Chapter

Compost, Social Sustainability, and Circular Economy in Guatemala

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Abstract

The research presented in this chapter explores a variety of objectives: first, what are the dynamics and associated requirements for initiating a new start-up composting business that would embrace the principles of Circular Economy? Secondly, is there a market for compost both in an urban environment and for farmers regionally in a development world economy such as Guatemala? With this, how can employment opportunities for at-risk youth from the most impoverished neighborhood in Guatemala City be created while adhering to the tenants of social sustainability? And finally, what were the requirements involved in making compost in the challenging high altitude climatic conditions of Guatemala City?

Keywords: compost, social sustainability, circular economy, Guatemala

1. Introduction

This chapter reports on the success and failure of making compost for soil amendment using green waste from a large fruit and vegetable market situated in Guatemala City, Central America. Perhaps the term "failure" is inappropriate and should be referred to as, "factors that contributed to limiting the intended success of a start-up business." For anyone who has initiated a new business, you are continuously faced with innumerable problems complicating its success—such as the availability of skilled labor, licensure, market dependability for your product, managing the costs for materials, adapting to unpredictable weather and climate, marketing or branding of your product, and 100 s of other variabilities beyond your control. Perhaps the more successful ventures are those who can remain flexible and adapt quickly to externalities. Starting a new business and managing it on a daily basis is not for the faint of heart, however if the passion for what you have intended to accomplish is great and if it can bring significant improvement for people, the environment, and local economies, then this alone is a measurement of success. The challenges and "failings" of this work are discussed in the Results and Discussion section of this chapter.

Yet, how does one measure success in a broader context and how does one know that their efforts were productive and effective? For this research project, creating change within the lives and future prospects of perhaps the most disadvantaged youth from one of the poorest neighborhoods in the capital city of a developing world nation—Guatemala City—became the key measurement of success.

Certainly, developing a successful business that embraced the principles of circular economy while not losing money and remaining solvent were equally important. However as stated above, achieving measurable social sustainability was the driver in defining success, perhaps even more so than simply being viable and achieving a measure of environmental and economic sustainability.

Guatemala is situated in the northern portion of Central America with the Pacific Ocean to the west and the Caribbean Sea to the east, with international borders of Mexico to the north, to the southeast Honduras and El Salvador, and Belize on its eastern frontier (**Figure 1**). The capital, Guatemala City, is centrally positioned in the southern portion of the country at 1500 meters in elevation (nearly 5000 feet). Thus, nighttime temperatures are moderately cool in the summer. This is in stark contrast to the very warm and humid climate of the eastern portion of

Figure 1.
Guatemala situated in the northern portion of Central American shares borders with Mexico, Belize, Honduras and El Salvador (Guia Geografico).

the country, known as the Peten, home to Tikal and the Mayan Biosphere reserve. Guatemala City has a population of nearly 2.9 million residents with more than 4 million or greater migrating to the capital city during each business week from rural areas [1]. Many low-income people live within the city and are concentrated into 22 neighborhood and employment zones based upon social and economic class separation. Zone 3 is the most impoverished where squat housing has been constructed upon early remnants of the nearby landfill, referred to locally as the *basurero* (**Figure 2**). People who work in the *basurero*—not for a living wage but rather to pick through the unsorted trash for subsistence—have erected a neighborhood of shanty houses using concrete blocks and corrugated metal as construction materials [2]. Most of the inhabitants here are fixed or rather trapped in conditions best characterized as abject poverty. They mostly subsist upon trash from the city as it is dumped from garbage trucks (**Figure 3**). They pick through the trash to collect plastic and glass which they then turn in for cash at recycling facilities, perhaps discarded food to eat, or cast-off household items to use; no doubt this is a grim existence for their families [3]. Guatemala City experiences a rainy season that can last for up to five or six months (May through October). The rainy season can and does cause the unstable terrain at the landfill to collapse [4], literally swallowing the people who are sorting through the trash. It is a tragedy that their bodies are rarely recovered due to the high levels of methane gas generated from the organic waste. Further hazards come from the greenhouse gas released from the decomposing waste which can cause cancerous tumors. Many of these people who are picking through the trash have marginable options for receiving basic health care and their injuries go untreated.

The research reported in this chapter set out to establish if compost could be produced to amend the marginal soil in the City's parks and landscaped planting beds using green waste typically discarded from a large City-managed fruit and

Figure 2.
Dwellings have been constructed upon portions of a former landfill using concrete blocks and corrugated metal.

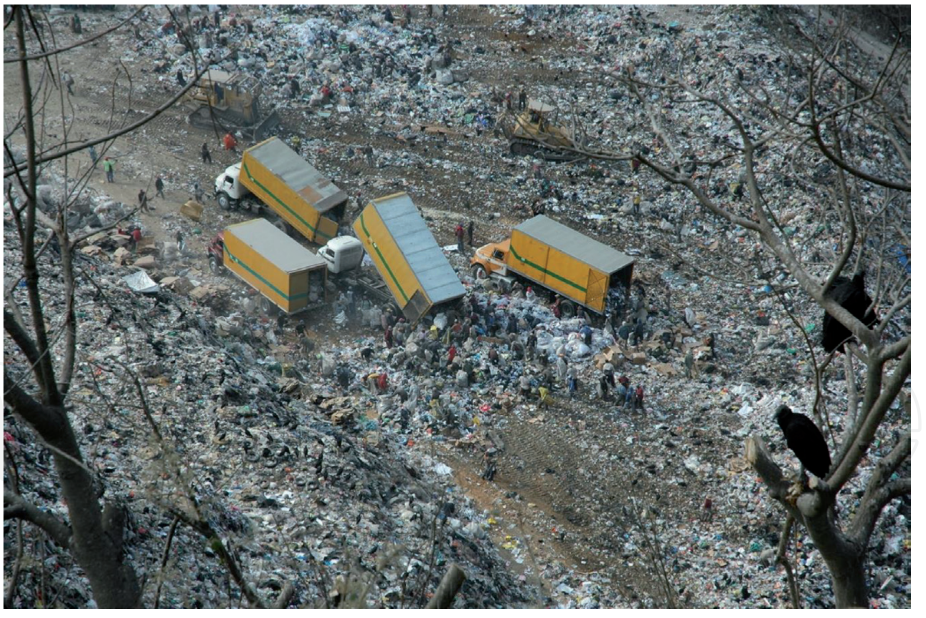

Figure 3.
Families sort the recently dumped trash from garbage trucks to gather recyclables, discarded household items and edible food.

Figure 4.
Trucks that deliver farm produce to the central market could be used to deliver compost back to the farm for soil enrichment.

vegetable market known as CENMA. Diverting the additional organic waste from disposal in the landfill made logical sense; why throw away something that could be used to create something else of value? However, what was unknown were the challenges in using the organic waste to produce compost in this high altitude and temperately cool environment during the spring and summer months. In addition to selling the finished product locally, the research attempted to determine if the finished compost might have a regional market, meaning might there be a broader client for the newly prepared compost? Could the compost also be delivered to the farms who had originally grown the fruit and vegetables to be used for enrichment of their soil, employing the same trucks (**Figure 4**) that brought commodity to the market on their return trip?

2. Circular economy, closed loop systems, and agricultural byproducts

Whereas the author of this chapter is not an expert scholar within the burgeoning field of Circular Economy (CE), it is important to point out similarities of CE to what was once referred to as a closed loop system; the creation of a closed-loop system for producing compost, coffee or clothing, for example, should be based upon the principles of (CE). It is important to mention that the term circular economy first appeared in the literature as part of a study by Pearce and Turner (1990) [5]. This earlier research, referenced by Anderson (2007) and later Kumble (2019), worked to establish a link between production activities in industry [6, 7]. Thus, CE is recognized as a good strategy that can minimize any unneeded waste by increasing manufacturing efficient [8–10]. In general terms, this was called a closed-loop system, and was initially introduced by Boulding (1966) and later refined by Leontief (1991). The concept is based upon using raw materials and the superfluous waste contained within a closed loop [11, 12], meaning that you recycle the end product and its associated components in the manufacturing of a new item. Obviously, this is perhaps a standard used within the agricultural industry, but it can also be applied at a much smaller scale. An excellent example of this is where organic waste is converted into fertilizer and recycled into the soil. A closed loop system is a bit more complicated to achieve within the manufacturing industries given the huge variety of the product being produced. Nevertheless, if one were to try to explain CE as it might relate to ecological efficiency as demonstrated in agricultural production, things become perhaps less clear due to the diversity of what we make and how it is both distributed and consumed, as mentioned above. The literature has established that sophisticated cultures demand more resources to meet both their social and economic needs [13–15] at the cost of resource depletion, many of which are finite and ultimately not sustainable.

As presented in an extensive literature review of more than 500 articles, Merli et al. (2018), the authors established that CE can overcome what they referred to as the "take–make–disposal linear pattern of production and consumption" [16]. Whereas this may sound like a mouthful, pun intended, the principle behind this phrase aimed to preserve raw materials resources, within the production system as long as possible. Although one might think that all manufacturing aims to do this as a way to cut costs and improve efficiency, the sheer volume of industrial waste that ends up being disposed of in a landfill or elsewhere suggests otherwise. Merli et al. established a connection between the temporal scale with product production and reuse—the longer and greater diversity of how raw products are used play to the benefit of sustainable efficiency. Unfortunately, scholars seldom consider both the social and institutional inferences of CE at the environmental and economic level. Professor of landscape architecture John T. Lyle demonstrated this dysfunction as part of his applied research nearly 40 years ago, launching a movement which later became more broadly referred to as *regenerative design*. This work was published in the book, *Design for Human Ecosystems* [17], which eloquently demonstrated how closed-loop systems are used for waste water recycling, integrated pest management, renewable energy production, and efficient use of finite resources. Professor Lyle's applied work can be found today at the Center for Regenerative Studies on the campus of Cal Poly Pomona, California, USA.

It is interesting yet not surprising that Circular Economy is a contested title and description [18, 19]. I believe that this is attributed to the fact that it is very much an interdisciplinary topic, with feet in different scholarly and professional fields. Such definitive controversy or tension is not unique to CE. For example, ecotourism experiences a similar level of confusion and uncertainty; is it part of the tourism industry or simply a movement that promotes natural or cultural resource conservation with a focus upon nature-based experiences while also accounting for the intended educational and learning experience of the place visited? Perhaps even the often and over used terminology—sustainability—shares the dubious distinction of uncertainly, different meanings, and "gray" clarity. Regardless, ascribing CE within the context of compost production in a developing-world economy is not flawed or inappropriate, nor does it create confusion. In fact, it might even help to provide a clearer category for how recycling through compost production fits within the broader business of manufacturing. In an effort to lend clarity to this topic, Kumble (2019), reported on how Kirchherr et al. (2017) evaluated 114 definitions of the term CE, which led to the creation of the following definition: "*...CE describes an economic system that is based on business models which replace the end of life concept with reducing, and alternatively reusing and recycling materials in production, distribution, and consumption processes...*" [20]. Perhaps the confusion does not exist within trying to actually define what truly is CE, but rather which through what business or policy models to use [7]. As with ecotourism or even the popularized term sustainability, it is perhaps better expressed as a verb and not a noun; it is about action and should not be boxed-in with a one-fits-all place-based definition. What is exciting is that now CE can be perceived as a possible means by which achieve the principles of sustainable development [21], and more specific for the work in Guatemala contained in this chapter, achieving social sustainability.

More recent literature describes the need for quantifiable factors associated with the lifespan of a product to best determine the efficiency of CE. It seems that this current trend is attempting to alleviate the uncertainty mentioned above. This then introduces a new set of questions, such as what those indicators should be and of course how to account for variability? Again, this raises the question of boxing-in, a trend with rigid definitions. A plausible definition of lifespan of a product might be related to the number of times or repetition that a something is used and reused while also considering the longevity or duration of that use. Research by Figge et al. (2018) contend that the duration (temporal) and circularity (complexity) are necessary for sustainable resource use, but how should one clearly ascribe measurements that combine both approaches such as temporal complexity [22]? Again, Figge's research team argued for a complex matrix to measure both, which is not surprising given their background in economic studies. If then one were to use this model and apply it toward the production of compost from green waste and brown carbon such as cardboard or wood chips, this production technique would achieve temporal longevity. What now becomes significant is that compost production suggests quantitative and qualitative factors that are key concepts of CE.

Sama, et al. (2018) described how the food industry has successfully made the more toward the production of fair-trade products and socially responsible consumption, both which are a critical measurement of sustainability within CE [23]. With that, the world has been moving, albeit slowly, toward circular economy with the demand to become more sustainable its daily life with the production of coffee, clothing, or perhaps compost. With the popularizing of fair-trade products, consumer demand for these goods produced in developing countries such as Guatemala can be found at a worldwide scale. This trend is evident in the move toward "green projects" that supports environmentally sustainable investments, as reported by Falcone el al. (2018) [24] on ethical socially responsible projects. They reported on the trend for funding radical green innovation. It could be argued that this is simply *green washing*, or it might suggest a new paradigm shift in how business is being conducted due to reduced costs, reduced energy consumption, and the added benefit of producing a positive and sustainable result. George, et al. (2015) discussed the connection between green finance within circular economy [25] specific to the biomass production sector; this is akin to the production of compost.

The United Nations Environmental Program (UNEP) published a report in 2011 reporting on the trend toward an economy based upon low carbon outputs, signaling the move toward green businesses [26]. Has this been a true shift in response to climate change or as mentioned earlier, simply green washing? With regard toward the aforementioned biomass production, the movement toward renewable energy and associated industries—such as making compost from green waste in Guatemala—is no doubt significant. Again, the UNEP report found that the money required worldwide could be 2% of global GDP between 2010 and 2050 [27]. Although a significant sum, are their other viable alternatives?

When weighing the costs and long-term benefits of the global movement toward being more green, not because it is marketable but because it is necessary, what are then the implications of making compost from market waste, and how can this small action by the municipal government in Guatemala City be a model for other communities to follow? When trying to apply a change in how business is conducted, some world economies have adopted a top-down centralized approach [28], while others believe that a community-based bottom-up movement is more appropriate [29]. It is difficult to generalize which is more appropriate and perhaps local conditions and the size or scale of the problem is the main determinant.

No doubt, CE contains numerous complexities in both how it might be defined and quantified, likely due to the various disciplines associated, as argued above. With this understanding, or perhaps the uncertainty of how to best demonstrate the circular nature of making compost, in addition with how does it in fact represent a closed loop system applicable in Guatemala or any other culture, the research presented in this chapter attempted to achieve a variety of applied and theoretical objectives:

- What is necessary for starting a business that demonstrates the principles of CE using the production of compost as an outcome?

- Could this action trigger a break from what clearly appears to be dim prospects for teenagers from the Zone 3 neighborhood in Guatemala City thus providing an alternative for their future livelihood?

- When considering the precepts of social sustainability [30] and basic human rights [31], what role could or should green investment in compost production play?

- Are there unknown obstacles toward making compost in the high in altitude climatic conditions of Guatemala City with cool nighttime temperatures during the summer, periods of low rainfall during portions of the year, and inundation from rain during other times?

- Could a simplified technique of making compost produce enough end product equal to the more industrial windrow commercial production approach?

The work reported in this chapter did in fact have multiple objectives as described above. Initiating a startup business and its associated challenges of balancing economic, environmental, and social objectives was not to be taken lightly, however altruistic as they may have seemed. These three pillars or three Es are the foundations of sustainability [32], but how should one bridge gap between pedagogical theory and real-world working conditions while factoring in a myriad of political and social challenges? Perhaps a brief revisit of how sustainability became part of the world dialog is in order.

3. Discussion of circular economy and sustainability in practice

Recognition of the critical importance for sustainable development within our lives began nearly 30 years ago in 1992 at the Earth Summit in Rio de Janeiro and again 20 years ago at the World Summit for Sustainable Development in Johannesburg [33]. Ironically, for some readers, these two important events predate their birth, yet they are no less significant as both signaled a paradigm shift in global awareness. Of the three Es as pillars of sustainability, one could argue that achieving social sustainability is particularly complex due to the constant changes or variability within localized society. As described by Kumble (2019) [7], Boyer et al. (2016) [30] enumerated and analyzed the particular difficulties in understanding social sustainability, however they citied the variable definitions and gaps due to the interdisciplinary nature of the topic. This is not necessarily a failing in the general research but more likely attributed to the complexity of interdisciplinary topics; each field is interpreted and understood differently by its associated scholars and proponents. In retrospect, social sustainability along with environmental factors and drivers of any economy are very much place based [7]. Boyer's research team appropriately used the comparison of a three-legged stool and the 3Ps—prosperity, planet and people—for understanding complex problems withing the world and to not inventing new paradigms which would only busy an already crowded field of understanding.

Working on the principle of simplicity in action, the research presented in this chapter would appear to be a positive and logical situation whereby the compost that was created from organic waste diverted from a landfill could then be used to amend marginal soil, train workers, create jobs, mitigate an ecological and environmental crisis, and provide a future of skilled employment. Making compost would embrace the theories of CE, would mitigate the terrible environmental impacts from the batsuro while triggering new opportunities in the business market, consistent with the bottom-up model proposed by Ghisellini el al., 2016 [29] described above. As mentioned earlier in this chapter, the idea of the closed loop system of manufacturing has been in use for many generations in the industrial sectors of the world associated with manufacturing [34, 35]. The startup business for making compost wished to explore if this could be done in Guatemala City and not be hindered by the numerous complex cultural, environmental, and economic obstacles.

4. Challenges of Guatemala City

Although making compost from green market waste was one of key goals of the project reported in this chapter, it was really based on the foundational intention of creating future employment opportunities for the disenfranchised and poorly educated youth from the squat neighborhood in Zone 3. Perhaps if one of these goals could be accomplished—compost production—it would trigger the success of the other—future opportunities for the youth who had little future prospects. With this clear objective, the work aimed to explore how to achieve social sustainability. Minica and France (2008) postulated that social sustainability is in fact composed of the following four key objectives: 1. education and training; 2. promoting human health; 3. winning the fight against poverty; 4. creating a equitable and just working environment [36]. Yes, self-empowerment can be achieved through education, however with only 69.1% of the population in Guatemala who can read and write, it is perhaps the most illiterate nation in Central America. Similarly, 8 out of 10 people will never graduate from high school, not because they are lazy or lack ambition but because they must leave school while they are still kids to find work in support of

Figure 5.
Approximately 80 percent of Guatemalans will never complete high school. This is particularly acute in Zone 3.

their family (**Figure 5**). Finding jobs for this age group from Zone 3 is very difficult due to their insufficient education [37]. Thus, as mentioned above, the key research initiative of this work determined that the social pillar of sustainable development should be the most important because of the need to create opportunities for the future of the youth from Zone 3.

The CENMA fruit and vegetable market generates a huge amount of green waste each day as part of the trimming and packaging of the commodity for local and international markets. Not surprisingly, some 115 cubic meters (150 cubic yards) of organic waste is trucked daily to the landfill; yet it need not be. The head for Public Works of Guatemala City agreed to collaborate with the author and his graduate students from the University of Massachusetts, Department of Landscape Architecture and Regional Planning, for a variety of reasons: technical knowhow and enthusiastic students with a strong adherence to environmental justice. The City agreed to a student-initiated start-up business to produce useable compost on a small tract of land situated immediately adjoining CENMA. The site was unfortunately very small, 0.48 hectares (1.2 acres), but it would allow the team to attempt to test the principles of CE and pillars of sustainability.

The Municipal Parks Department in Guatemala City were investing nearly $300,000 USD each year to amend the soil on their land at the parks and landscaped planting beds. The director of Public Works agreed to the purchase of compost from the new startup business for their public-sector landscaping projects.

5. Summary review of techniques for producing compost

Whereas the intention of this chapter is not to explain new technologies for the production of compost, it is useful to review of how one makes compost, such as the careful mixing of brown and green raw material. It is important to point out that no animal manure or carcasses are used because animal waste can spread diseases. The composting process presented in this chapter describes the use of organic plant material often referred to as brown and green material (**Table 1**) [38]. Brown material is comprised of shredded wood chips, dry grass stalks, or cardboard and

Brown material	Green material
Straw or hay	Fruit
Woodchips	Vegetables
Cardboard	Egg shells
Dry leaves or grass	Coffee grounds
Tree bark	Freshly cut grass
Sawdust	

Table 1.
The differences between brown and green organic material.

thus does not decompose as rapidly as green material. So why use brown material? It provides the finished compost product with a light texture. In comparison, green material refers to more recently cut or harvested wet waste such as vegetables or plant biomass and will decompose quickly. In the mixing of brown and green, the brown material is more stable, meaning that the amount of time required for it to break down or decompose is more predictable [39], likely due to the fact that it contains much less moisture.

Organic waste is comprised of the leaves, stems, and bark of plants and insects. Interestingly enough, manure or animal feces is also a fertilizer that is referred to as organic. Brown materials such as wood chips, sawdust and cardboard, although processed by man, comes from trees and is organic unless it contains dyes or is coated with plastic. Man-made pesticides are natural and are not considered as organic material. However, it is important to understand that sometimes pesticides are organic because some plants will create chemicals naturally in their leaves to protect against insects [7].

The natural process of decomposition of organic material can be described as the breaking down of organic material. We can observe this process in the forest understory, within the leaf litter or dead wood from trees and shrubs. Nutrient-enriched humus returns organic material to the soil providing essential minerals supporting and accelerating plant growth; it should be thought of as enriched food stock for root system of plants [40]. Much of the decomposed humus is often in the top layers of soil—typically the O-layer—and is the darker color that can be seen when inserting a soil probe and extracting a sample. Non-organic waste is very slow to decompose and can take hundreds of years to break down into useful material [41].

A commercial or production compost operation manages the decomposition of organic material in a more controlled environment, allowing the process to occur more rapidly to produce a consistent and useable quality product. It does this by regulating the amount of oxygen, water, and brown to green material intentionally. When we refer to a 'compost pile' it suggests a mound or pile of organic measurable waste that is undergoing decomposing [42]. This finished end-product we call 'compost' (**Figure 6**), and can be used to amend existing soil, making that soil healthier or more alive and better suited for retaining soil moisture content and thus the growing of plants. When one tills the soil and harvests fruit and vegetables, the soil can become less vital or degraded. By adding compost or barnyard waste into soil, it becomes replenished with fresh nutrients, contributing to increased soil fertility [43].

In a healthy forest, decomposition of organic matter occurs as part of the digestive processes enabled by a variety of microorganisms [41] that feed on dead or dying plant material and animals. The organisms reproduce, die, and recycle themselves as new organic material through the process of decomposition. These

Figure 6.
This large pile of newly produced compost is mixed with existing soil to increase fertility and plant growth.

tiny creatures are contained in decomposing organic material and do not need to be added to a commercial composting pile. As with any alive material, these microorganisms require food, water, and air to live, consuming some of the organic material found in a compost pile. Whereas insects, worms, and even snails are valuable for making compost, they actually perform less work to in the decomposition process than do the microorganisms. Thus, microorganisms are an essential and necessary component for the production of compost.

As mentioned above, air, water, and the appropriate mix of organic material will allow the decomposition of organic material to reach its finished state in a predictable amount of time yielding healthy and useable compost. Typically, the composting process for organic material (in a compost bin, windrow, or pile) requires 90 to 120 days to occur [44], provided that the organic waste is receiving the needed combination of oxygen and moisture, and most importantly and that it is turned or churned regularly to allow air and moisture to effectively enter the pile [45]. Of course, this entire process can be accelerated significantly by increasing the amount of oxygen that enters the composting material; some operations can produce useable compost in very short time of 30 to 45 days, although the energy and financial costs of doing this may not be realistic.

How should one then choose to produce useable compost from organic brown and green waste? There are two commonly used technologies employed today; commercial operations often use a approach commonly referred to as windrows [46], which are basically very long and narrow piles of compost (**Figure 7**). A windrow is at a minimum 1.5 m (5 feet) tall with equal width and are difficult to manage with only manual labor [7]. As mentioned, a commercial operation often will use the windrow method due to their efficiency in accommodating a larger mass or volume of organic waste material. Due to their size and particularly their length, the windrow technology typically require many hectares of useable surface area and expensive commercial machinery such as a tractor that can effectively pull the mechanized windrow turner (**Figure 8**) which creates a uniform shape of the windrow pile while also churning or mixing the compost allowing necessary oxygen to enter and accelerate the decomposing process. Trial and error have determined that the tractor must use a 'creeper' gear whereby it moves very slowly yet allows the PTO (power take off drive) to spin the turner at a fast speed.

Figure 7.
This is an example of a municipal compost facility using wind-rows for large-scale production.

Figure 8.
This mechanized device is pulled by a tractor and is used to shape, turn, or churn the compost in the windrows.

As an alternative to windrows, smaller operations will use what is typically referred to as the in-cell technique. As its name suggests, this approach uses modular structures that hold the compost in place and look somewhat like a large cube [7]. The biggest advantage of the in-cell or 3-cell technology are that they can be maintained using manual labor and do not require expensive machinery such as a tractor and windrow turner for turning or churning the compost mix while it is in the process of decomposition. There were some obvious reasons why the in-cell composting technique was employed at the compost operation in Guatemala. These include the following:

- By using manual labor to move the compost from one cell to another and thus accelerating the decomposition process, more youths could be employed;

- Cells do not involve the need for expensive equipment typical of the windrow system; and

- Cells do not require training of employees to operate mechanized machinery or do they require maintenance and upkeep.

The in-cell compost technique looks much more like the compost "bin" that a homeowner might use for decomposing kitchen and yard organic waste (**Figure 9**). Home-composting typically has one compost bin/cell. Yes, some households can and do have multiple compost bins, however the contents are seldom mixed or shoveled into an adjoining bin. For this reason, three cells should be employed to be more effective (**Figure 10**). But why three cells? One should begin with a new compost mix that is started in cell A: once the contents begin to shrink in size as the green waste decomposes, all of the contents from cell A should then be shoveled into cell B and a new batch started in the now available cell A. The act of moving the mix from cell A to cell B adds oxygen and mixes the contents, similar to what a windrow turning machine might accomplish. Later, the contents from cell B are moved into cell C for completion, and a new batch is begun in cell A, which has seen its material moved into cell B.

There are perhaps many ways to construct cells for producing compost, all based on the availability of cost-effective materials and creativity of the builder. Wooden shipping pallets were selected for use at the CENMA site because they are inexpensive and were easily obtained. Each of the shipping pallets were simply fastened together using long screws or nails to join one to another (**Figures 10** and **11**). Small sections of chain link fencing were used to enclose the front opening for each cell. Initially, the intention was to use steel fencing post which would be hammered into the ground forming each of the corners, coupled with welded wire fencing fastened to the posts to form the enclosed sides. However, the hard and rocky surface area found at the test site rendered this approach unfeasible as it was impossible to drive the metal posts into the ground. The wooden shipping pallets were readily available, easy to fasten together, and inexpensive.

For a newly established compost pile (in cell A), one must regularly monitor the internal temperature during the initial weeks to determine the rate of

Figure 9.
A compost bin or cell is used to make compost from household green waste, fallen leaves, and grass clippings.

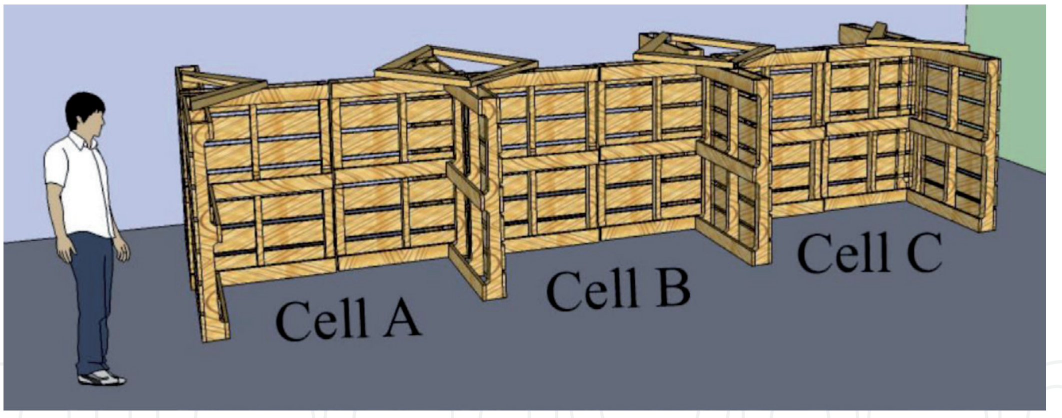

Figure 10.
This schematic illustrates how wooden pallets can easily fastened together as a three-cell compost system (illustration by Seth Morrow).

Figure 11.
Wooden shipping pallets are readily available and can be simply fastened together to replicate the three-cell compost system.

decomposition (or cooking as it is referred to). At the same time, the size of the pile decreases or shrinks in size as the green material breaks down. Similar to that of a windrow, a thermometer with a long one-meter probe is used to measure the internal temperature (**Figure 12**) to determine if and how fast the compost process is successfully occurring. **Table 2** illustrates cell-monitoring data for one of the two test cells constructed. The data was monitored in order to chart the time and temperature on a weekly basis, in addition to observed odor (smelliness). Approximately one month after the pile is made, the temperature cease increasing while the shrinkage of the pile should also decrease in rate. When this occurs, the pile should be shoveled into cell B. This process of turning the pile simply involves taking the material out of the cell and mixing it up, meaning that it is important to move the decomposing material from the middle of the pile to the outside layers of the relocated pile, now in the second cell (cell B).

Figure 12.
Decomposition temperature is monitored regularly using this thermometer with a 1 meter long probe.

The microorganisms should be actively feeding on the organic material, meaning that they are now consuming the composting mass of material. Obviously, the microorganisms do not have the ability to move very far, so it is very important to adequately mix the pile, putting the microorganisms into direct contact with organic material to continue the decomposition process. Whereas the turning of a pile will introduce oxygen, it is quickly consumed, and it is not the primary function of turning or mixing the contents. Oxygen should enter a compost pile through proper ventilation and pore space (voids in the mix). Some people will also include perforated plastic pipe, similar to that used for stormwater under-drainage, and place the pipe across the bottom and then extending perpendicularly and vertically up through the pile to better allow the movement of oxygen.

Date	*Days*	Height	*Change*	Temp	*Change*	Smell	*Change*	Humidity	*Change*
Wendell									
22-Mar		**30**		75		**3**		**4**	
27-Mar	5	**26**	-4	**120**	45	**3**	0	**4**	0
3-Apr	7	**23**	−3	**130**	10	**2**	−1	**3**	−1
13-Apr	10	**23**	0	**130**	0	**1**	−1	**1**	−2
Wes									
22-Mar		**30**		75		**3**		**4**	
27-Mar	5	**27**	−3	**120**	45	**3**	0	**3**	−1
3-Apr	7	**26**	−1	75	−45	**2**	−1	**1**	−2
13-Apr	10	**26**	0	75	0	**1**	−1	**1**	0

The units for Height are in inches, Temperature is in F, and Humidity is based upon relative %. Smell was subjective with 1 being low and 3 being high.

Table 2.
The rate of decomposition, changes in temperature, humidity and odor were monitored weekly in each of the test compost cells.

6. Compost cells at the test site in Guatemala

The useable compost production space provided at CENMA could physically accommodate approximately 400 cells and produced approximately 1480 cubic meters of compost annually. The three-cell system, constructed from wooden shipping palettes, were 1.8 meters (6 feet) deep, 1.5 meters (5 feet) wide, and 1.2 meters (4 feet) tall. An estimated 140 cubic meters of newly produced compost was stored on-site each month [7]. The new compost was stored on-site to facilitate loading it onto transport truck for distribution to its final destination.

Much of the green waste deposited into collection barrels at the CENMA market actually contained a large amount of non-compostable garbage, such as cans, bottles, dirty diapers, etc. (**Figure 13**). It was an awful mess to clean and sort and necessitated a different approach; clearly those using the market mistook the collection

Figure 13.
Non organic waste is unfortunately disposed of into the compost collection barrels in the market.

Figure 14.
Clearly marked barrels were relocated close to fruit and vegetable processing.

barrels as suitable for general waste disposal. Clearly marked barrels were later placed in strategic locations close to where fruit and vegetables were being processed for sale (**Figure 14**). The prototype compost facility was able to receive 20 cubic meters of raw materials daily: (1/3 organic waste, 1/3 wood chips, 1/3 cardboard).

7. Technical and organizational challenges

Whereas then proposed composting business was to be situated next to the market on a large flat tract of land used by transport trucks, the market manager

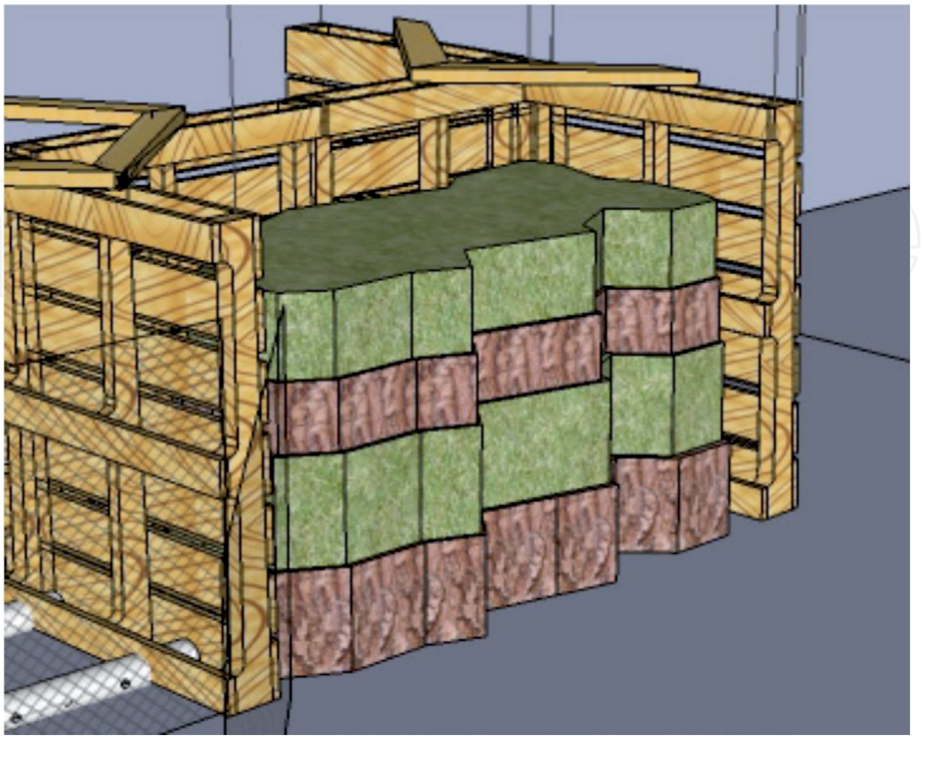

Figure 15.
This schematic illustration shows the alternating layers of brown and green material in addition to the perforated plastic pipes to allow for oxygen to move more freely (illustration by Seth Morrow).

was concerned that the compost would smell and become a hinderance to market vendors and the general public. He was fearful that it would smell as bad as a landfill and would only allow the use of a narrow tract of land adjacent to CENMA. Unfortunately, this site was not ideal for two reasons: 1. it was not large enough to produce the volume of required useable compost to meet municipal demand by the City's landscaping division, and 2. it was much too small to accommodate the available organic waste generated daily by the market.

The teenage employees from the Zone 3 neighborhood were hired, trained, and were responsible for many of the chores such as sorting waste from the collection barrels and mixing the compost from cell A to B and then to C (**Figure 15**). These young workers were also trained in how to monitor the moisture and temperature of the new compost piles in production. Ten to twelve workers were initially employed, selected from youth from Zone 3 who needed jobs. Only youth who were enrolled and remained in a secondary school were eligible and they had to remain in school to be employed in the compost business. Each of the youth were trained in how to maintain a bank account to receive their weekly pay. Sponsors from the USA participated in a cost-share program, matching the money earned by the Guatemalan youth with a matching donation, doubling the money earned.

8. Results and discussion

The startup composting business discussed in this chapter aimed to provide useable compost for the Guatemala City's municipal government (MUNI) who were using on an annual basis nearly 15,000 cubic meters of soil for landscaping the along the roads and parks. Because the base soil was of such poor quality, the mix of compost to soil would need to be 1:1, creating a demand for up to 7500 cubic meters each year. As stated earlier in this chapter, the 0.48-hectare site adjacent to the CENMA market was inadequately small and could not meet the needs of the City for soil amendment; a larger production workspace had to be provided. This study found that in order to produce 7500 cubic meters of useable compost each year, nearly 625 cubic meters would need to be generated each month, or approximately 30 cubic meters on a daily basis. To meet the demand for just the compost needed by the City government, the necessary site had to be nearly six times larger than that of the CENMA site, or approximately 2.6 hectares (6.4 acres). Interestingly enough, if one were to adopt the wind-row method for compost production, discussed earlier in this chapter, the area needed to meet the municipal demand is estimated to be approximately 1.6 hectares (4.0 acres) because windrows are more efficient in their use of space and production. Discussions with the head for public works in Guatemala City promised space for a larger scale production facility situated below (to the south) of CENMA; unfortunately, this expansion never occurred. Ironically, the City requested an even greater volume of compost from the startup company if it could be produced. The positive element here was that a broader market demand existed for the compost, and at that point in time, no one else was able to or willing to step up and make it.

Also ironic was the volume of organic waste trucked to the landfill each day, equaling roughly 138 cubic meters. When one considers that the initial small production space, or for that matter the 2.6 hectares site discussed above, both were incapable to accommodate all of the organic waste generated by the market assuming that it could be converted into useable compost; to do so would require a site of approximately 5.8 hectares. Unfortunately, production space limitations resulted in unacceptable shortfalls of the volume of compost that was produced, and as such, the project could not live up to its potential. Yet from a more positive perspective, the raw unprepared product was available—free of charge—with a willing client and inexpensive labor, suggesting that the failure of the business idea was not due to a flawed business plan but rather necessary space. With some abandoned brownfield sites (former industrial manufacturing facilities) nearby, this could be readily overcome.

Referring back to the success and failures of this research projected mentioned in the introduction of this chapter, the startup business was never able to meet the real demand for compost by the Municipal Government of Guatemala City; however, with a larger working production site, this could be achieved in the future. And with that, the ability to achieve the intended goal for a business that would demonstrate the principles of circular economy and social sustainability could be achieved.

Monitoring data conducted weekly at the two test cells that were constructed as a control experiment (**Table 2**) reveled that the high altitude and dry climate of Guatemala City caused much of the moisture in the newly mixed compost (cell A) to dry out prematurely, resulting in a very slow or even stalled rate of decomposition. This was unexpected and required altering the brown to green mix to increase the green organic volume during the initial mixing of the new compost piles in cell A.

9. Conclusions

Initiating a startup venture Poverty in Guatemala City will never be completely overcome and improved living conditions for those from Zone 3 achieved through a commercial composting business. However, each step toward this goal can and will make a tangible, and most importantly a sustainable difference in the future of children who live in Zone 3 and who have minimal future opportunities for a prosperous life.

Such as the one presented in this chapter demonstrated that one must find their own unique skills to contribute, whether it is the desire for developing programs to address social justice, expanding the knowledge-base of composting methods in different environments, or finding creative fund-raising opportunities. Each part or component of the program for recycling green waste from CENMA, putting to

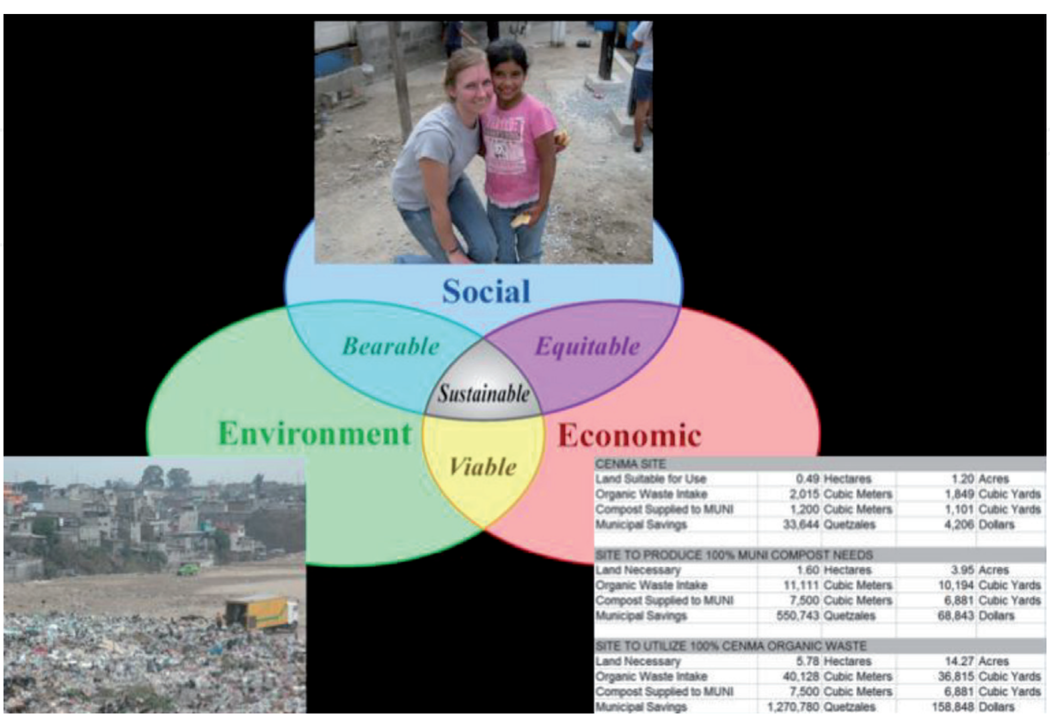

Figure 16.
This diagram depicts the three-pillars of sustainability in action.

work at-risk youths of Zone 3 neighborhoods, and creating a useable product that was economically viable adhered to the three pillars of sustainably (**Figure 16**).

Sustainability in practice applies here, regardless of whether one is a proponent of social justice, an entrepreneur in search of starting a sustainable company to help the poor, or a public official determining the level of feasibility of a project, or even a potential financial donor. One need not look for complex operations that utilize high technology. Simplicity in action and techniques that achieve multiple objectives simultaneously are often the most effective and resilient.

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