage Caused by Municipal Wastewater Treatment Plants ($/ccf)**	**Total External Cost of Municipal Wastewater Treatment ($/ccf)**
$0.011	**$0.007**	**$0.017**	**$0.253**	**$0.288**

Appendix Q

Wastewater Internalization Scenario 2: Will Business Be Able to Raise Funds?

Analyzing the Return on Equity

In determining whether to invest in a startup, investors typically start by analyzing whether the return on their equity investment is commesurate with the riskiness of the investment

Equity Investment Required	**$150,000.00**				
	Year 1	**Year 2**	**Year 3**	**Year 4**	**Year 5**
Return to Investors	$32,250.01	$39,018.19	$39,018.19	$39,018.19	$39,018.19
Return on Equity	21.50%	26.01%	26.01%	26.01%	26.01%
Annualized Return on Equity (ROE) over Five Years	**25.11%**				
Target Minimum Annualized ROE for Startups	25%-40%				

Analyzing the Business as an Internal Investment Project

In this model, the business is evaluated as a project with a cash outflow of -150,000 in year 0 and then positive retuns in each year thereafter.

Scenario 1: No Discounting

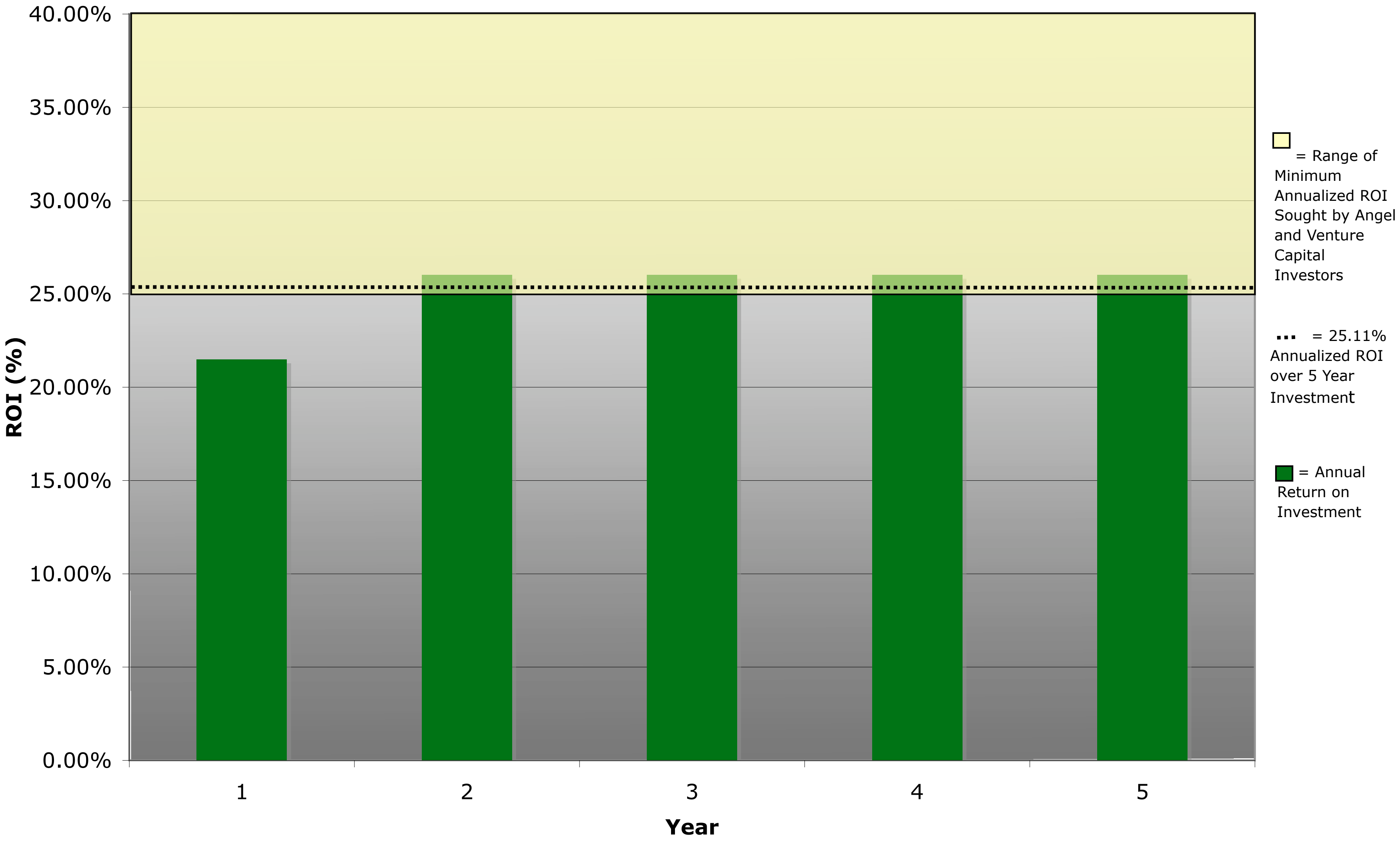
	Year 0	**Year 1**	**Year 2**	**Year 3**	**Year 4**	**Year 5**
Non-Discounted Return to Investors	($150,000.00)	$32,250.01	$39,018.19	$39,018.19	$39,018.19	$39,018.19
Return on Investment over Five Years	25.55%					
Annualized Return over Five Years	**4.66%**					

	Year 0	**Year 1**	**Year 2**	**Year 3**	**Year 4**	**Year 5**
Discounted Cash Flows (by Risk Free Rate=2.5%)	($150,000.00)	$31,460.35	$37,130.83	$36,221.67	$35,334.77	$34,469.58
Net Present Value	$24,617.20					
Discounted Return on Investment over Five Years	16.41%					
Annualized Discounted Return on Investment	3.09%					

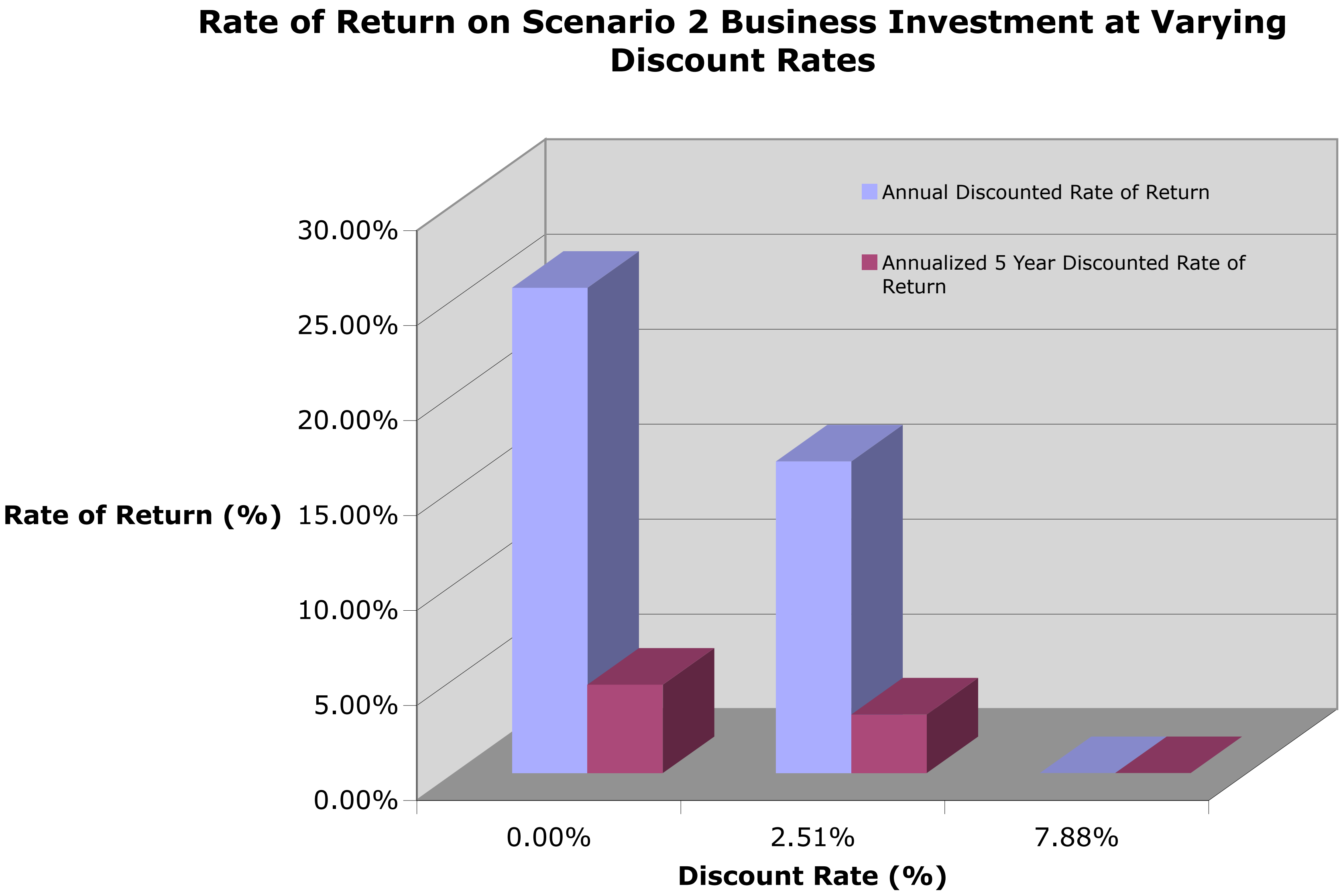
Internal Rate of Return	7.88%

Appendix Q

Wastewater Internalization Scenario 2: Annual Return on Investment



Appendix Q


Rate of Return on Scenario 2 Business Investment at Varying Discount Rates
Annual Discounted Rate of Return
Annualized 5 Year Discounted Rate of Return
30.00%
25.00%
20.00%
15.00%
10.00%
5.00%
0.00%
Rate of Return (%)
0.00%
2.51%
7.88%
Discount Rate (%)

Appendix R - Cost of Decentralized Septic Waste Treatment

Explanation of Method

Municipalities typically have to add 16 feet of pipe per new sewer connection at a cost of $59. However, in rural areas, the piping costs for adding a building to the system is prohibitively expensive and decentralized waste treatment is the norm. In order to determine the viability of my decentralized wastewater treatment in rural areas, I calculated the cost of the average septic system. Then, I normalized this cost by calculating the cost of the septic system amortized per unit per month.

Permitting Cost

Average Cost of Septic Tank Permit ($/installation)	Cost of RI Required Riser and Filter ($/installation)	Lifetime of Septic System (years)	**Amortized Cost of Installation Requirements ($/month)**
300	150	20	**$1.88**

System Cost

Size of a Septic System for a Two-Person Home (gallons)	Cost of Septic System ($/gallon)	Cost of Septic System Installation ($/unit)	Lifetime of Septic System (years)	**Amortized Cost of Septic Tank ($/month)**
1000	2.5	2500	20	**$10.42**

Maintenance Cost

Cost of Emptying Out Septic Tank	Number of Times Septic Tank is Emptied in a Year	Lifetime of Septic System (years)	**Cost of Emptying Septic Tank ($/month)**
250	0.5	20	**$10.42**

Cost of Septic System per Unit per Month (without discounting) = $22.71

Appendix S

Decentralized Rural Scenario 3: Will Business Be Able to Raise Funds?

Analyzing the Return on Equity

In determining whether to invest in a startup, investors typically start by analyzing whether the return on their equity investment is commesurate with the riskiness of the investment

Equity Investment Required **$150,000.00**

	Year 1	Year 2	Year 3	Year 4	Year 5
Return to Investors	$37,502.42	$44,451.72	$44,451.72	$44,451.72	$44,451.72
Return on Equity	25.00%	29.63%	29.63%	29.63%	29.63%

Annualized Return on Equity (ROE) over Five Years	**28.71%**
Target Minimum Annualized ROE for Startups	25%-40%

Analyzing the Business as an Internal Investment Project

In this model, the business is evaluated as a project with a cash outflow of -150,000 in year 0 and then positive retuns in each year thereafter.

Scenario 1: No Discounting

	Year 0	Year 1	Year 2	Year 3	Year 4	Year 5
Non-Discounted Return to Investors	($150,000.00)	$37,502.42	$44,451.72	$44,451.72	$44,451.72	$44,451.72

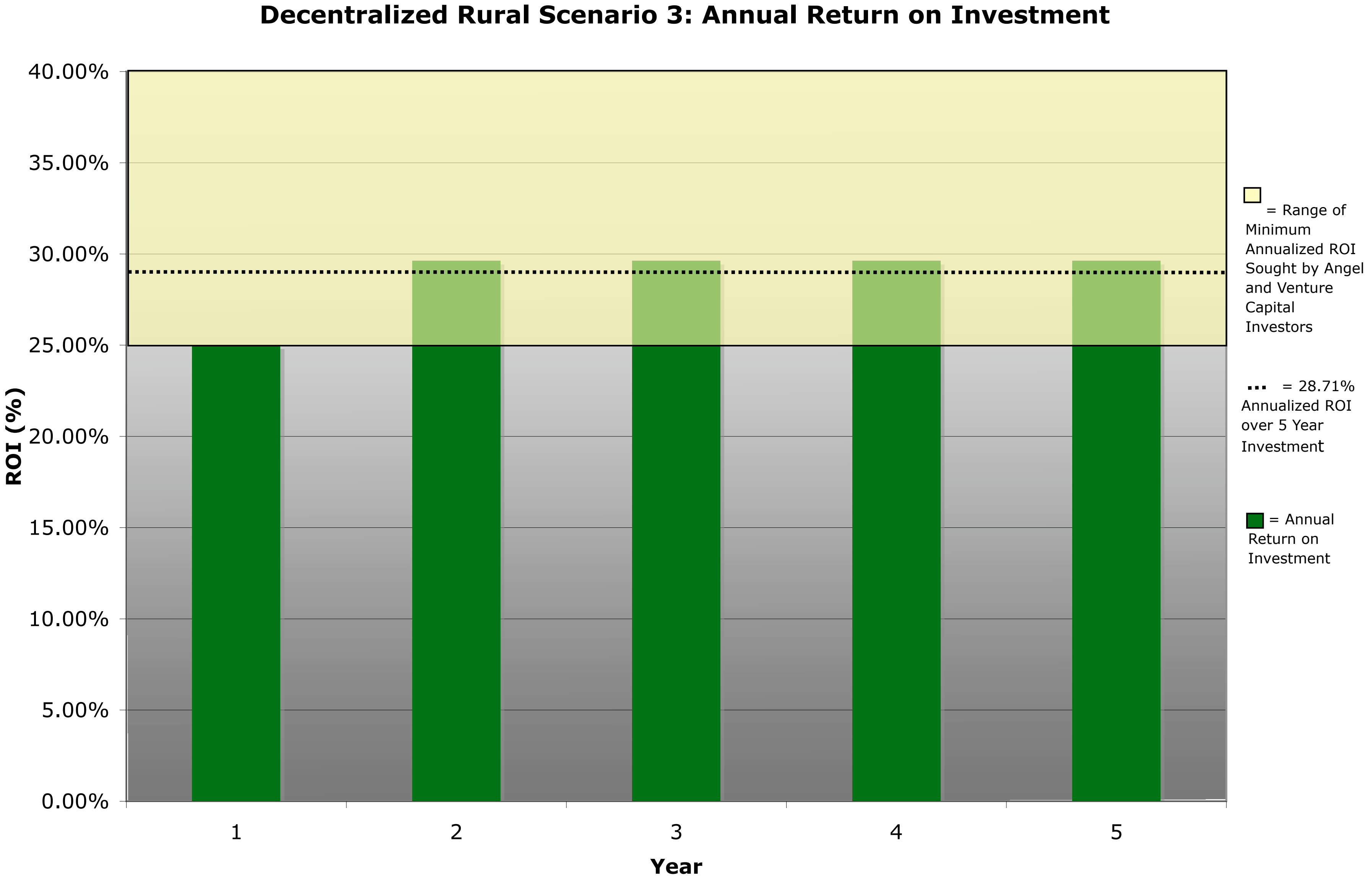
Return on Investment over Five Years	43.54%
Annualized Return over Five Years	**7.50%**

	Year 0	Year 1	Year 2	Year 3	Year 4	Year 5
Discounted Cash Flows (by Risk Free Rate=2.5%)	($150,000.00)	$36,584.15	$42,301.53	$41,265.76	$40,255.35	$39,269.68

Net Present Value	$49,676.48
Discounted Return on Investment over Five Years	33.12%
Annualized Discounted Return on Investment	5.89%

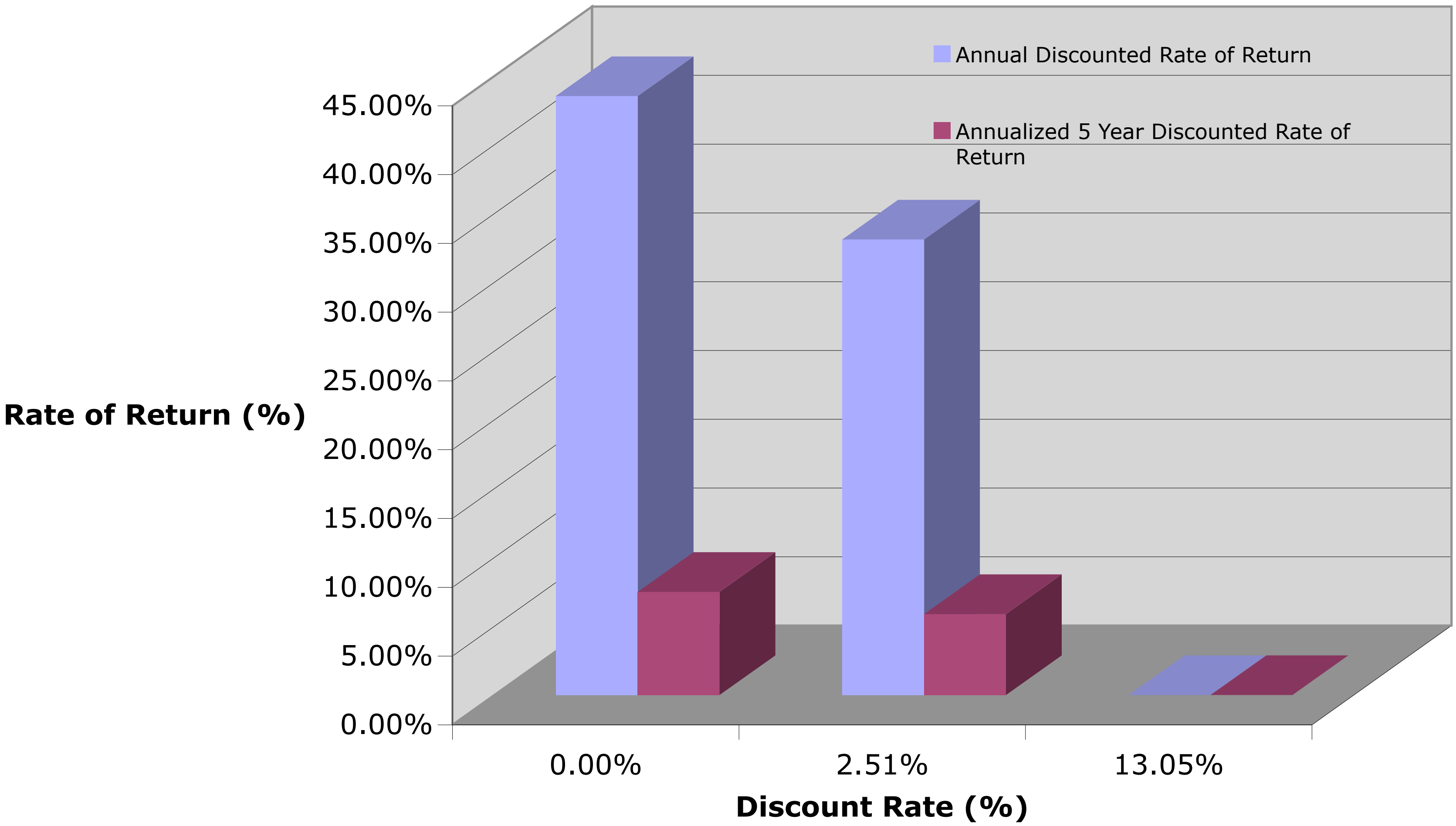
Internal Rate of Return	13.05%

Appendix S


Decentralized Rural Scenario 3: Annual Return on Investment
40.00%
35.00%
30.00%
25.00%
20.00%
15.00%
10.00%
5.00%
0.00%
ROI (%)
1
2
3
4
5
Year
= Range of Minimum Annualized ROI Sought by Angel and Venture Capital Investors
= 28.71% Annualized ROI over 5 Year Investment
= Annual Return on Investment

Appendix S

Rate of Return on Scenario 3 Business Investment at Varying Discount Rates



Appendix T - Marginal Cost of Adding Capacity to Municipal Waste Treatment System

Explanation of Method

Every municipality has a different sized wastewater treatment plant and population paying fees to finance that syst
projections.

Scenario 1) Average Sewer Rate Increase in Situation Where Significant Capacity is Not Added

Average Sewer Rate Increases Across Ohio

Year	(Accounting for Inflation)
1989	3.8%
1990	2.5%
1991	2.5%
1992	2.0%
1993	3.6%
1994	0.5%
1995	1.1%
1996	1.1%
1997	1.9%
1998	2.0%
10-Year Average Rate Increase	**2.1%**

Scenario 2) Average Sewer Rate Increase When Capacity is Added to the Wastewater Treament Plant. Data is compiled for Cities Similar in Size to Providence, RI, and Normalized Over the 5 Year Period Used for Financial Projections

Average Annual Rate Increase for Cities Adding Significant (>10%) Capacity to Wastewater Treatment Plant

Location	City Population	Total Rate Increase Over 5-Year Period	Average Annual Rate Increase
Arlington, Virginia	199,776	101.14%	15.00%
Bismarck, North Dakota	55,532	30.21%	5.42%
Charleston, South Carolina	107,845	21.00%	3.89%
Indianapolis, Indiana	785,597	86.47%	13.27%
Juneau, Alaska	30,711	39.00%	6.81%
Las Vegas, Nevada	552,539	33%	5.87%
Manchester, New Hampshire	109,497	57.23%	9.47%
Providence, Rhode Island	*175,255*	-	-
Salt Lake City, Utah	178,858	51.04%	8.60%
San Diego, California	1,256,951	35.40%	6.25%
Santa Monica	88,050	61.63%	10.08%
Seattle, Washington	582,454	39.50%	6.88%
Average	**394,781**	**55.56%**	**9.15%**

Appendix U

Margin of Overburdened Plant Scenario 4: Will Business Be Able to Raise Funds?

Analyzing the Return on Equity

In determining whether to invest in a startup, investors typically start by analyzing whether the return on their equity investment is commesurate with the riskiness of the investment

Equity Investment Required	**$150,000.00**				
	Year 1	**Year 2**	**Year 3**	**Year 4**	**Year 5**
Return to Investors	$34,636.76	$46,751.29	$46,751.29	$46,751.29	$46,751.29
Return on Equity	23.09%	31.17%	31.17%	31.17%	31.17%
Annualized Return on Equity (ROE) over Five Years	**29.55%**				
Target Minimum Annualized ROE for Startups	25%-40%				

Analyzing the Business as an Internal Investment Project

In this model, the business is evaluated as a project with a cash outflow of -150,000 in year 0 and then positive retuns in each year thereafter.

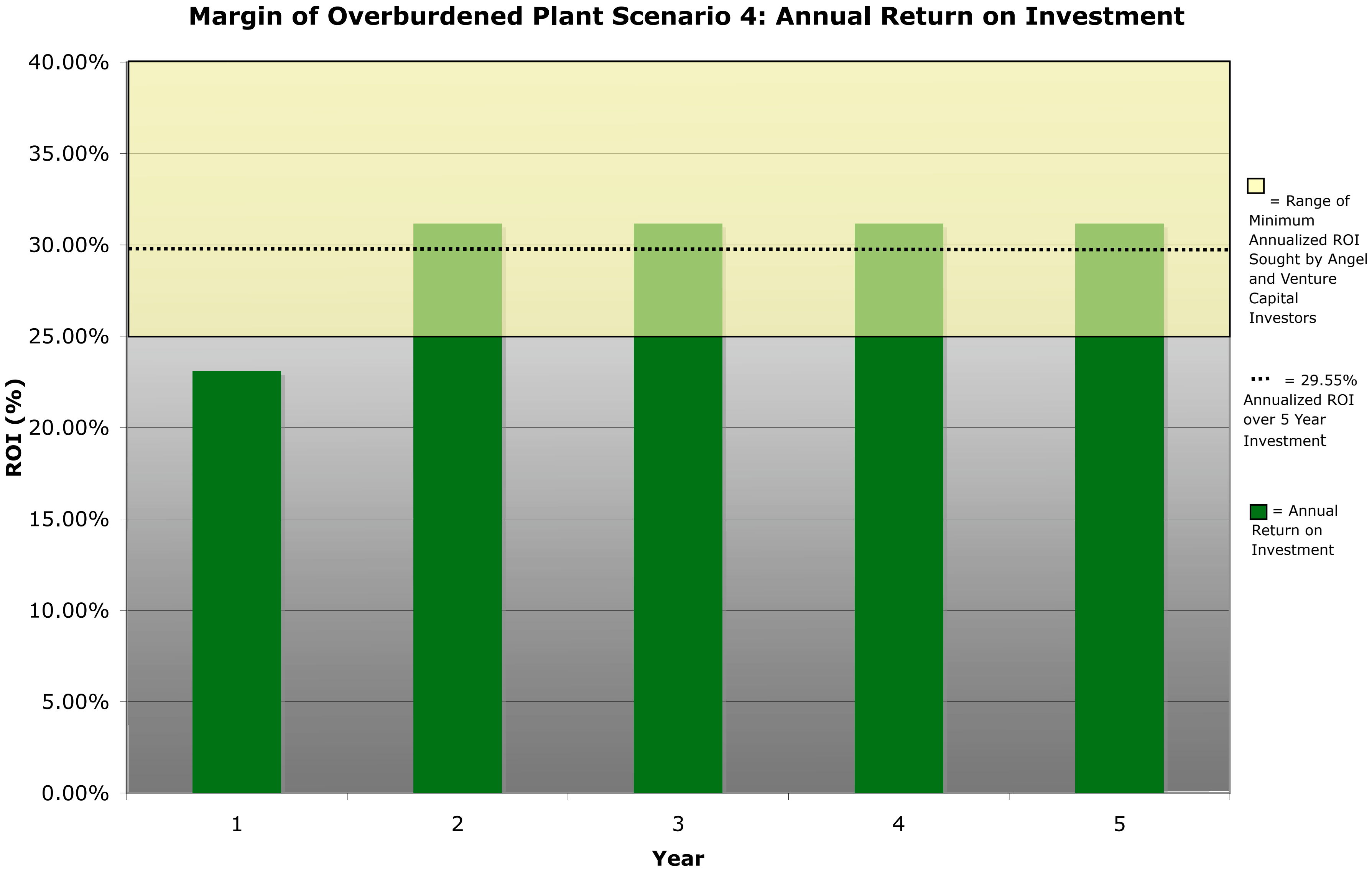
Scenario 1: No Discounting

	Year 0	**Year 1**	**Year 2**	**Year 3**	**Year 4**	**Year 5**
Non-Discounted Return to Investors	($150,000.00)	$34,636.76	$46,751.29	$46,751.29	$46,751.29	$46,751.29
Return on Investment over Five Years	47.76%					
Annualized Return over Five Years	**8.12%**					

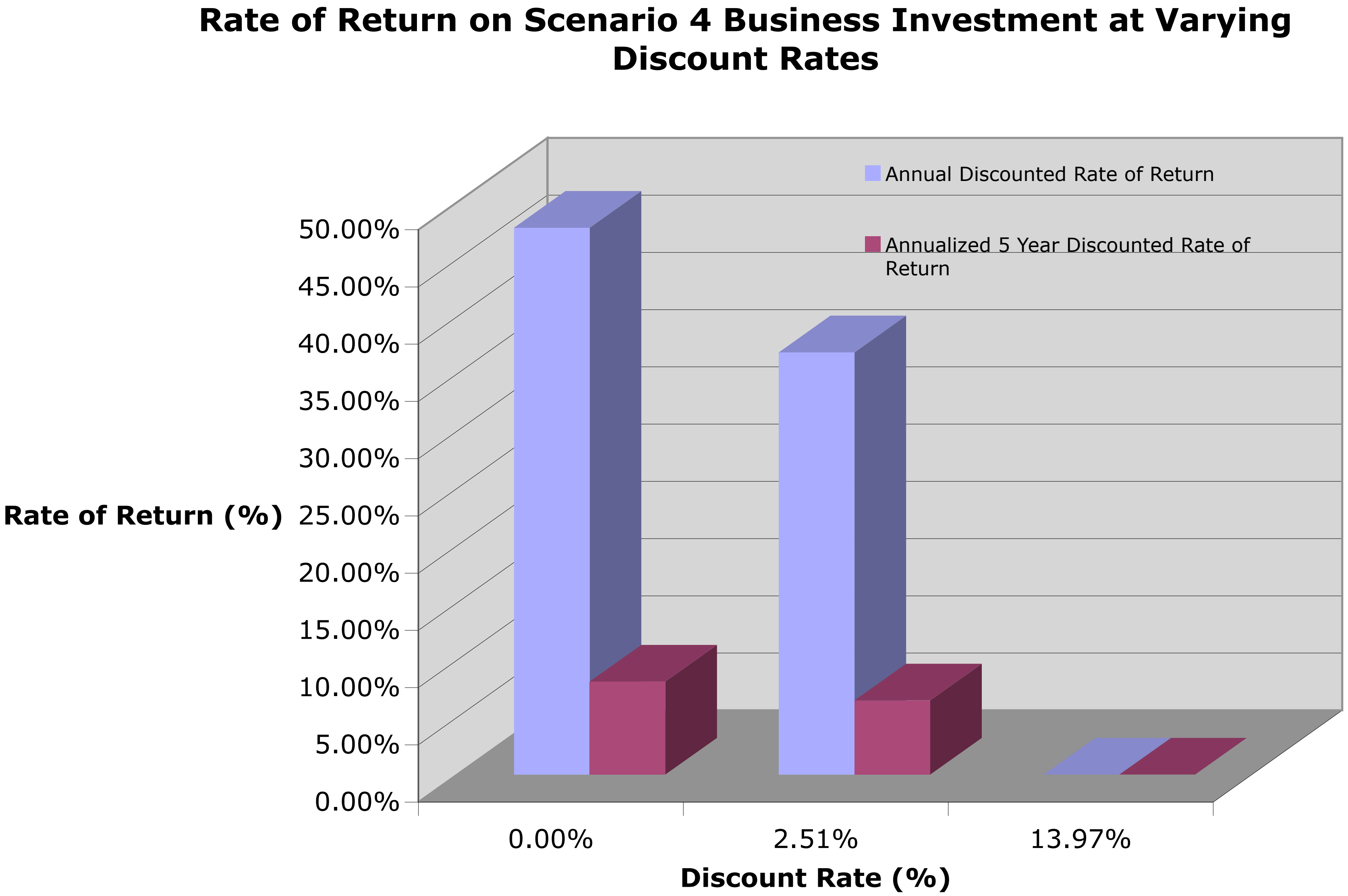
	Year 0	**Year 1**	**Year 2**	**Year 3**	**Year 4**	**Year 5**
Discounted Cash Flows (by Risk Free Rate=2.5%)	($150,000.00)	$33,788.66	$44,489.87	$43,400.52	$42,337.84	$41,301.18
Net Present Value	$55,318.06					
Discounted Return on Investment over Five Years	36.88%					
Annualized Discounted Return on Investment	6.48%					

Internal Rate of Return	13.97%

Appendix U


Margin of Overburdened Plant Scenario 4: Annual Return on Investment
40.00%
35.00%
30.00%
25.00%
20.00%
15.00%
10.00%
5.00%
0.00%
ROI (%)
1
2
3
4
5
Year
= Range of Minimum Annualized ROI Sought by Angel and Venture Capital Investors
= 29.55% Annualized ROI over 5 Year Investment
= Annual Return on Investment

Appendix U


Rate of Return on Scenario 4 Business Investment at Varying Discount Rates
Annual Discounted Rate of Return
Annualized 5 Year Discounted Rate of Return
Rate of Return (%)
50.00%
45.00%
40.00%
35.00%
30.00%
25.00%
20.00%
15.00%
10.00%
5.00%
0.00%
0.00%
2.51%
13.97%
Discount Rate (%)