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From Waste to Resource: A Systems-based Approach to Sustainable Community Development through Equitable Enterprise and Agriculturally Derived Polymeric Composites

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FROM WASTE TO RESOURCE: A SYSTEMS-BASED APPROACH TO SUSTAINABLE COMMUNITY DEVELOPMENT THROUGH EQUITABLE ENTERPRISE AND AGRICULTURALLY-DERIVED POLYMERIC COMPOSITES

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From Waste-to-Resource: A Systems-Based Approach to Sustainable Community Development Through Equitable Enterprise and Agriculturally Derived Polymeric Composites

Thesis directed by Professor Bernard Amadei.

ABSTRACT

Rural communities in developing countries are most vulnerable to the plight of requiring repeated infusions of charitable aid over time. Micro-business opportunities that effectively break the cycle of poverty in resource-rich countries in the developing world are limited. However, a strong model for global commerce can break the cycle of donor-based economic supplements and limited local economic growth. Sustainable economic development can materialize when a robust framework combines engineering with the generous investment of profits back into the community. This research presents a novel, systems-based approach to sustainable community development in which a waste-to-resource methodology catalyzes the disruption of rural poverty.

The framework developed in this thesis was applied to the rural communities of Cagmanaba and Badian, Philippines. An initial assessment of these communities showed that community members are extremely poor, but they possess an abundant natural resource: coconuts. The various parts of the coconut offer excellent potential value in global commerce. Today the sale of coconut water is on the rise, and coconut oil is an established $3 billion market annually that is also growing rapidly.

Since these current industries harvest only two parts of the coconut (meat and water), the 50 billion coconuts that grow annually leave behind approximately 100 billion pounds of coconut shell and husk as agricultural waste. Coconuts thus provide an opportunity to create and test a waste-to-resource model. Intensive materials analysis, research, development, and optimization proved that coconut shell, currently burned as a fuel or discarded as agricultural waste, can be manufactured into high-grade coconut shell powder (CSP), which can be a viable filler in polymeric composites.

This framework was modeled and tested as a case study in a manufacturing facility known as a Community Transformation Plant (CTP) in Cagmanaba, Philippines. The CTP enables local creation of globally viable products from agricultural waste. This researcher seeks to encourage the propagation of CTPs throughout developing communities worldwide, each profiting from its own waste-to-resource value.

DEDICATION

This thesis is dedicated to the people of Cagmanaba and Badian, Philippines. You have taught me what it means to be truly rich, and what it means to live life to the fullest, regardless of circumstances. When I visit your communities, I feel like I am at home with dear family and friends. Thank you for your dedication and for sharing the vision of seeing your community flourish.

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Thank you to the members of my research committee, Professors Bernard Amadei, Walter Bradley, Don Byker, Paul Chinowsky, Rita Klees, and Sarah Revi Sterling. These mentors have invested their time and wisdom throughout this research, and it has been priceless. Special thanks goes to my committee chair, Professor Bernard Amadei. His drive and passion for engineering with soul is contagious and makes me want to go forward doing the same. Additionally, I'd like to thank two of my former professors, Bryan Willson and Omnia El-Hakim.

To close, I would like to thank God for walking with me in this journey and my wonderful family. Words cannot express my thanks to my dear husband Blake, my father Rey, my mother Brenda, who has always supported and encouraged us to pursue our dreams and help others, and my sweet sister Rosemary. Additionally, I would like to thank my grandmothers Mary and Zoila, who taught me about the importance of education and hard work from an early age. Finally, special thanks to my work and research colleagues Gene Birdwell, Ryan Vano, and Matt Kirby for their support and for collaborating on both research and papers over the last several years.

CONTENTS

CHAPTER

APPENDIX

TABLES

Table

FIGURES

Figure

Figure

CHAPTER I

INTRODUCTION AND RESEARCH FRAMEWORK

1.1 Problem Statement

Rural communities in developing countries often require repeated infusions of charitable aid. Despite various attempts to solve this problem, a lingering question remains: How can community development become sustainable in low- and middle-income countries? In low-income but resource-rich countries, poverty traps generations of people, despite ready access to an abundance of natural resources. In places like the Philippines, natural resources—particularly plant and fruit crops—are easily accessible, but the communities do not have the means to turn their raw natural resources or their agricultural waste into commercial products. They lack the manufacturing technology necessary to add value to the available resources, and they are unable to access regional and global markets. For example, conventional methods of extracting coconut oil and water leave an abundance of wasted material. Coconut farmers traditionally receive little profit from the sale of the coconut water and oil, and there is no reasonable market for the tremendous amount of waste in the form of shell or husk (coir) left behind.

The following research demonstrates a strong model for sustainable community development (SCD). The model succeeds when a robust systems engineering framework ensures that the following key parts work effectively and efficiently together: (1) incisive community assessment; (2) disciplined analysis of global market opportunities; (3) creative science and engineering to add value through positive technical impact; (4)

profitable commercial impact via vertical integration of local production with global marketing and sales; (5) equitable sharing of profits and ownership, including generous reinvestment in the community.

The research also charts a rural community's path out of poverty through new business that transforms agricultural waste into viable commercial products. The tools of systems thinking are used to validate the waste-to-resource framework by documenting the transformation of agricultural waste into engineered composite materials.

The concepts of sustainability, sustainable development, and human development are essential in this dissertation, using the following definitions:

1. The Brundtland Commission Report defines sustainable development as "stable" when: "The needs of the present are met without compromising the ability of future generations to meet their own needs" (1987).

2. In "Sustainability: The Five Core Principles," Michael Ben-Eli suggests that there are five core principles to sustainability: material, economic, life, social, and spiritual (2005). He defines Sustainability as: "A dynamic equilibrium in the processes of interaction between a population and the carrying capacity of an environment, such that the population develops to express its full potential without adversely and irreversibly affecting the carrying capacity of the environment upon which it depends" (2005).

3. According to a recent Human Development Report (HDR), human development is the fundamental framework that promotes the expansion of people's freedoms and ability to "lead lives that they value and have reason to value. It's about expanding choices" (UNDP, 2011).

This research draws upon the above definitions, particularly Ben-Eli's. His five core principles of material, economic, life, social, and spiritual sustainability comprise the foundation of this thesis. The importance of *community* within sustainable development is also paramount. Neglecting appropriations for community has the effect of removing the potential for development to be sustainable. The results are heartbreaking. A case in point is the water-scarce communities in Africa that were provided wells without the expertise or means to repair them when they malfunctioned (Schneider et. al., 2008). Separately, a project community failed to prosper in spite of crops and housing being provided. Compare this to the non-participant who borrowed money, planted his own crops, and built his own house *adjacent* to the failed community development (Schneider et. al., 2008). When the *community* portion (e.g., human impact) is the focus of the effort, the likelihood of true sustainability increases greatly.

1.2 Research Questions

Within the practice of sustainable community development, this research is the first to present a waste-to-resource framework for sustainable community development that demonstrates how agricultural waste from developing rural communities can be transformed into engineered products. The promising result from the initial stages of this research is the commercialization of the waste-based polymeric composite by a multinational automotive company. The key research question to be addressed in this dissertation is: ***What are the steps necessary to create a highly efficient, successful model for sustainable rural community development utilizing agricultural waste?*** This overarching question can be answered by addressing a subset of specific questions summarized in Table 1-1. A brief discussion of each research question follows.

Table 1-1

Research Questions to be Addressed in This Dissertation

Question no.	Research area	Specific research questions that address gaps	Chapter	Keywords
1	Factors and conditions needed for community development to become sustainable in low-income countries.	What key indicators must be identified in a community for a waste-to-resource model to be successful?	3	Community Assessment (ICI) Case Study, Indicators
2	The global market for new technologies, such as waste-based composite materials.	What are the technical benefits of using coconut shell powder (CSP) in composite materials that could accelerate the use of valuable new products to disrupt rural poverty?	4	Technical Impact Environmental Impact Commercial Impact
3	Environmental impacts of natural resources, particularly the waste from plant and fruit crops, for a waste-to-resource transformation approach for SCD.	What are the likely environmental impacts of waste-to-resource transformation?		
4	Capturing all available value streams of the limited waste-to-resources solutions while equitably treating the people who are harvesting and working the waste stream.	What does it mean to be equitable and generous when using a waste-to-resources model as a systems approach to community development?	5	Human Impact Equity Dignity
5	Engineering-based micro-businesses where profits are shared.	How could the benefits be fairly shared among the various stakeholders?		

What key indicators must be identified in a community for a waste-to-resource model to be successful? (Chapter 3) The assessment tools presented here were designed to identify a community's strengths and weaknesses, then subsequently to determine if the community is ready to use a waste-to-resource model. A survey was conducted within the target rural communities of Cagmanaba and Badian, Philippines, to consider the communities' perspectives on a waste-to-resource business model. Its successful implementation is expected to generate higher incomes. The survey also queried for sources and quantities of solid waste.

What are the technical *benefits of using coconut shell powder (CSP) in composite materials that could accelerate the use of valuable new products to disrupt rural poverty? (Chapter 4)* The technical benefits of using CSP in composite materials are examined in Chapter 4. In addition to the mechanical properties of the coconut shell powder-filled polymeric composite, comparisons against other functional fillers are presented.

What are the likely environmental impacts of waste-to-resource transformation? (Chapter 4) An abbreviated environmental assessment calculates the embodied energy of the composite. The combination of this and materials-testing comparisons comprises the technical value proposition of the waste-to-resource model. Early adopters of this new material are companies like Ford and General Motors, each of which has its preferences for sustainability in materials. In general, GM prefers unfilled (highly recyclable) polymers vs. filled polymers (that reduce total plastic content), which is Ford's preference.

What does it mean to be equitable and generous when using a waste-to-resources model as a systems approach to community development? (Chapter 5) In addition to studying the technical feasibility of CSP in composite materials, several societal factors were also investigated using the survey. These factors are introduced in Chapter 3 and, to complete this discussion, Chapter 5 treats human impact factors by delineating techniques for equitably sharing the benefits among various stakeholders. This promotes equity through the ways monetary gains are distributed; thus, dignity is encouraged. The principal ways for promoting equity are:

- assigning community benefits from this system-based approach;
- framing equity as an essential component of human development;
- multiplying various benefits that development can bring;
- addressing counterproductive outcomes.

How could the benefits be fairly shared among the various stakeholders? (Chapter 5)

The human impact assessment concludes with a discussion of how the profits from a waste-to-resource model could be shared, with a discussion of a triple bottom-line approach. This includes an analysis of the effect of the model on people, planet, and profit, presenting equations to explain the framework used for this research.

1.3 A Systems-Based Framework

Sustainable community development involves multiple systems: human, economic, infrastructure, environmental etc. Given this complexity of influences and interactions, modeling communities requires using systems tools rather than traditional linear ones. Instead of being comprised of elements that evolve in a linear progression, a system organizes its elements in a contextual, interwoven manner. Analyzing interconnection among the parts helps capture the complexity to be addressed when trying to solve a systems-level problem, such as poverty.

In a system, each part can cause the behavior of other parts to change (Richmond, 2002). A system has stocks (places of accumulations) and flows (places of change), as well as feedback loops. Systems thinking is the discipline that breaks down how the parts in a system interact, behave, and influence each other (Richmond, 1994; Aronson, 1996). These interactions make the problem-solving approach slower at the start but more effective overall, since they describe the nonlinearity present in even the most basic systems problems (Richmond, 2002).

Systems thinking is valuable because the feedback loops within a system create an iterative opportunity to evaluate the impact of a proposed solution (Braun, 2002; Meadows, 1999; Rashid et al., 2013); thus a systems approach is well-suited to solve *complex* problems. The distinction between *complicated* and *complex* problems is pivotal in this context and can be illustrated by the following two examples.

Manufacturing a car is *complicated:* Its principal difficulty lies in the precise timing required to orchestrate the confluence of multiple linear sequences, each containing separate moving parts. These lines are fairly separated, and there are no feedback loops between them. In effect, though difficult, a vehicle's assembly is straightforward. Parts go into certain places, the design is well understood, all parts have a known purpose, and their modes of failure are documented (schematically represented in Fig. 1-1 [LEFT]). In complicated systems, we know the unknown.

Sustainable community development (SCD) involves *complexity*, since a country or a community specifically needing development has multi-dimensional and interrelated problems and challenges, which must be solved simultaneously. In a complex system, feedback loops are present, where each possesses the power to topple the entire system

(Fig. 1-1 [RIGHT]). The resulting uncertainty makes complex systems difficult to predict and to affect in a straightforward way. In such systems, we don't know the unknown, and decisions need to be made in an interactive and adaptive way.

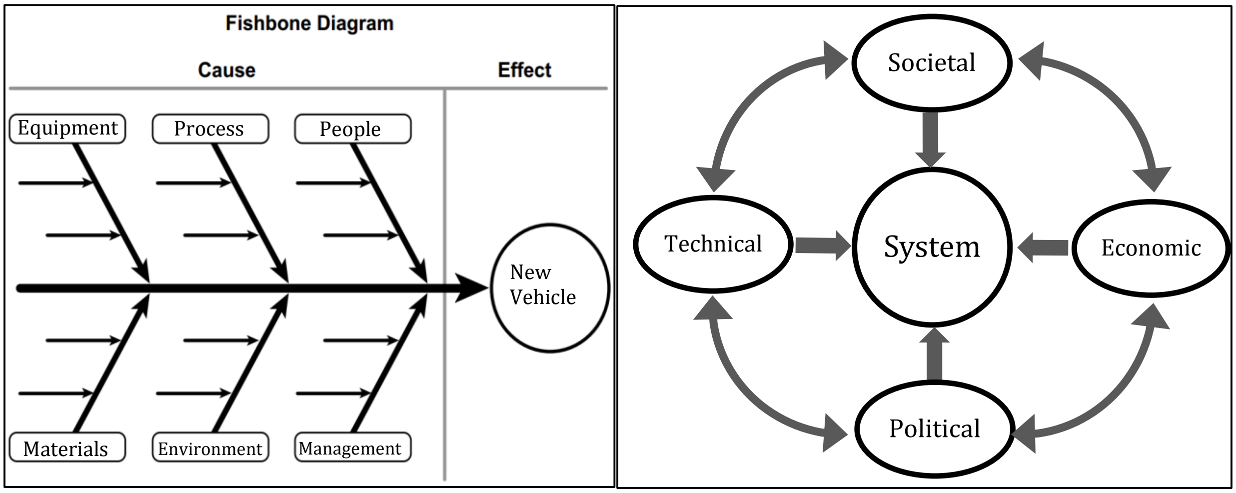


Figure 1-1: Complicated versus complex system diagrams. Complicated system (via Fishbone, or Ishikawa Diagram) [LEFT] (Vandevall, 2013); Complex system diagram [RIGHT].

In Figure 1-1, we can see that the human system is *complex,* having four major influences: societal, technical, political and economic (Figure 1-1). In the waste-to-resource model, both mechanical and human systems intertwine. Unlike straightforward mechanical systems, human systems are often unpredictable. The complexities of human systems make it difficult to solve problems such as poverty. Actions can have both positive and negative effects, can change the parameters of the system, and can make it dynamic and difficult to control one variable at a time.

Economic circumstances strongly influence political systems; conversely, politicians can incentivize new areas of technical growth and economic effects to feed societal trends. Consider Tesla Motors: this car company offers only one viable ground-up product, largely the result of governmental incentives (zero-interest loans to the company and federal tax credits to consumers). Yet Morgan Stanley cites Tesla's abilities to bridge the gap between a technology and manufacturing company, meeting the challenge of transportation through a systems approach and dubbing Tesla the most important car company today (Assis, 2014). BMW, Toyota and Mercedes Benz collaborate with Tesla, five states are vying for its new battery factory, and it is having no trouble courting business with suppliers (Assis, 2014). By simultaneously creating a cross-country network of supercharging stations (which charge for free and can provide half a charge in thirty minutes), innovating in solar panel technology to power these charging stations (through its sister company Solar City), providing cars that travel 265 miles on a single charge (eliminating range anxiety), and offering sales directly from company-owned stores, Tesla is removing obstacles to purchasing an electric vehicle (Tesla Motor Co., 2014). In short, technical innovations that were initiated by governmental response to environmental pressures have created a systems solution to transportation challenges. Established car companies are scrambling to innovate within this modern ecosystem.

Poverty is an outcome of various systems problems; it persists in spite of the many efforts made toward eradicating it. As Meadows (2008) explains, problems such as poverty are not intentionally created; however, they continually occur because these are actually systems problems that people are trying to solve with linear approaches. Systems-based SCD seeks to frame a development problem by analyzing all constituent parts in relation to the whole community. Likely positive and negative impacts are assessed, and consequences—both intended and unintended—are considered. Often the solution to a complex problem is not singular but a combination of mixed-dynamic and cross-disciplinary approaches that can increase the likelihood of providing a robust outcome.

1.4 Methodology

The test bed of this waste-to-resource framework for systems-based SCD is a new tool for helping to bring products to market: the Community Transformation Plant (CTP). Started by Dignity Products and Services, the CTP in Cagmanaba, Philippines, is a community-centered manufacturing plant. The CTP concept brings global and local investors together with developing communities worldwide, creating a network of stakeholders who are interested in building products, businesses, and communities through social entrepreneurship. A CTP can become a great asset to a rural community, since such communities often have natural resources available but lack the commercial or technical knowledge to convert these resources into value-added products that can be sold in global markets. In a CTP, individuals learn marketable skills—as well as learning how to engage more effectively in their local community, government, and families—all while making valuable commodities from waste that would otherwise spoil their environment.

A CTP is more than a factory. It provides the nexus for an ecosystem of sustainable community development. One of the primary goals of a CTP is to share ownership among the employees and investors. No single entity has controlling ownership, and a shared-profit model is at its core. Dignity Products and Services has started CTP-1 to serve Cagmanaba and Badian, Philippines; the facility utilizes a zero-waste approach to processing the whole coconut so that the enterprise can create as much wealth as possible. Coconut shell waste is an example of a successful waste-to-resource implementation unique to this facility. Other CTPs may be built in 2015-2019 in the Philippines, Thailand, and Indonesia. The results of this study will make a methodology available for rural communities looking to transform waste in their communities into value-added products that can bring truly sustainable community development.

In community development, planning between the target community and the development agent must occur from the outset of the project; the waste-to-resource analysis helps achieve this. The systems-based SCD framework in this thesis assesses the community, considers what materials are available, and examines which of those materials have not yet been optimally utilized. It then explores how value can be added, designs and implements appropriate means to add value, measures results, and allocates benefits to be shared. The waste-to-resource framework could be applied to various communities around the globe, but it was developed focusing on rural communities that have access to natural resources. Figure 1-2 shows each method used as part of this waste-to-resource framework and is divided into three sections, each comprising a chapter of this thesis and each answering a question posed in section 1.2.

Waste-to-Resources Framework for Sustainable Community Development				
	Method	**Action**	**Description**	
Community Assessments, Case Study and Indicators	Stakeholder Assessment	SWOT analysis	Strengths, weaknesses, opportunities, threats Review capacity and vulnerability	**Chapter 3**
		Stakeholder identification and recruitment	Roles and responsibilities within partnerships	
	Primary and Secondary Data Collection	Collect primary and secondary data for all categories in the community assessment	Location Education and livelihood Governance Vulnerability to natural disasters Infrastructure Family structure Capacity and resiliency	
	Community Survey	Conduct and administer questionnaire	Waste questions Resources questions Legacy questions	
	Materials Assessment	Identify materials	Survey community for locally available materials—link possible applications	
	Causal Analysis	Problem tree	Map problems in community	
	Modeling the Waste Stream Transformation	In partnership with CTP, begin transforming waste.	Process waste stream and begin assessment. STELLA Model	
	Give Indicators for Success	Review partners, indicators and impacts	All stakeholders, infrastructure, governance, logistics, materials, technical, environmental, and human	
Enterprise Impact	Technical Assessments	Measure technical Impact	Material and mechanical property validation	**Chapter 4**
	Environmental Assessment	Measure environmental impact	Embodied energy calculations	
	Commercial Assessment	Sell initial waste product to client	Work with partner companies (product sales)	
Human Impact	Human Assessment	Measure human impact	Review community impact	**Chapter 5**
	Profit sharing	Build equity in community, sharing profits from waste-to-resource sales	Monthly giving-match Employee Shareholder 401k, continuing education, Community Revitalization Projects, Livelihood programs, etc.	

Figure 1-2: Components of the waste-to-resources framework.

Technically, the materials science and engineering of the natural composites show that transforming coconut waste into engineered fillers for various plastics is a viable approach. In resources such as coconut, however, mechanical properties are not yet fully leveraged, nor are environmental and human benefits realized from the waste byproduct. Finally, profit sharing and other community programs broadly serve the equity component of the sustainable community development work, rounding out this research. Regarding the remainder of this thesis, Chapter II will present a literature review, Chapters III-V will cover the research framework, and Chapter VI will offer conclusions and recommendations for future work.

CHAPTER II

LITERATURE REVIEW

Models that center on the use of waste have not been adequately addressed in the literature. Thamae et al. (2008) describe a lack of knowledge or technical know-how about ways to transform waste effectively and efficiently into other resources. Specifically, few models exist on how to transform waste materials available in a community into economic development opportunities that will enable sustainable development (Sianipar et al., 2013). A literature review exploring these gaps in both publications and current methods was conducted in the course of this research.

This chapter investigates waste material transformation and reviews the approaches to waste from a systems perspective (Chan & Huang, 2004). Transforming waste into resources is a game changer for a community. Waste management improves sanitation (Pasang et al., 2007), and using waste as a new resource provides material for economic development. The latter takes three forms: (a) providing jobs collecting and organizing the waste, (b) providing jobs by processing the waste, and (c) engineering and building products from the waste. To put these strategies into practice, materials science and engineering-based technology can be used to create new, commercially viable innovations from agricultural waste (Ballie et al., 2012; Wallace, 2005). To date, a waste-to-resource methodology to make polymeric composites that are both technically and commercially viable has not been clearly mapped or modeled.

The literature shows potential for such innovations as well as examples where transforming waste into new materials has been accomplished (Brasileiro et al., 2013). It also shows that agricultural waste is not efficiently being transformed into engineered composite materials (Corscadden et al., 2014). Material innovations can create technical breakthroughs that have a positive impact both socially and environmentally. The combination of these leads to triple bottom line approaches that are most helpful to the community (Mori & Christodoulou, 2012). Finally, the literature review explores how Judeo-Christian theology has been a part of sustainable development and its impact within the communities in the Philippines where the model is to be implemented (Becker, 2000; Chan, 2011).

2.1 The Untapped Potential of Global Waste

The amount of global waste is projected to double by 2025 (Lacey, 2012). The literature shows that waste is an underutilized resource; those who are able to tap into it can be successful and reap value-added profits of various kinds (Chalmin & Gaillochet, 2009). A waste-to-resource model can help divert the waste from landfills, roadside dumps, or backyard piles in rural settings (Troschinetz & Mihelcic, 2009).

Aiming for a zero-waste approach can help a waste-to-resource model to be most efficient. Cost-benefit analyses help to show the value of zero waste (Allen et al., 2012). San Francisco, California, a city that is world-renowned for its recycling and solid waste management practices, pays residents for their waste. The city has an 85% waste reclamation rate. This showcase city is not zero-waste, but it is one of the closest examples found in the literature (Sullivan, 2011).

In Boulder, Colorado, Eco-Cycle is a nonprofit organization that transforms waste into revenue (Eco-Cycle, 2011). As a nonprofit, Eco-Cycle doesn't produce a significant amount of revenue, but the organization is indeed functioning and creating wealth in ways other than monetary; they are creating a richer environment for the community.

The global waste composition in developing countries varies largely by levels of income, with the percentage of organic waste being greater in poorer communities. Identifying opportunities to transform available resources into commercial opportunities is paramount. Disaster, war, or a lack of infrastructure often create an abundance of waste. The World Bank estimates that almost half of the total waste in the world is organic (46%). In developing countries 64%, of the waste is organic (Figure 2-1) including food waste (Ash, 2012). In comparison, in countries where development has occurred, only 28% of the waste is organic (Hoornweg & Bhada-Tata, 2012; US EPA, 2012).

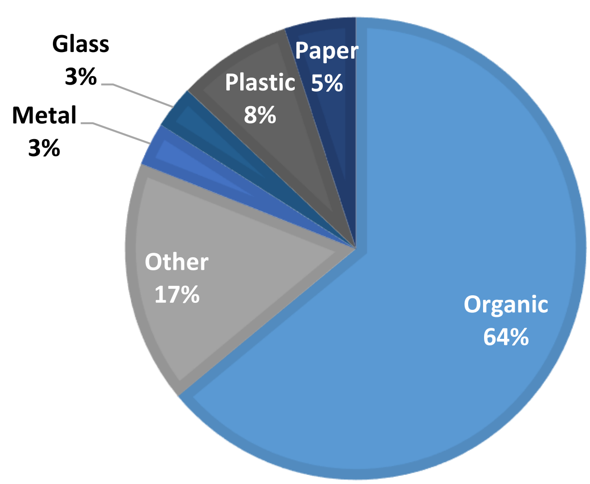


Figure 2-1: Low-income country waste composition. Image reference: World Bank Report, "What a Waste: A Global Review to Municipal Solid Waste" (2012).

Regarding organic waste itself, imagine recovering and reusing coconut fiber or coconut shell that is a waste byproduct for 10 million coconut farmers and their families around the world. Or visualize millions of old tires filling a landfill. Now imagine a new technology that combines recovered coconut shell waste and old tires to make new hybrid composites (Teipel et al., 2011). Apart from our imagination, though, the reality is that the discarding of both organic and inorganic waste in landfills or dumpsites is part of the traditional cradle-to-grave linear system of most materials (Troschinetz & Mihelcic, 2009).

What if, instead of going to landfills, wastes were mapped, sourced, and converted into new materials, as with the imagined coconut shells and old tires? An even newer approach combines coconut shells and old tires to make new hybrid composites (Teipel et al., 2011). Such new materials could enter a global enterprise system that includes product development and innovation, generating profits in the local or regional marketplace (Lebel et al., 2010; Berkhout et al., 2010). Engineered materials that can improve the production of consumer goods will provide profit opportunities, which could contribute to sustainable, broad-spectrum poverty reduction (Karamchandani et al., 2009). A waste-to-resource systems-based approach for recovering and reusing waste in developing communities could be a catalyst for holistic community development. Materials engineering and enterprise-based methods can shape the business and social climate to lead people and governments to self-sufficiency (McCornack, 2012).

2.2 A Systems Approach to Waste

In developed countries, only some waste items that have commodity values are reclaimed and recycled (Adeyemi et al., 2001). To achieve sustainable community development, sustainability should be viewed as a multi-dimensional, cross-disciplinary goal (Mayer, 2008; Szitar, 2014). Sustainable development requires a systems thinking approach (Chan & Huang, 2004), since such problems are complex in nature and solved by nonlinear, non-dynamic methods, requiring a review of many aspects (Casillello & Villarruel, 2011).

Reclaiming and repurposing materials reduces waste and provides opportunity in such a system, and reusing materials within a community helps move forward the common motto, "*Think globally, act locally, plan regionally*" (Chang & Huang, 2004). Overall, the desire to use systems approaches is becoming more common in the field of sustainable community development (Wible, 2012), often seen as the best way to deal with complex problems (Chang & Huang, 2004). An example of a large development effort that could greatly benefit from systems thinking is USAID's Grand Challenges for Development, which includes priorities such as securing water for food, saving lives at birth, all children reading, power for agriculture, and making all voices count (USAID, 2013).

USAID believes that "science and technology, when applied appropriately, can have transformational effects. Engaging the world in the quest for solutions is critical to instigating breakthrough progress" (USAID, 2013). Addressing challenges that need cross-disciplinary solutions requires the creation and support of "self-perpetuating systems, rather than one-off inventions or interventions" (USAID, 2013). Five Grand Challenges have been launched but are not progressing as readily as they could, since the execution of such approaches is lacking, though the need for cross-disciplinary approaches has been acknowledged.

While systems thinking is considered more and more often as a solution, owing to the complexities of development, (Wible, 2012), there is still a long way to go to convince traditional development work agencies that systems approaches are the way of both the present and the future (Richmond, 2002). Because of the feedback loops in systems, the iterative process to evaluate the impact of the intervention allows for a more successful implementation (Braun, 2002; Meadows, 1999, Rashid et al., 2013).

Some of the sustainable development approaches have worked and some have not; learning what succeeds is key in implementing a new model (Deakin, 2011). In recent years, researchers have been focusing on improving social, economic, and environmental components of development and involving stakeholders (De Graaf et al., 2008). Engineered materials can introduce new stakeholders along with more financial gain and opportunity for communities looking to develop sustainably (García et al., 2007). By adding value to discarded materials, such as engineering composites using agricultural waste, higher profits can be generated locally and regionally, which in turn can provide financial wealth and a more stable economy for countries and communities (Teipel et al., 2011).

Engineered materials offer opportunities for communities looking to develop sustainable economic growth (Baillie et al., 2011). By adding value to discarded waste materials through engineering agricultural waste-based composites, significant profits can be generated. This in turn, can provide economic growth and a more stable economy for communities (Teipel et al., 2011). A waste-to-resource system model can focus on the recovery and transformation of waste materials into composite materials that in time could reach both local and global markets. The World Bank calculated that the global solid waste composition varies dramatically according to a country's level of income (Hoornweg & Bhada-Tata, 2012). In low-income countries, waste is 64% organic, which indicates availability of raw materials for waste-to-resource models to take root in local economies.

2.2.1 Negative feedback in waste-to-resource systems. The waste-to-resource model considers unintended, undesirable consequences as well as the benefits of reclaiming and reusing waste. In the communities studied (Cagmanaba and Badian), there is no formal or consistent informal waste collection system. Some community members recognize the opportunity to add value to waste and are already doing so, on a very small scale, by reclaiming certain types of waste. Therefore, if a large-scale operation for waste recovery managed to be successful, it could harm some in the community by removing their micro-business opportunity (Troschinetz & Mihelcic, 2009). Ideally, these community members would be trained to become integral agents within a broader system.

All human systems offer the potential for negative feedback loops (Singh et al., 2009). Tensions may arise from new or changing waste-to-resource value propositions and operations. If and when tensions occur, a thoughtful systems approach helps manage the outcomes for greater acceptance.

Preparation for negative feedback starts by addressing possible unintended consequences (Richmond, 1993). Overall, waste material recovery and reuse provide a model to aid in breaking the cyclicality of extreme poverty, since the approach includes combining economic enterprise and the building of community capacity. Conventional wisdom and past experience dictate that development will occur and have intentional or unintentional, planned or unplanned consequences and outcomes (Peredo & Chrisman, 2006). Sustainable development can also be facilitated through innovation across all disciplines by careful planning and systems modeling (Radziki, 2004).

2.2.2 Present-day informal waste recovery systems. Scavengers, or waste pickers, are the most common type of informal waste-collection system in developing communities (Medina, 2000). People who scavenge through waste are often the poorest of the poor, being members of the most vulnerable groups. A few examples of traditional waste reclamation and recycling groups are the Cartoneros, the waste pickers of Argentina (Medina, 2000); those who work in Brazilian slums; and the Zabaleen, Coptic Christians known to be the traditional waste pickers of Cairo (Fahmi, 2005). Scavenger cooperatives are prevalent in Asia, Africa, Latin America, and even on a smaller scale in communities throughout Europe, the United States, and Canada (Sembiring & Nitivattananon, 2010; Tremblay et al., 2010).

The Zabaleen serve as an example of a community that has experienced both the good and the bad of waste reclamation. Prior to the recent privatization of solid waste management in Cairo, the Zabaleen garbage collectors created what could easily be considered one of the most efficient resource recovery and waste recovery systems in the world (Fahmi, 2005). As cultural outsiders in search of work, the Zabaleen assumed the role of waste collectors. Their primary work was to collect and transport waste; many of these individuals would not have had jobs without this occupation. However, they added little value beyond the initial waste collection and transportation.

Another example is seen in Guadalajara, Mexico. As the city grew, the waste grew exponentially into the rural outskirts and became a problem not only for the environment but also for the many scavengers who flocked to the designated landfill area (Bernache, 2003). Without a system to handle the waste and only informal regulations at best, the informal open dumpsites grew quickly. As a result, the community members who relied on picking through the waste as their livelihood feared for their safety and for their lives.

Waste management in developing countries and communities tends to be informal, and little value is added by the community members who collect the waste (Wilson et al., 2006). Though waste pickers around the world are incredibly skilled at seeing value in waste, generally the value stops at the point of reclaiming and selling the raw material. Most traditional waste pickers sell their recovered goods for a small fraction of the downstream fair market value. Unfortunately, this is to be expected, since little value is added to the material by only reclaiming it (Sembiring & Nitivattananon, 2010).

2.2.3 Improving waste recovery. A person who is scavenging or collecting waste usually has a low income, one that often is not stable and depends on the amount of waste collected (Medina, 2000). A key to making higher profits from scavenging waste is to accumulate the waste stream and then try to sell it in bulk (Wilson et al., 2006). Gaining a still higher profit margin requires access to a vertically integrated chain; thus, the more integrated the community is within the value chain, the better off it will be.

Assessing the available household waste in a community helps to characterize the waste of the region (Benítez et al., 2008). Following waste characterization, waste transformation can occur more easily. When items are discarded versus collected or accumulated separately, there is potentially less value in them (Wilson et al., 2006). As such, waste materials are untapped resources for engineered materials, specifically polymeric (plastic) composites. In a number of ways, waste has been transformed into a viable resource around the world (Corscadden et al., 2014; Teipel et al., 2013; Troschinetz & Mihelcic, 2009).

Wilson et al. (2006) describe the classification of solid waste in developing countries as a way of bringing higher value. In low-income and middle-income countries, the lack of classification makes it difficult to obtain accurate results of what waste is available in the area prior to staging an intervention. This is primarily due to the lack of data and studies (Buenrostro et al., 2001). Though studies have been conducted in low-income communities, there is not a one-size-fits-all solution for waste recovery, especially in low-income or middle-income countries (Broitman el al., 2012). Typically, high-income countries can more easily achieve success with vertically integrated, streamlined waste recovery approaches (Hoornweg & Bhada-Tata, 2012).

A successful informal waste recovery system similar to that of the Zabaleen community could be introduced into rich agricultural waste areas such as Cagmanaba and Badian. Alternatively, a more formal profitable social enterprise could pave the way for waste-based composites to enter the market (Thamae et al., 2008; Noel, 2010). If such a system were created and introduced, societal, political, economic, and technical aspects would be affected within the community (Casiello & Villarruel, 2011). These examples demonstrate how two worlds can sometimes collide but then work together for the good of the community.

2.2.4 Profit-seeking impacts waste recovery. Collecting, reclaiming, and reusing waste must focus on the principle of the stable profit margin (Karamchandani et al., 2009). Conversely, the goal of profit margins can have negative implications as seen in Cairo. Cairo's interest in privatizing municipal solid waste collection invited multinational companies to submit bids to the city government for waste-collection contracts. The total value was approximately $50 million (Fahmi, 2005). The threat of private-profit commercial waste collection put the livelihood of the Zabaleen community at risk (DiDero, 2012).

Herein, then, lies an opportunity for a waste-to-resource product model. Nearly two decades ago, 85% of the waste recovered by the Zabaleen was recycled and reused via micro-enterprise (Wilson et al., 2006; Fahmi, 2005). A major problem was that most of the transformation was minimal. Though hardworking and innovative, the members of the Zabaleen community were (and continue to be) considerably undereducated, yet the Zabaleen community was a rare leader in the informal waste reclamation and reuse industry. They have seen how a waste recovery model can bring income, but they also understand how continued success is in jeopardy due to large-scale waste companies taking over waste transformation opportunities.

Pasang et al. (2007) give another example of the effects of waste in a community—over the past 25 years, technical, economic, political, and social factors have contributed to the failure of waste recovery and reclamation models in smaller communities in Jakarta, Indonesia. Governance is a major factor for the long-term sustainability of a waste recovery model (McCornack, 2012; Ahmed & Ali, 2006). Shortly after waste gains value, somebody will want to stake a financial claim in it, particularly in areas of corrupt governance, where individuals and the community as a whole are vulnerable (Bernstein, 2004).

The biggest problem, aside from serious health and safety concerns, is the relationship with the material buyers. Within informal waste recovery systems, buyers often cheat the waste collectors out of money (Bernache, 2003). The same kinds of problems developed in Southeast Asia, where a plan for waste management was not established, and the problems associated with waste continue to be compounded by natural disasters (Karunasena et al., 2009).

2.2.5 Seeking dignity and equity in waste recovery. In Vancouver, Canada, a better approach can be seen firsthand through the practice of United We Can (UWC). This organization was started as a social enterprise that served over 1500 clients in the downtown eastside of Vancouver (Thremblay et al., 2009). Though this is not a rural area, it is one of the poorest areas of this urban setting. Many of the systemic problems in an urban or rural setting can be helped by social enterprise if implemented correctly (Giovannini, 2012). The UWC organization takes individual “binners,” as they are called in Vancouver, off the street and centralizes them in a safe, clean working environment. This provides dignity for the worker along with consistent wages and safety regulations.

Studying a factory in a low-income community, like the system in Vancouver, along with its complexities has been useful for setting up a waste-to-resource model in Cagmanaba, Philippines. A central plant allows for a sense of community and belonging with a group. Social enterprise has shown early stages of success, particularly when developers work with the community directly to get them involved as key stakeholders, rather than merely extracting a resource from their community (Juwana et al., 2012; Ahmed & Ali, 2006). In the past, top-down approaches to delivering aid or engineering interventions have been questionable and the results unpromising (Amadei & Wallace, 2009).

In the literature, good governance is shown to be necessary for successful community development models. In Eastern Africa and Haiti, the most common expectation for solid waste management is for the government (local city or town) to be responsible for the waste collection (Oosterveer, 2009; Philippe & Culot, 2009). However, in most low-income countries (as in this study and sub-Saharan Africa), access to sanitation and waste collection is very low (Imam et al., 2008).

In rural areas such as Cagmanaba, Philippines, the same is true. Waste is either burned or piled up because it is not seen to have utility or value. The same is true for Indonesia and Sri Lanka, which are rich in natural resources (Pasang et al., 2007; Karunasena et al., 2009).

2.3 Waste Materials as New Resources

When waste is merely recovered or reclaimed, it produces little profit (Sembiring & Nitivattananon, 2010). The profit margin is much higher for the company or individual broker buying the materials or for the end user of the material, particularly for scrap metals or plastics. Recovering agricultural waste currently has less value around the world, and this is where a waste-to-resource model can make a significant contribution to community income.

As an example of a waste converted into a resource, consider coconuts. Currently, coconut oil is an established $3 billion global commodity, based on the average market value multiplied by the number of metric tons [mt] of coconut oil produced (UNCTAD, 2012). A commodity such as coconut oil already has some established informal waste economies and supply chains for the coconut waste byproduct. In fact, some coconut husk fiber is purchased by China for mattress stuffing. Coconut shell is used for activated carbon and handcrafts. The pith is known for its absorption properties and can be used in gardening (Mahr, 2012). However, only minimal value has been added in these applications. Consequently, farmers—and most of the community members in Cagmanaba are farmers—are earning only pennies for each nut they harvest.

When using waste as a new resource, the value chain includes collection, sorting, accumulation of volume, pre-processing, small manufacturing, market intelligence, and trading (Wilson et al., 2006). Although small-scale projects can alleviate some poverty locally, greater impact requires a large-scale approach (Szitar, 2014). In the following section, some examples of waste turned into resource will be discussed.

2.3.1 Examples of waste as a new resource. New applications in transforming waste range from using agricultural waste fibers, to paper mill waste (Jiang et al., 2012), to plastic trash from the slums of Argentina (Thamae et al., 2008). Waste can also be used or reused in packaging materials (Davis & Song, 2006; Kofoworola, 2007; Da Cruz et al., 2012), since studies show waste materials being used to make composites for packaging (Adrados et al., 2012) as well as for cook stove fuel (Vitali et al., 2013). Rice waste can be combined with discarded tires to create new composites (García et al., 2007). In Canada, minimally-processed sheep wool has been used as renewable insulation in building materials (Corscadden et al., 2014). Nano waste-based composites made from pineapple, leather waste, and even cassava are on the rise (Dos Santos et al., 2013; Ashokkumar et al., 2013; Jorgetto et al., 2014). Cellulose, rice straw, and even banana plant waste are under consideration because of their material characterizations (Ibrahim et al., 2013).

At the same time these new technologies are emerging, markets around the world are ripe for alternative bio-based materials (Karamchandani et al., 2009). One example is found in the automotive market, a segment where more people have access to cars than ever before. New composites made with lignocellulose have increased thermal stability and mechanical properties of polymer composites, allowing more use within automobiles (Teipel et al., 2011). From packaging—both pulp and plastic film—to thermoplastic and thermoset composites, the field is broadening for new materials that can reduce the carbon impact and increase mechanical properties (Baille et al., 2011; Thamae et al., 2008). Used tires can be incorporated not only in polymeric composites but also in concrete mixtures as reinforcement (Li et al., 2004). The increase of the composite's mechanical properties when agricultural waste is used shows promise for the sustainability of a waste-to-resource model (García et al., 2007). Mechanical properties show improvements such as flexural strength, which translates into an increase in both stiffness and impact resistance (Baillie et al., 2011). It is clear that materials science and engineering utilizing waste for feedstock can empower a community (Sianipar et al., 2013).

2.3.2 Managing waste as a new resource*.* As a whole, waste around the world is seen increasingly as an untapped resource; innovators around the globe are making progress in finding new applications for waste (Thorneloe et al., 2007). Mechanical properties and material characterization techniques can be used to categorize agricultural waste byproducts' intrinsic properties ahead of manufacture (Ho et al., 2012). Once a waste stock is identified, proper techniques must be used to convert the raw material into powder or fibrous form to be used as functional fillers in composites (Baillie et al., 2011). New ways to develop greener and lighter materials are of key interest to automotive companies (Durbin, 2014). In formulating new agricultural waste-based materials, testing and optimization provide breakthroughs (Thamae et al., 2008; Ho et al., 2012; Robinson et al., 2013).

Another way to manage waste is by transposing rather than transforming it. Transposition moves waste into a new context or location, seen in many examples around the world (Sardinha et al., 2013). Objects considered waste in some places have value in others. The awareness of possible transpositions depends heavily on a community's view of waste and the types of items considered as waste.

One historical example in the Philippines is the jeepney, now a common form of transportation. After World War II, U.S. military jeeps were left behind by American troops (Tourism, 2008). The Filipinos retrofitted the jeeps with parallel benches and rooftops to serve as small local buses. These retrofitted jeep-turned-jeepney minibuses exemplify how waste can become a source of new value—in this case, low-priced public transportation.

What happens when the waste that was once transposed into something useful no longer holds its value? Moving waste from one place or from one context to the next can usually be done easily, but after one or more cycles, extending the waste's useful life can become more challenging. Eventually, the transposed waste will lose its value, leaving its last owner to figure out what to do with the waste.

The transposition of waste around the world, whether it is donated clothing from a developed country or the old World War II jeeps left behind, leads to re-examining waste transformation models over time and also provides an example of how waste can benefit the environment (Broitman et al., 2012). For many religious organizations, embracing the idea of waste transformation for sustainable development is a logical next step, since it goes hand in hand with their firm stance on the front lines combating poverty.

2.4 Judeo-Christian Theology in Sustainable Development

Recent studies have shown a link between spiritual beliefs and caring for the environment along with solid waste management (Taylor, 2004; Mohamad et al., 2012). Some religious communities are even finding success with recycling waste within their communities (Mohamad et al., 2012). Though at this stage the link is more anecdotal than scientifically studied, a community's predominantly Christian-Catholic beliefs and how that theology has played a role in its development are relevant to the implementation of a waste-to-resource framework.

In rural communities of the Philippines, a spiritual context is an oft-discussed component of everyday life. The majority of community members who live in Cagmanaba and Badian, Philippines, identify themselves as Catholic or evangelical Christian. Therefore, it is important to explore the impact of the Judeo-Christian influence on the community and on sustainable development.

A belief in God and particularly the centrality of the saving message and power of His son Jesus Christ has been the motivating cornerstone for Christian development in many remote communities. Christian-based beliefs impact and influence both the members of the community and the partners working with the community. Specifically, in this present work, the Christian beliefs of the researcher align with those of this predominantly Catholic-Christian community.

For the last two centuries, the Christian church has played an active role in sustainable community development by focusing, or attempting to focus, on the development of the whole person (Starling, 2010; Schneider et al., 2011). A waste-to-resource approach to sustainable community development is not merely about building economic prosperity. Jesus tells the parable of the wealthy man who chooses to tear down his barns and build bigger ones so he can hoard his huge harvest (Luke 12, Zondervan, 1995). The rich man focuses on his success and his accomplishments by storing grain for many years so that later, he can take life easy, eat, drink, and be merry with nothing else in mind. In doing so, he slips from an ordinary wealthy man to one who is missing the greater picture.

Money is an attribute of wealth, but wealth is more than money. Wealth considers benefit to the community, and it considers equity. True wealth encompasses more than increased income and rightfully so. Waste-to-resource transformation should organically foster new opportunities for farmers and employees; then the newly earned money can be used to nurture families, to love neighbors, and to invest in communities. These actions would increase peace, both personal and political, on Earth. This transformative focus of Christian theology is what many members of Cagmanaba and Badian profess as the most meaningful to them.

Part of being truly wealthy is carefully considering how best to help others. Behavior Change Communication (BCC) helps foster lasting change as a necessary component for a community to be dynamically developing and transforming, especially with new financial benefits involved (C-change, 2012). BCC promotes positive behavior, such as not squandering money. The methods provide a supportive environment that enables individuals, communities, and societies to sustain positive desirable behavioral outcomes.

In "Sustainability: The Five Core Principles," Michael Ben-Eli (2005) states that there are five core principles (or domains) to sustainability: material, economic, life, social, and spiritual. To Ben-Eli, sustainable development is more than meeting the needs of the present without compromising the future. Development is based on capacity, where the human potential to develop fully is a function of the environment's full capacity. Ben-Eli's five core principles comprise, in essence, a balanced person, community, and system. First, consider the *people in the community.* In the Christian tradition, adherents have been created and called to care for one another and be good stewards of what people are given, including the environment. This creates a desire to care for the home environment. In essence, suggesting a waste-to-resource framework for sustainable community development links, the material, environmental, and spiritual principles.

Today there are many available development approaches (Singh et al., 2009), and deciding which is the best fit depends on a variety of constraints. Unfortunately, an intervention often depends on the organization's goals rather than the needs of the people (Barkemeyer et al., 2011). In the end, if the intervention is not a proper fit to the community's true needs, the state of development will regress to the way it was before the ambitious endeavor.

In the end, the discussion must center on sustainability at all levels, from local to global, according to the UN's Human Development Report (UNDP, 2011). Once joined together, all five principles (material, economic, life, social, and spiritual), and the belief in God, can create a platform for true sustainable development.

2.4.1 The presence of a belief in God. An exploration of the role that Judeo-Christian theology plays in the area of sustainable community development is essential to this research. This is primarily due to the second greatest commandment: we are to love our neighbors as ourselves (Matthew 22:39). The strong value of community is contained in this commandment. Rural communities are intrinsically tight-knit; furthermore, one who espouses a Christian worldview will place a high value on community, and members will consider themselves wealthier if the quality of their community is high.

The communities of Cagmanaba and Badian value their prevalent belief in God, and though their income is lower than in most developing communities, many community members consider themselves to be rich in God and rich in love. Community members tend to believe that to know God is to be rich and that to have a relationship with God surpasses all wealth in material things. This belief reflects a holistic view of what is important in sustainable community development. The Christian church over the centuries has had as its Biblical center a command to care for the oppressed and the financially poor (Matthew 25; Hebrews 13). This command in part led to the formation of liberation theology.

2.4.2 Liberation theology. "To work justice is to know God; when justice does not exist among humans, God is ignored" (Hennelly, 1990). Liberation theology is a movement in Christian theology that began in the 1960s in Latin America (Rowland, 2007). This theology accentuates freedom from social, political, and economic oppression as an anticipation of ultimate salvation (Chan, 2011). Liberation theology encourages Christians to commit themselves to the liberation of the poor and oppressed (Litonjua, 1998).

Contemporary evangelical Christians sometimes voice a concern regarding liberation theology in that it accentuates the horizontal, neighbor-to-neighbor, component of the faith to the detriment of substantive focus on the vertical component, God-to-human, which is the bedrock of the Judeo-Christian worldview. A strict focus only on physical forms of oppression (lack of physical needs being met—food, shelter, living standards) can miss the spiritual oppression that is also of great importance to the beliefs of the Christian church and its members (Chan, 2011). Because of this, the holistic church is called not only to help the poor and oppressed, but to address and equip the spiritual needs of a community as well (Allen, 2000).

While liberation theology addresses the importance of liberation from oppression, it labels increasing financial capacity, via capitalism, as negative (Bell, 2003). Evidence of this is seen in one of the early influential liberation theologians, Gustavo Gutiérrez, who wanted to institute major reform of the socioeconomic structure in Latin America, taking control from the oligarchies while removing the capitalistic system that was in place (Gutiérrez, 1990). Practitioners of liberation theology often view capitalism as the system to blame for the exploitation and oppression of the poor (Burns, 1992). Traditional liberation theology can clash with a reformed or hybrid approach to both liberation theology and conscientious capitalism (Volf, 2003).

As a systems approach, capitalism has the potential to elevate many out of oppression (Volf, 2003). Synthesizing these three concepts, (1) liberation theology and its focus on freedom from physical oppression, (2) freedom from spiritual oppression, and (3) the potential conscientious capitalism can have on a system, provides a solid conceptual foundation from which a successful waste-to-resource model can be developed and implemented. Chan says it best in this journal article, "How Liberation Theology Has Influenced My Practice":

> The potential for capitalism to enhance human life and allow for social development should not be ignored. A balance must be sought, allowing capitalism to benefit people but not allowing it to control all, not deviating from Christian teachings and God's commandments to love our neighbors, and not overindulging in material pursuits and pleasure of the flesh. (2011)

The concepts in liberation theology are central to Christian teaching; therefore, they have a tremendous impact on efforts toward sustainable community development around the world. A balance, however, is necessary to stay true to the gospel message of the Bible and Christian theology. *Capacity* is a foundational attribute used to quantify the *capability* of a community. Capacity is measured in terms of: institutional, human resource, technical, economic, energy, environmental, social, and cultural capacity. These attributes, in parallel with the five core principles of sustainable development (material, economic, life, social, and spiritual), depict the foundation for a stable and resilient thriving community.

In closing, a review of the literature shows an untapped potential exists to convert waste to engineered materials. A systems approach can be utilized to properly contextualize these new resources. Considering development through the lens of Judeo-Christian theology adequately addresses the whole person and provides the most robust solution to the challenges at hand.

CHAPTER III

COMMUNITY ASSESSMENT AND CASE STUDY

As part of the waste-to-resource framework for sustainable community development, this chapter describes the results of a community assessment conducted in the communities of Cagmanaba and Badian, Philippines, and presents a case study of agricultural waste-to-resource implementation, which provides the context for rural SCD.

In sustainable development, community assessment is vital to long-term success. While getting to know the community and determining what the goals of its members are for SCD, a foundation for model implementation was established. Though some members from the Dignity team have been working in the Albay province for the past twenty years, only recently (2010–2013) did Dignity Products and Services built its Community Transformation Plant (CTP) in this remote seaside region near the southern tip of Luzon, Philippines (see Figs. 3-1, 3-2, and 3-3).

The waste-to-resource framework could have been tested in various locations. It was actually tested and iterated around the Dignity Products and Services CTP in Cagmanaba, Philippines, because the CTP offers a unique method of partnering with the community to create manufacturing and skill building opportunities. Additionally, Dignity Partners had been working in the area prior to the CTP being constructed, so outcomes are more likely to be seen sooner than in a community with no previous encounter with community development.

The waste-to-resource framework yields results more quickly and efficiently when this type of partnership has already been formed between the community and the company, as the system is already mostly established. Since team members affiliated with Dignity Products and Services have been working in the area over the past 20 years, mostly in the educational system, they provided a connection for getting to know the community, helping to build relationships and to assess the community's members who could take up leadership roles when the time came to start a CTP. Therefore, the researcher and framework developer (Elisa Teipel) chose to test the model in this setting.

In summary, the waste-to-resource framework could be used in any developing community that has waste at their disposal, since waste materials can be processed into new resources almost anywhere. However, the duration of each stage to implement the framework and the time to market will vary greatly depending on the community's capacity and resiliency to begin with. Therefore, if the model is to be used in a community that has less capacity, less educational access, or fewer existing partnerships, adjustments and perhaps more iterations be needed. Further discussion includes the Indicators for Success in section 3.4, as well as the Future Work section in chapter 6.

3.1 Community Assessment Tools

Community assessment, case study, and indicators make up a large portion of the waste-to-resource framework. The community assessment is made up of sub-assessments (analyses), which include: (1) stakeholder assessment, (2) primary data collection, (3) community survey, (4) material assessment, and (5) causal analysis. Primary and secondary data was collected for the purpose of building the context of the location and constructing the survey. The community survey, materials assessment and causal analysis are presented in section 3.2.

3.1.1 Stakeholder assessment. Once the community has been identified and a causal analysis performed, a stakeholder assessment of all participants is the next step in the waste-to-resource framework (Warner, 2006). The stakeholder assessment includes an analysis of Strength, Weaknesses, Opportunities, and Threats (SWOT), as well as a Stakeholder Analysis Profile Matrix. In Cagmanaba and Badian, analyzing the SWOT helped the project team prepare to implement the framework. The SWOT analysis in Table 3-1 highlights the communities' capabilities, dictating the issues the response team can realistically address.

Table 3-1

SWOT Analysis of the Communities of Cagmanaba and Badian

	Helpful to achieving goals and objectives	Harmful to achieving goals and objectives
Internal	STRENGTHS	WEAKNESSES
	Hard workers, look for ways to use their skills Seeking employment Offer their best to host and welcome visitors Work well on teams, willing to try new things Wiliness to learn and be trained, willing to try various jobs regardless of how pleasant or unpleasant the jobs are Family is very important Loyal to each other as a community i.e. in emergencies Would like to improve their community	Rural location Financial constraints in their incomes General health issues, high rate of diabetes and heart problems Unskilled in manufacturing, mostly fishermen and farmers, a more timid community Education: community has primary-level education, with 50% having some secondary school Local infrastructure lacking, roads are not complete, few ports in the area can handle 40-foot shipping containers Gambling and drinking cause conflict in families and create family tensions
External	OPPORTUNITIES	THREATS / CHALLENGES
	Area has abundance of natural resources, i.e. waste Dignity Products and services has partnered with the community and wants to continue collaborating with the community Some funding to expand the business opportunities Partnership with local schools and government offices Socially conscious investors, business, and education partners are eager to work with community Governor's office has this community highlighted as one they'd like to see flourish	Language expectations from the outside No access to basic local infrastructure needs: medical, banking, and food Hard to keep community thriving under such conditions No official local police, safety measures are lacking for added business security and capacity of infrastructure Jobs, current job market can be especially hard on this community—high unemployment rate Larger companies could come in and exploit the group

In a project that involves various groups of interested partners and collaborators, collectively known as stakeholders, an assessment of each helps to organize the development process. Seven different groups of stakeholders have been identified for the initial case study in the communities of Cagmanaba and Badian. Table 3-2 summarizes the various stakeholders' relationship to the project, their interests, and the parameters that influence them, along with how they relate to the other project stakeholders.

Some stakeholders are located in the community: the community members, the Philippines arm of Dignity Products and Services, International Teams, and Grace Christian Mission High School. The financial investors and Essentium Materials (product sales, some R&D) are located in the U.S., primarily interacting with the community through Dignity Partners. The business partners, as noted in the table's bottom row, are the end users of the engineered materials. Although these stakeholders may profess interest in the products and the path by which the products are obtained, those interests are anecdotal until supported with evidence. American automotive companies, for instance, are bound by product-quality and product-cost constraints. Unless waste-to-resource materials meet these constraints, the automakers are reticent to use certain products simply because they are sourced sustainably from rural communities working to alleviate their poverty.

Table 3-2

Summary Stakeholder Analysis Profile Matrix

Stakeholder	Interest in partnership	Effect of project on interests	Capacity and motivation to participate in waste-to-resource framework	Relationship to other stakeholders
Communities of Cagmanaba and Badian (Community)	High	High	High—Improve livelihood situation	Everyone in varying capacities
Dignity Products and Service, LLC (Dignity)	High	High	High—Vision for community	Everyone in varying capacities
International Teams (IT)	High	Medium-High	Low—Capacity is high, but participation with engineering solution is low. Can share team members to work on the project	Communities, Dignity, Grace Christian mission
Grace Christian Mission High School (GCM)	Medium-High	Medium-High	Medium—Encourage graduating high school students to pursue working in SCD field	Communities, Dignity, International Teams
Essentium Materials, LLC (EM)	High	High	High—Motivation, medium capacity (high knowledge, limited time)	Communities, Dignity
Investors (Invest)	Medium-High	Medium-High	High—For return on investment but low in actual framework implementation	Dignity, Community
Business Partners (BUS)	Low	Low-Medium	Low—Business, industry partners linked to Essentium want to have a good product first and foremost	Essentium, Dignity

3.1.2 Primary and secondary data collection. Through both primary and secondary data collection, the communities' assessment includes these factors: (a) location, (b) education and livelihood, (c) governance, (d) propensity to natural disasters, (e) infrastructure, (f) family structure, (g) capacity and resiliency (Stone, 2001). Additionally, a community's capability to participate in sustainable development must be ascertained. Primary and secondary data collected in Cagmanaba and Badian follow.

3.1.2.1 Location. The neighboring communities of barangay Cagmanaba in the Oas Municipality and barangay Badian in the Ligao Municipality, both located in Albay Province, Philippines, are featured in this study. Barangay is the Tagalog term for village, district, or ward. These two barangays are nestled along a coastal front collectively referred to as the Seaside Villages in the Bicol region of Luzon Island, approximately 290 miles southeast of Manila (Figure 3-1). The Bicol region is said to be home to the most coconuts per capita in the Philippines, but it is also one of the poorest regions of the country (Barrientos, 2013). Barangays Cagmanaba and Badian are medium-to-large communities, not big enough to be incorporated as municipalities by Philippines' standards. Together, they are home to approximately 6,000 people (Figure 3-2 and 3-3).

Figure 3-1: Southern Luzon, where Cagmanaba and Badian are located.

Figure 3-2: Barangays Cagmanaba and Badian, Albay, Bicol, Philippines, on the island of Luzon.

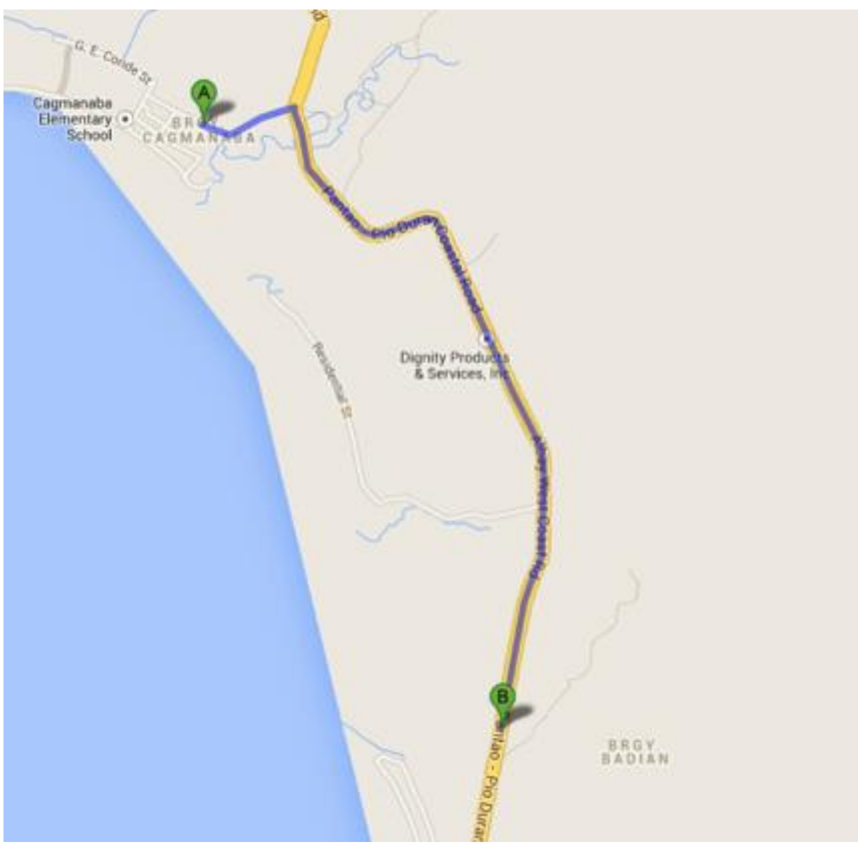


Figure 3-3: Neighboring barangay Badian, 3km from Cagmanaba.

3.1.2.2 Education and livelihood. The communities of Cagmanaba and Badian are rural seaside villages that rely almost completely on subsistence fishing and farming, with minimal industry. Until recently, other than the private Christian high school started by a Filipina missionary teacher from Manila (Grace Christian Mission, which opened in 1980), there were no high schools in the area. The education of most citizens ends at the elementary level.

Subsistence existence characterizes the region, and the unemployment rate is approximately 80% among eligible males (Dignity, 2013). Occasional day laborer positions are rare but present, especially with road construction increasing in the area,. Some resale of grocery goods purchased in the larger cities occurs in the barangays: in lieu of stores, some families sell goods from shelves in front of a house. Some family members leave for 3–4 months at a time to find work in larger cities or other countries and send money home.

The soil is fertile, and the people could grow many types of healthy green vegetables, but the locals do not consume many green vegetables as a consistent part of their diet. They eat a lot of fish and other abundant food resources in the area—rice, coconut, bananas, and other fruits. There is petty crime in the area, but after the National People's Army (guerillas) left the area over ten years ago, the incidence of murder is low.

3.1.2.3 Governance. Each barangay has a captain, similar to a mayor, who represents the barangay council at community and provincial meetings. Across the Philippines, numerous other government agencies take various roles in the community. The barangay captains can work with these agencies, typically located in larger cities with other arms of the government. For example, the Philippine Coconut Authority, known as the PCA, has a barangay official in charge of all coconut-related issues, as do the Carp

Fishers Association and the Seashore Preservation Association. Within the local Christian churches, community leaders help the community members mobilize for new projects in the area. On the one hand, having the assistance of local leaders contributes to the sense of community. On the other hand, some local leadership can be roadblocks to change—not every outside idea is immediately embraced. As a result of these dynamics, new development models, like the waste-to-resource framework presented in this research, should be shared with these community leaders first to reach consensus and facilitate synergistic development.

In rural areas, often the predominant local ambition or goal is to become an elected official. Upon attaining office, politicians acquire government money that can be used at their discretion. Local politicians often make promises while on the campaign trail, and they grant special favors to their supporters after being elected. Since budgeted government money can be used at the official's discretion, the money can even be put back into the elected official's own campaign. Such pork barrel politics tend to create an opportunistic field for granting favors, often in exchange for votes. In its best form, this system offers government officials the ability to give money to certain projects right away, but in its worst form, it is the primary vehicle for local corruption.

3.1.2.4 Vulnerability to natural disasters. Typhoons are the number one natural disaster affecting the Philippines, which has a tropical climate similar to that of the Florida peninsula. A typhoon hit the coast of Cagmanaba and Badian a few years ago, and many of the houses were destroyed. Since the community subsists on rice, coconut, and fish, the typhoons have long-term consequences to two-thirds of the food supply. It was a full year after this typhoon before a full new crop of mature coconuts was ready for harvest. Overall, typhoons in the area tend to weaken before striking Cagmanaba and Badian, which have some steep hills providing protection. Burias and Masbate Islands provide an outer layer of protection from tsunamis. Cagmanaba and Badian are located on the Ring of Fire, presenting the potential for destruction by earthquakes. However, most communities are not on hillsides, nor do they have tall buildings, so they are at less risk for such destruction.

3.1.2.5 Infrastructure. As of 2011, 10% of the primarily coastal roads near Cagmanaba were paved. A two-lane road to the nearest coastal highway that goes all the way to the nearest port, Pio Duran, is now under construction. The nearest bank is a 1 hour drive from these barangays. Electrical distribution, where the infrastructure even exists, is subject to brownouts 50–75% of the time (Dignity, 2013). There is no easy access to clean water or plumbing. The community does not have a regularly functioning clinic. Rare visits by a government nurse are the only medical attention most community members ever receive. In the case of an emergency, the nearest hospital—a low-level, minimum-care facility—is 2.5 hours away.

Most sanitary facilities are outside the homes, typically pit latrines. The average home is a Nipa hut of 1 or 2 rooms, built of coconut lumber and bamboo slats with a thatched roof. If the home is made from cinder block, it typically consists of 3 rooms and dirt floors. There are only a few homes in the area that have block walls, metal roofs, and tile floors. The street is the main social artery of the community. People not only drive on it, but they go there to talk, dry their rice, and watch their children play.

3.1.2.6 Family structure. Gambling is a prevalent issue in the community; however, the social structures are strong overall, and there is a high level of family commitment. Like most of the northern Philippines, the majority of the population is predominantly Catholic.

There are five small Protestant churches in the area. Typical families have 3-4 children, who are usually spared household duties but participate in the rice harvest. Older children always take care of the younger children. Families generally exhibit a less-than-strict attitude to discipline. Although English is taught in the high schools, community members tend to be shy with their English and reluctant to speak it.

3.1.2.7 Capacity and resiliency. Turning waste into new resources can bring relief to a financially depressed region. Without exception, however, this transformation is susceptible to bringing harm as well as benefit. Newly created income from new materials and new resources is frequently squandered, and this outcome must be considered at the outset of any new development (Dignity, 2012). The possible life-threatening implications—such as robbery and murder that can occur with newfound prosperity—require full consideration prior to any implementation of new development.

Another potential problem with converting agricultural waste into new resources to produce income is partner organizations that commandeer innovations, believing that they better understand the needs of the community than the community itself does. These organizations sometimes rush to impose their own ill-researched solutions and plans. To balance such imposition, an initial metric must clarify each community's intrinsic context for waste and wealth.

Behavior change communication (BCC) is an essential component of lasting change within a population that is dynamically developing and transforming, especially in the face of new income. In this sense, BCC is geared toward developing strategies that promote positive behavior in areas such as personal financial management (C-change, 2012) These methods provide a supportive environment that enables individuals, communities, and societies to sustain positive behavioral outcomes (Freeman, 2012).

3.2 Case Study: Community Survey

The primary purpose of this study is to learn the communities' definitions for *waste* and *resource*. Additionally, the study examines the potential effects of wealth creation on the barangays of Cagmanaba and Badian. Fundamentally, a true waste-to-resource model employs a systems approach to account for the multiple influences on such a project, such as the economic, technical, political, and social impacts. The survey's goal was to gather this baseline data.

3.2.1 Data collection. Research questions were specifically formulated to understand how the communities of Badian and Cagmanaba define waste and resource. Transforming an agricultural waste into a resource in a community lacking much in the way of conventional development requires a deep understanding of that community's perception of waste as well as of wealth. The survey was conducted in 321 homes in the communities of Cagmanaba and Badian.

3.2.2 Survey questions. Twelve survey questions were first presented to community leaders by the lead researcher and a trained group of volunteers (see Appendix A). Designing the research survey questions was an iterative process involving interaction with local leadership; the questions were first presented to community leaders for verification of the appropriate cultural connotations and then later refined. Vocabulary was reviewed, and cross-examination by additional community members allowed for verification of the cultural and contextual appropriateness of the research questions for the given educational capacity of the community.

Research questions were tested in four households, then they were released to all community members participating in the survey. The researcher visited this subset of four families to ask general questions and broaden the dialog about how the households viewed waste and wealth. The goal was to better understand the community's context for answering these questions. After these initial four visits, the questions were reworked to ensure appropriate vocabulary as well as to encourage interviewees to understand and to feel comfortable with the questions.

3.2.3 Survey administration. The surveys were carried out over a period of six weeks. To date, the reported results include 321 households within the two neighboring communities. The communities together comprise approximately 1,000 households. The sample rate indicates every third household participated in the survey, meeting the goal of surveying 30% or more of the community. The responses helped frame the baseline for the systems-based waste-to-resource model and methodology, showing how the individual families within the community view waste. Also, the findings confirm some positive (intended) consequences and expose some negative (unintended) consequences of the newfound wealth created by the transformation of waste into newly engineered materials.

3.2.4 Survey results and discussion. The waste-to-resource research questions were proposed to improve our understanding of both the helpful and harmful implications of a waste-to-resource transformation in this community. Additionally, the responses contributed to finding appropriate ways to convert waste to resource. The questions were open-ended; thus some community members gave more than one response and others gave no response at all. The results showed quantitatively that there currently is no waste management system in place in Cagmanaba or Badian.

3.2.5 Waste questions. Three waste-related research questions were framed. First, community members were asked what is useless to them, which is considered waste. Figures 3-4 and 3-5 show the types of materials considered to be waste by the community, with an analysis of organic waste by type. In low-income countries like the Philippines, normally approximately 64% of household waste is categorized as organic waste (Hoornweg & Bhada-Tata, 2012). However, based on the household surveys conducted, Figure 3.6 shows nonorganic waste to make up 57% of the total response in Cagmanaba and Badian. Organic waste made up 41% of all responses; though the region has an abundance of coconuts, bulk organic waste was described as a mixture of banana leaves and grasses. This result is based on 104 responses (Figure 3-5). Only 10 responses indicated coconuts as an underutilized waste.

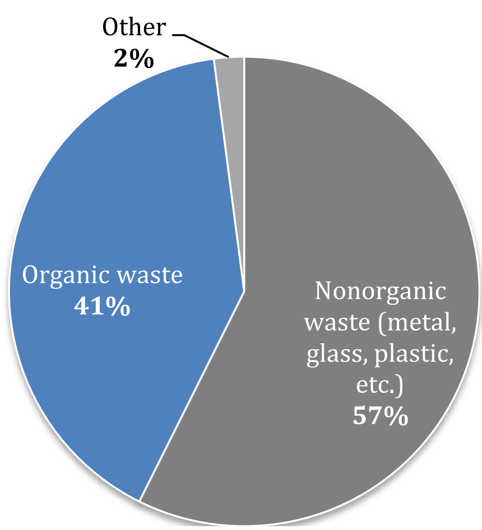


Figure 3-4: Materials considered useless by the communities of Cagmanaba and Badian.

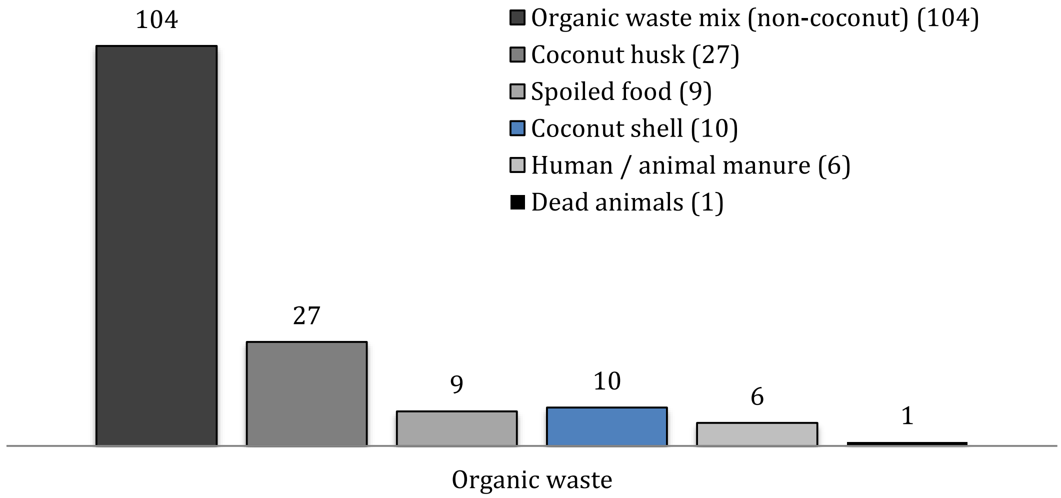


Figure 3-5: Types of organic waste identified by the communities of Cagmanaba and Badian.

The disparity between normal quantities of organic waste (64% across developing contexts) and the 41% from baranguays Cagmanaba and Badian could be due to the new community-based enterprise initiated by Dignity Partners, the community transformation plant. The CTP is already using a supply of coconuts and their byproducts for global markets. Therefore, the community may already view organic waste as a resource. Further research could reveal the cause of this perspective.

Community members were then asked: “Do you see something when you look around here that you think is not being used well?” Results were similar to those of the first question. Figure 3-6 shows these community members’ perspective on observed waste and what resources they felt were being under-utilized.

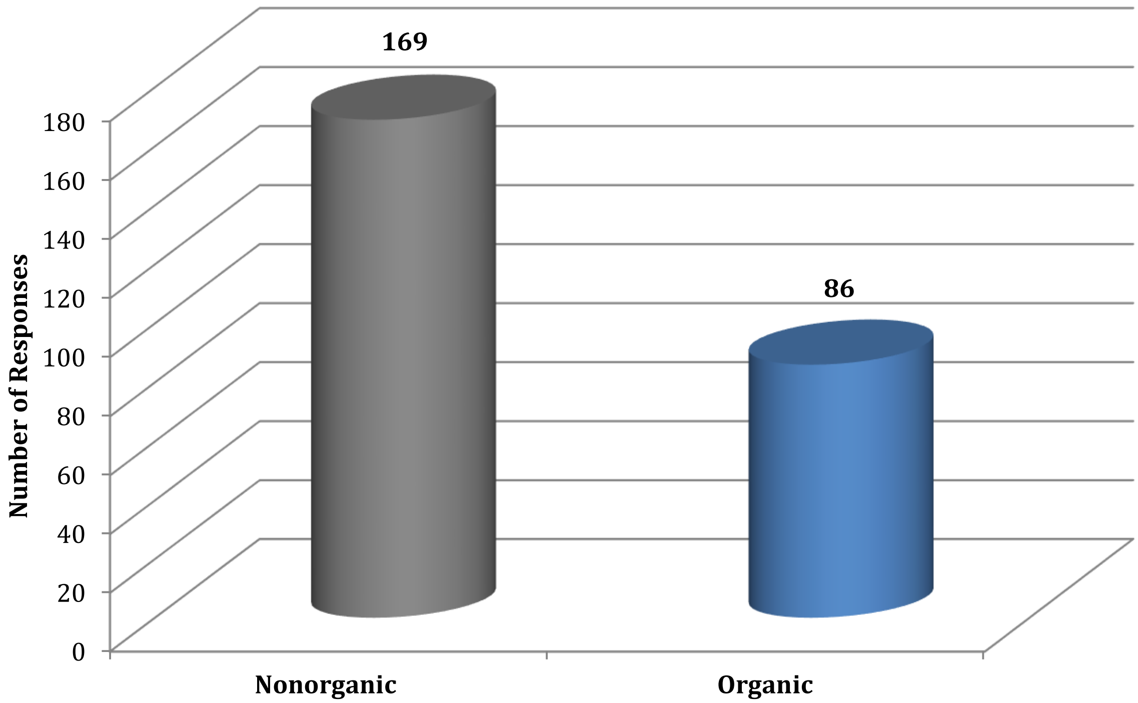


Figure 3-6: Under-utilized resources as seen by surveyed community members.

Figure 3-7 shows the communities' perspective on the types and ways that waste materials could be better utilized. Of the 321 households surveyed, 84% responded that they would recycle or reuse waste materials. Within this 84% of respondents, 43% said they would clean and endeavor to resell waste materials to their local community.

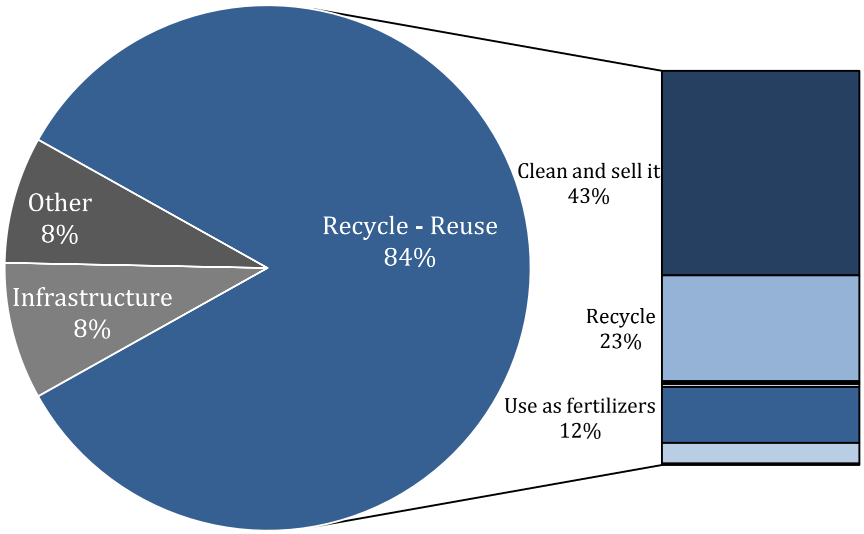


Figure 3-7: Better use of materials.

3.2.6 Resource questions. Newfound or newly added income to a previously low-income community can yield both positive and negative effects. When community members were asked to describe resources, and specifically what it meant to be wealthy or rich, they often answered that true wealth was to know God, to be loved by, and to love God in return. The Philippines is predominantly a Catholic Christian country, and the spiritual influences in the community are noticeable, especially in this region adjacent to the capitol of Albay. The majority of the population believes in the existence of a creator God, as described in the Judeo-Christian worldview, and holds that personally knowing God (i.e., endeavoring to commune consistently with God in the inner self) is to have true wealth. Other intangible responses to the question regarding wealth were: love, to have peace, and to be united with the community.

Community members also identified certain tangibles they defined as wealth. The original question was, "What does it mean to have wealth?" Before the study, it was noted that the four pilot households had a difficult time responding to the concept of wealth. The question in its original wording did not fit the cultural context, or possibly the interviewers had some difficulty in communicating it properly. When wealth was broken down conceptually as financial richness, the community found the question easier to answer. In the survey, 28% of the community responded that to be rich meant to have money or lots of money, and 26% reported that to be rich meant "to have work," specifically "full time employment." Results can be seen in Table 3-3.

Table 3-3
What Does It Mean To Be Rich?

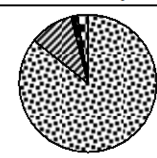
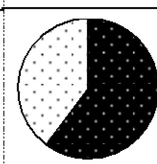
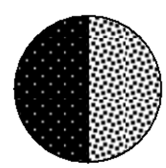
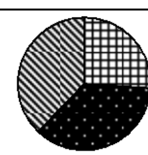
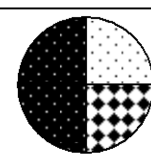
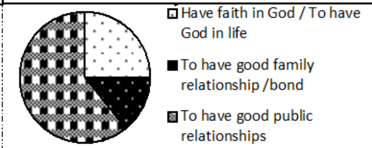
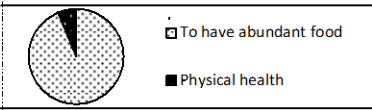
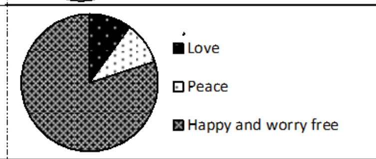
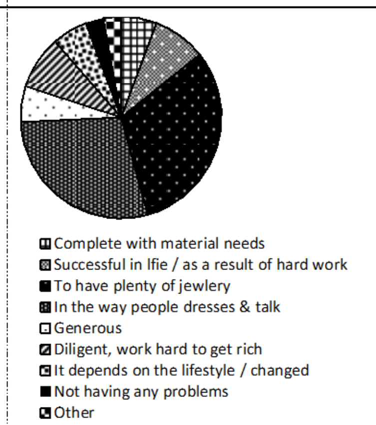
Category	Response	# of Responses	Percentage	Total Responses	Graph of Responses
Money	To have money (plenty of money)	108	86%	126	
	To have big savings/savings in the bank	13	10%		
	To be free from debts	2	2%		
	Can afford anything	3	2%		
House and Properties	To have nice house	50	60%	83	
	Many Real Estate properties	33	40%		
Transportation	To have car	17	50%	34	
	To have many cars	17	50%		
Work	Employed (To have regular work/employment)	31	26%	119	
	To have business	43	36%		
	To have many businesses	45	38%		
Education - Experience	Degree holder	1	25%	4	
	To have children finished their studies/college	1	25%		
	To have worked abroad	2	50%		

Table 3-3 continued
Research Question: What Does It Mean To Be Rich?

Category	Response	# of Responses	Percentage	Total Responses	Graph of Responses
Relationships	Have faith in God / To have God in life	7	25%	28	
	To have good family relationship /bond	4	14%		
	To have good public relationships	17	61%		
Basic Needs	To have abundant food	15	94%	16	
	Physical health	1	6%		
Intangible Needs	Love	1	10%	10	
	Peace	1	10%		
	Happy and worry free	8	80%		
Others	Complete with material needs	2	6%	35	
	Successful in life / as a result of hard work	3	9%		
	To have plenty of jewelry	11	31%		
	In the way people dresses & talk	10	29%		
	Generous	2	6%		
	Diligent, work hard to get rich	3	9%		
	It depends on the lifestyle / changed	2	6%		
	Not having any problems	1	3%		
	Other	1	3%		

Additionally, it was found in the study that if the community members had greater disposable income, 97% would invest in a business of some sort (Figure 3-8). Almost a quarter of the community members, 22%, would use the money to help others within the community, specifically the poor. This point was interesting because the population surveyed is already low-income in a region with approximately 80% unemployment among working-age males (Dignity, 2013). All responses on this query can be seen in Table 3-3 entitled, “Research question: What does it mean to be rich?”

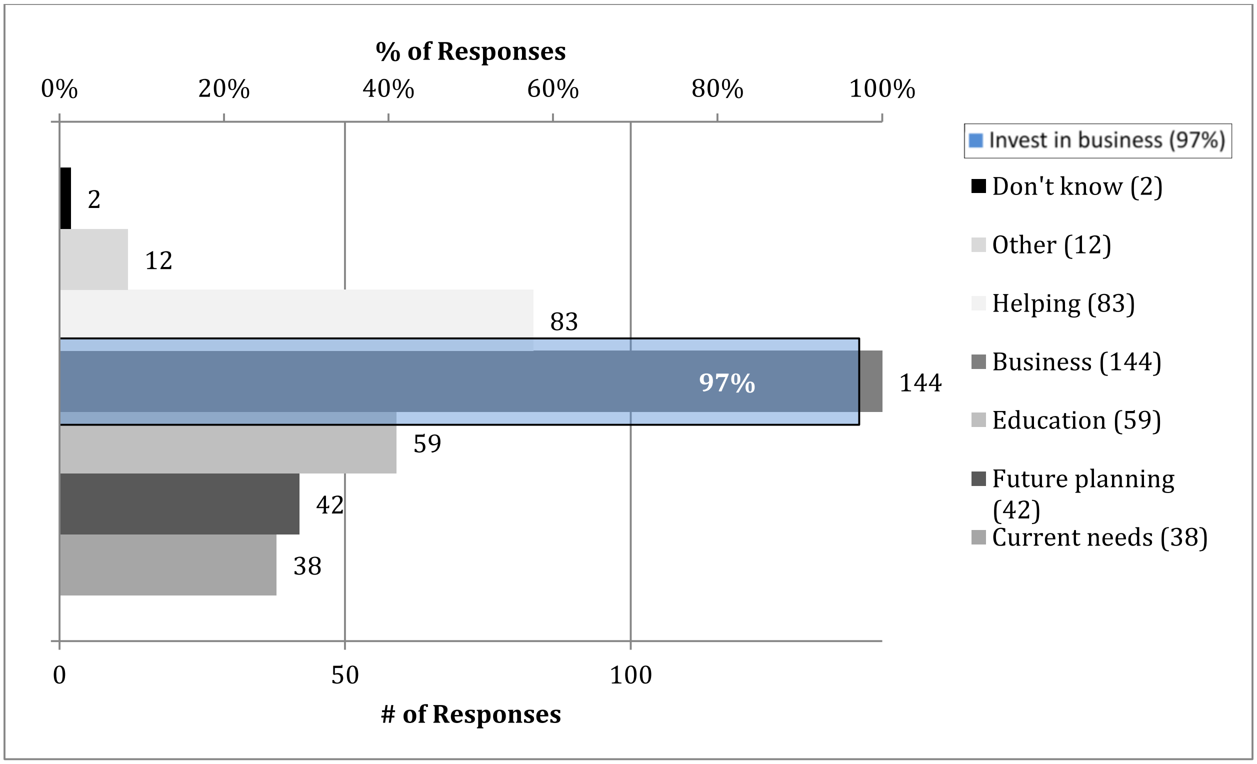


Figure 3-8: If respondents had more money.

The unintended consequences of creating wealth in an area with high unemployment were also considered. Table 3-4 shows responses to the question "Does having more money bring problems?" Approximately 90% of the community answered yes, that money does bring problems. This illustrates a serious implication that must be addressed by the waste-to-resource model.

Table 3-4
Community Responses Regarding Problems

Does having more money bring problems?	Response
Yes	256
It depends on how you use it	10
If not used in good ways	1
No	24
Maybe	7

Figures 3-9 and 3-10 describe problems that come with money within the context of the community members' personal experiences and perceptions. External consequences were categorized according to the most serious problems and therefore were highlighted in the results and discussion. Of the 321 households interviewed in Badian and Cagmanaba, 41% were concerned that having wealth would bring robbery and even murder. The other main concern within the community was that an increase in wealth in the community would have internal consequences. Figure 3-11 shows that 17% of the total responses indicated that having more money might increase an individual's vices.

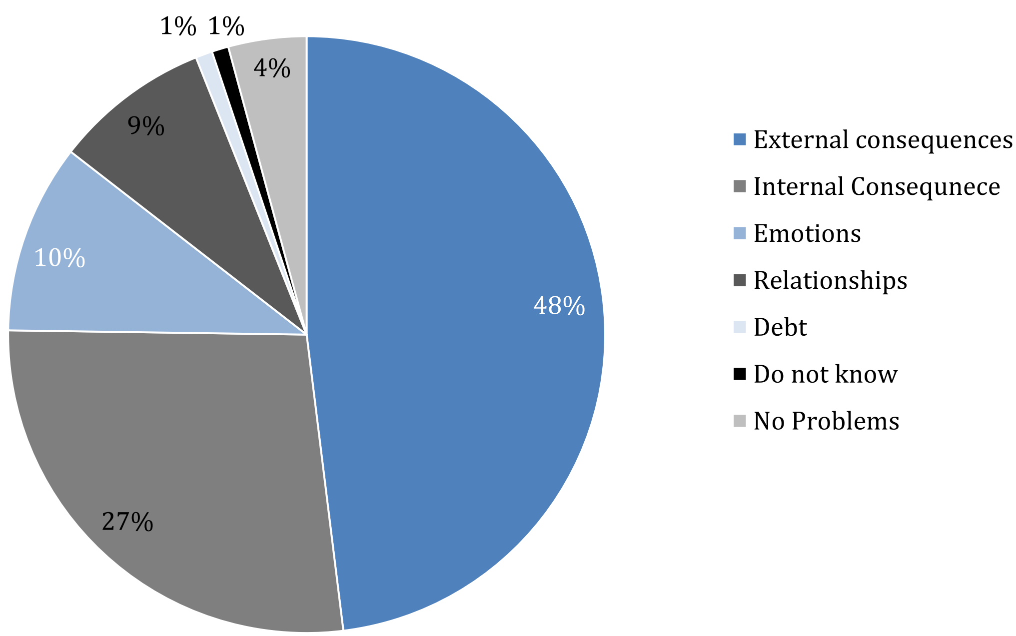


Figure 3-9: Problems associated with money reported by participants.

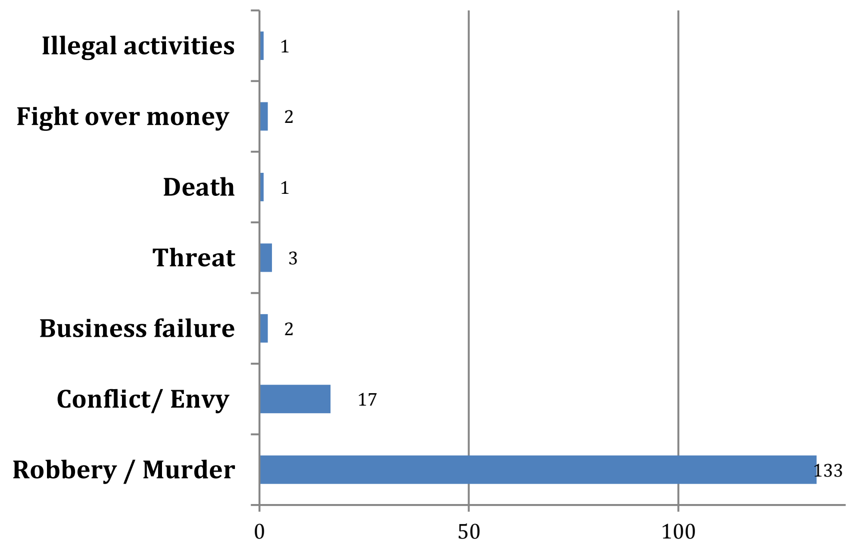


Figure 3-10: External consequences reported by participants.

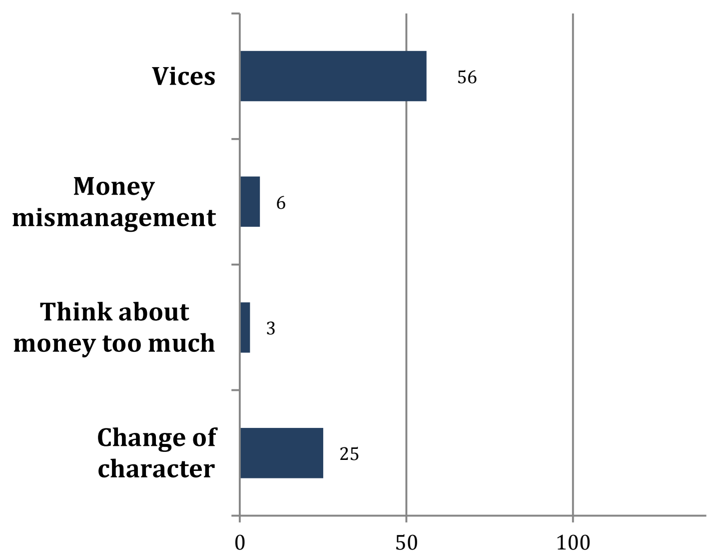


Figure 3-11: Internal consequences reported by participants.

In the Philippines, it is common for men to lose much of their wages gambling at cockfights. Careful analysis of the complexities generated by introducing a waste-to-resource system into a community will help find means of assisting employees and farmers to use their newly created wealth more wisely. Sustainable waste-to-resource production can be accomplished by accounting for economic, technical, political, and major social influences, along with sub-influences such as family, education, and training.

3.2.7 Legacy building. The effects of transforming waste into resource give rise to positive and negative impacts for both a community and an individual. The final research survey question was built around the notion of the community's legacy and of legacy building. The top social needs the community would like to focus on if it enjoyed a greater level income are shown in Figure 3-12.

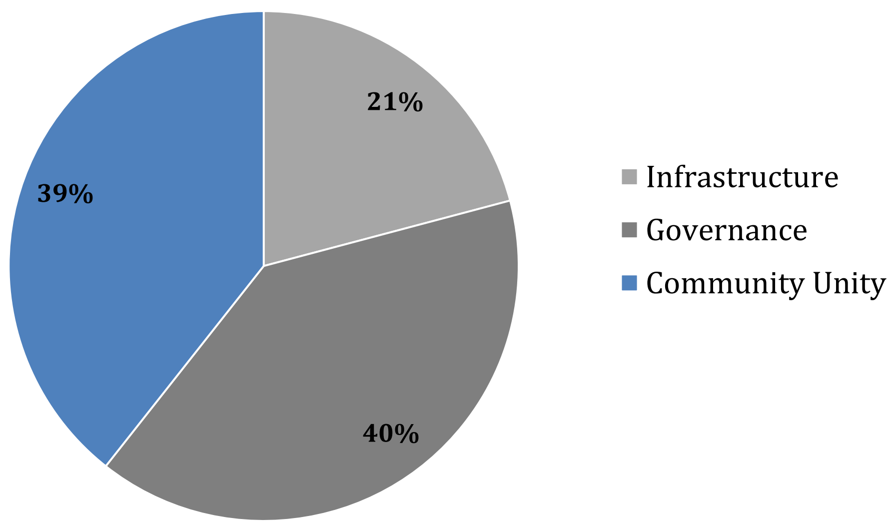


Figure 3-12: Communities' focus regarding improvements.

Figure 3-13 breaks down all the responses the community members gave when asked, "Is there anything that could make Cagmanaba and Badian better?" Governance and community unity were nearly tied in the number of community responses. Governance for fair leadership accounted for 40% of the returns, while the largest total responses within the 40% governance response (27%) focused on community members being good citizens. Additionally, community unity with regards to cooperation in barangay activities and projects was considered of high importance for the community members of both Badian and Cagmanaba.

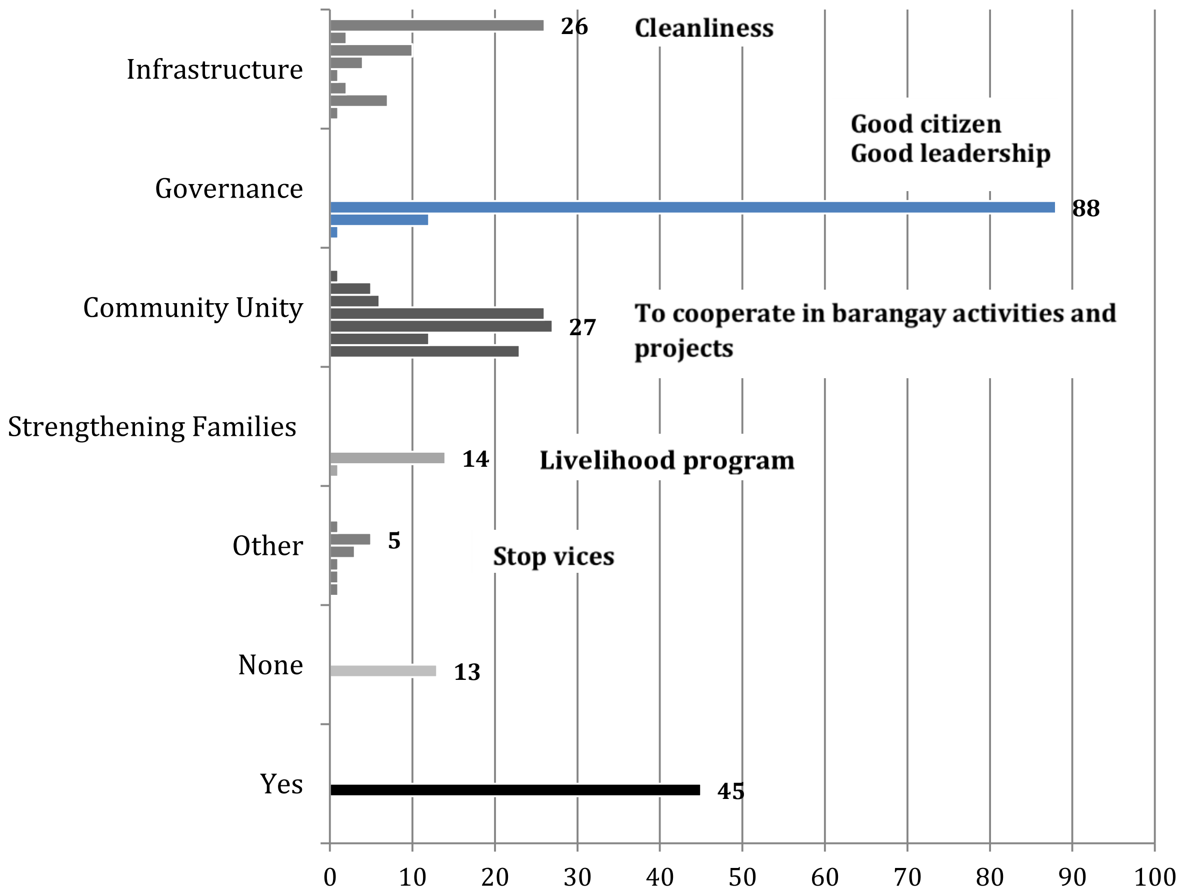


Figure 3-13: Legacy building.

3.2.8 Material assessment. After analyzing the survey results and examining the Cagmanaba and Badian regional areas, the abundance of agricultural waste in the area is clear. If, for example, a coconut is used only for its water, its virgin coconut oil, or its dried meat (copra), an abundance of agricultural waste is generated. From a materials science and innovation viewpoint, current reclaimed coconut waste sold in markets by informal waste collection sectors is an underutilized material collection resource. Mechanical properties are not currently leveraged, nor are environmental and health benefits extracted from the waste byproduct.

3.2.9 Causal analysis. Causal analysis is a technique to build a link between the community and the problem. Within the waste-to-resource framework, a causal analysis problem-cause-effect tree can illustrate root causes, helping to identify solutions (Figure 3-14 and 3-15). Problem and solution trees are useful as initial exercises prior to suggesting a new model or implementation.

These problem identification tools and methods are best used in partnership with the community to determine what they interpret as problems. Community engagement and participatory action research (PAR) are necessary for the success of a sustainable community development idea (Cornwall & Jewkes, 1995). Based on this problem and solution tree, as illustrated in Figures 3-14 and 3-15, root causes of rural poverty include a need for jobs and economic development, along with improvements in the access to education, healthcare, and training throughout the region.

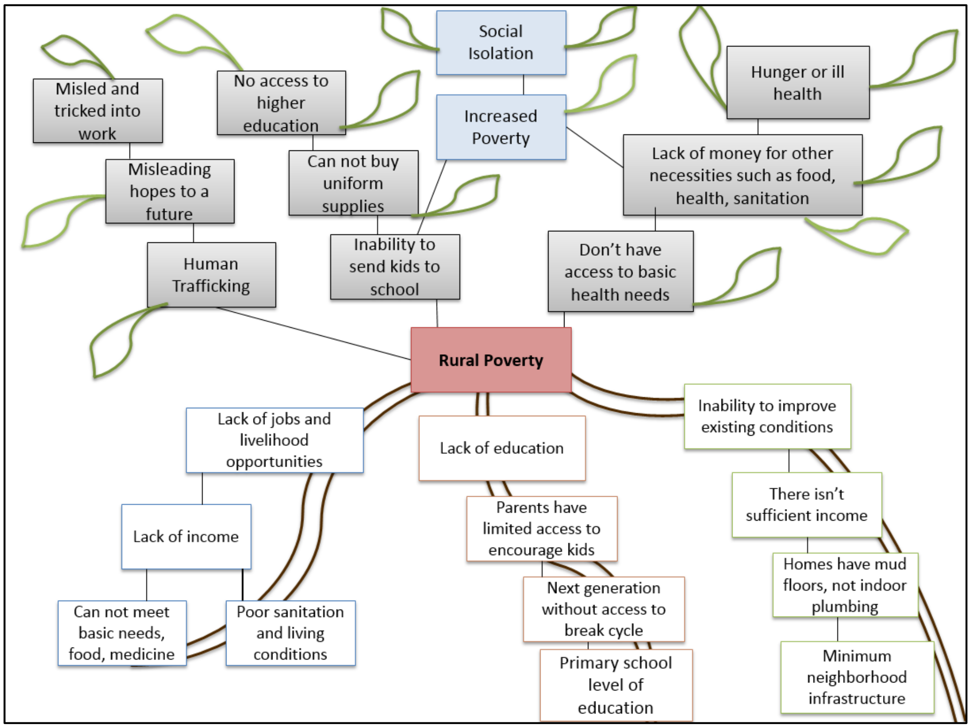


Figure 3-14: Sample problem tree for rural communities.

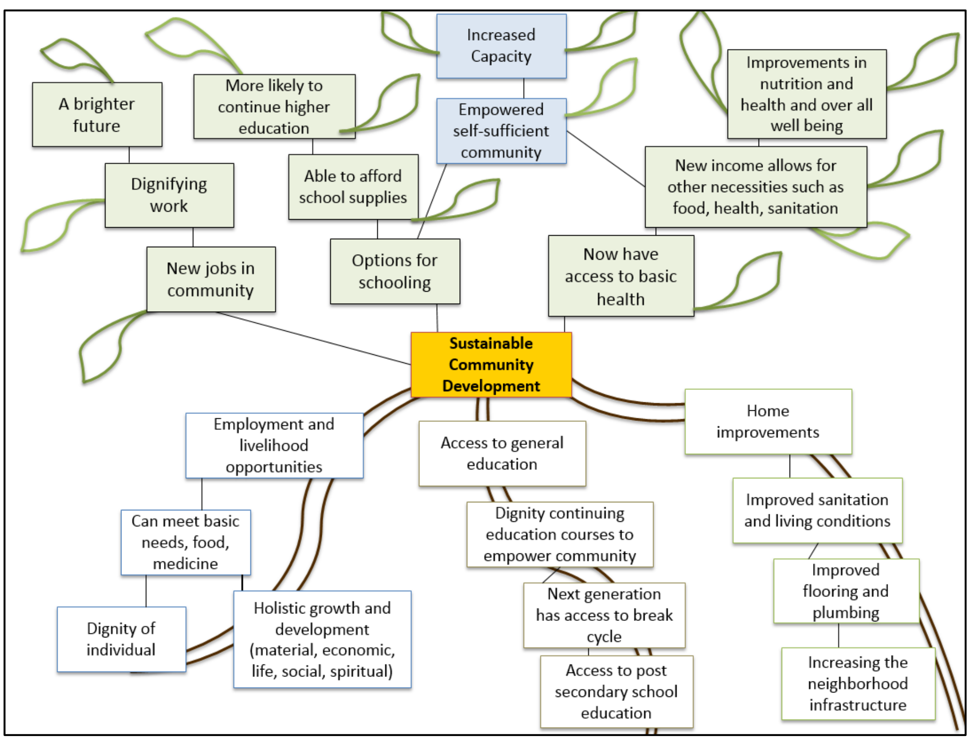


Figure 3-15: Sample solution tree for rural communities.

3.3 Conceptualizing the Waste Stream Model: CTP-1 in Cagmanaba

The waste-to-resource model was tested with the operational Dignity Products and Services Community Transformation Plant-1 (CTP-1), in Cagmanaba, Philippines. Figure3-16 shows a conceptual model created in the STELLA systems modeling software. Although the model was not run for this discussion, gathering proper inputs and values for converters would allow it to estimate the inputs and outputs for a given waste stream. The conceptual STELLA model (Figures 3-16 & 3-17) shows the various materials and products that can stem from a single resource.

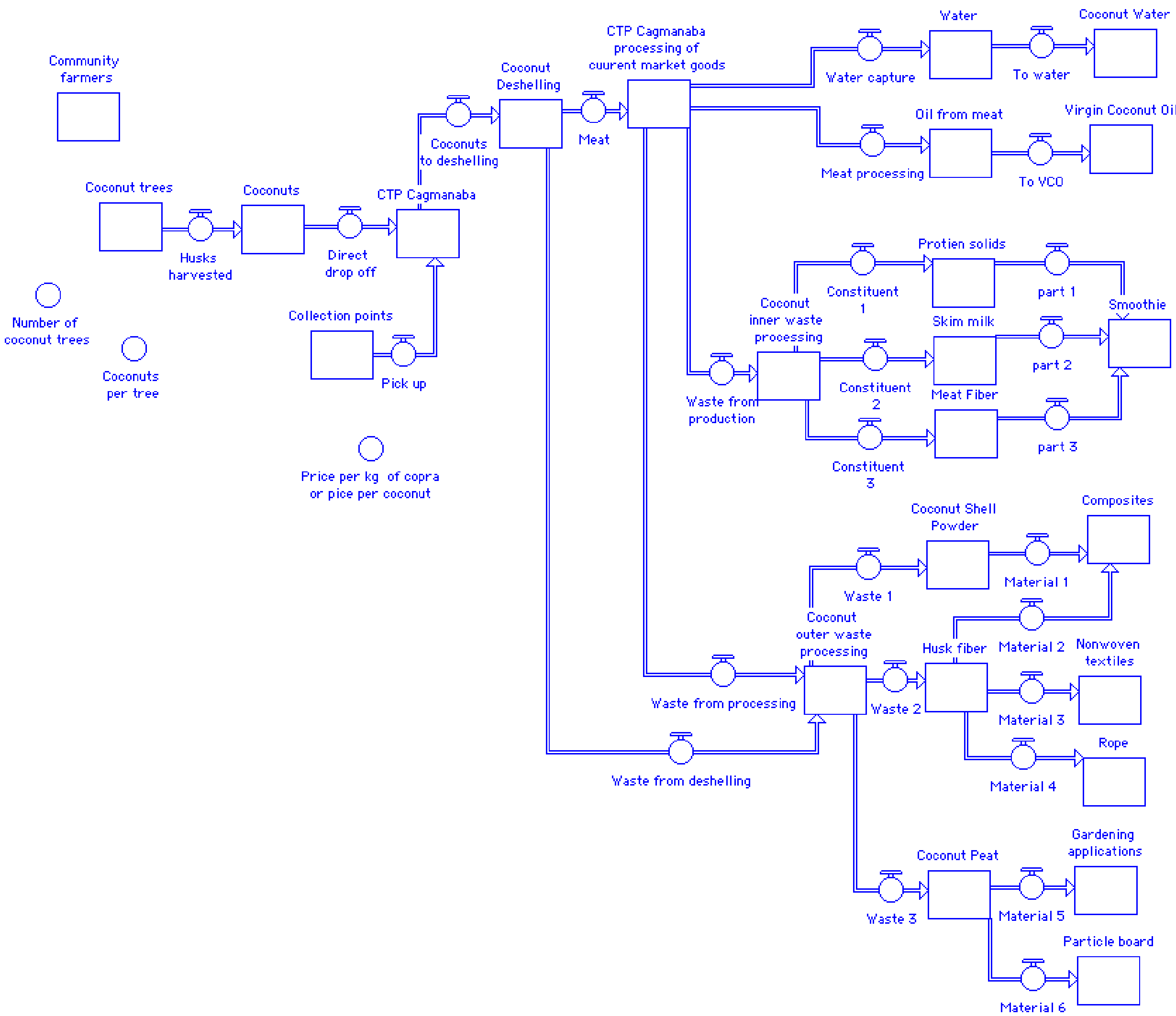


Figure 3-16: Community transformation plant map of process and waste streams.

At CTP-1, two products using the copra and the water from the coconut were initially used for SCD. The waste-to-resource framework presented can be used at a CTP-1 and other CTP's in the future to use more or even all of the waste that comes off the processing line. Setting up a conceptual STELLA model allows a team working to transform wastes to resources to better grasp the possibilities stemming from a resource and its waste stream and to track the flow paths of each option without having to run the model. Figure 3-16 shows how coconuts are dropped off at the CTP or collected at collection points. Once at the CTP, the coconut is processed into different direct products (e.g., coconut oil, coconut water), and new waste-based products such as the smoothie, polymeric composites, nonwovens, gardening products, etc.

Figure 3-17 offers the scaled-out 30,000 foot view demonstrating how a waste-to-resource model could be used for sustainable community development. Like Figure 3-16, Figure 3-17 is also a conceptual model created in STELLA, now showing how the waste collection and transformation could have some effect on SCD but with slightly different steps and results.

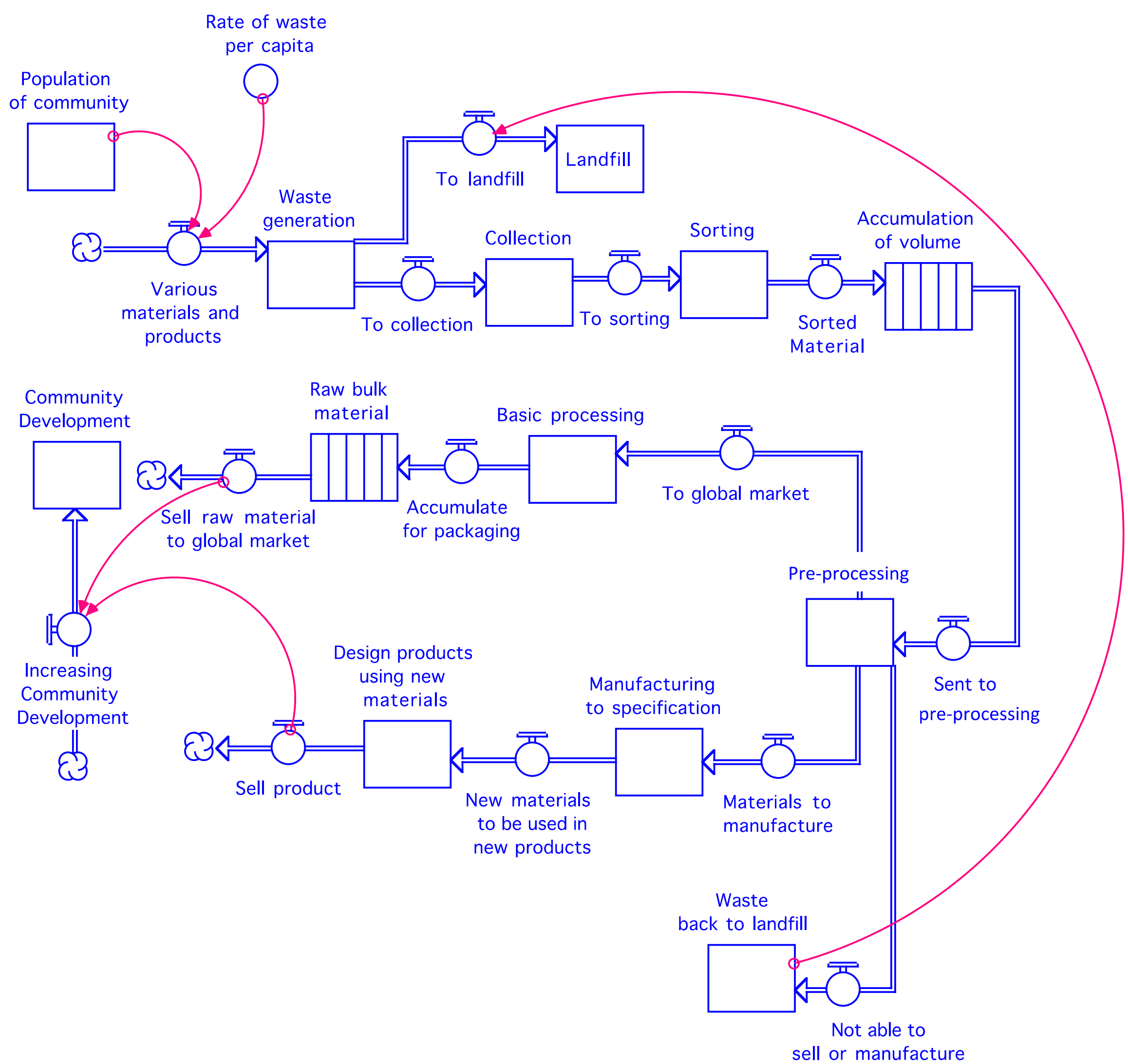


Figure 3-17: STELLA waste-to-resource model and how it inputs to SCD.

The waste-to-resource framework and model shown in Figures 3-16 and 3-17 is being tested in the operational Dignity Products and Services CTP-1, in Cagmanaba, Philippines. Though both models are conceptual, they were set up to choose a feedstock. After completing a material assessment, the material most likely to succeed should be chosen for modeling. For the conceptual model: input, population size, feedstock, and any data associated with the feedstock; i.e., the number of coconuts in the region were included and added to the STELLA model (Figure 3-17).

Since this particular CTP focuses on coconut waste, all the constituent parts of the coconut are shown in the model. After the waste stream has been modeled (Figure 3-16), the link to the larger system showing how the waste transformation can be used link to community development. Figure 3-17 maps a sustainable economic development framework that combines systems engineering with the generous investment of profits back into the community.

Beginning with the waste generated by a community per capita, the model captures each step of transforming waste into a new resource. Initially, waste can flow into a landfill, or it can be collected and reused. If the waste is collected, sorted, and accumulated to reach appropriate volumes, it can become a new resource. Waste that flows completely through the system has the opportunity to provide a profitable mechanism for community development. Figure 3-17 demonstrates one example of sustainable development with access to global commerce, where profits from materials and products are looped back into the community.

Waste to resource production is one example of sustainable development that can occur with access to global commerce. The model takes into account the waste generated by the community per capita. As the waste is collected and sorted, a conveyor demonstrates the accumulation of volume prior to the reclaimed waste materials being sent to the sorting reservoir.

Once a material flows into the pre-processing reservoir, the resulting output material could flow into three different new reservoirs. The first option here is to accumulate minimally processed material as a raw bulk material, such as empty aluminum cans or scrap wood turned into sawdust. The second option is to further process the material to meet specific commercial applications; e.g., coconut powder material used as filler for plastic composites. The final available option is for material to loop back into the landfill. In the latter case, the material cannot be sold as raw bulk material on the global market, nor can it be reused to create a new material.

In sum, waste material that is diverted from landfills can provide feedstock for waste-to-resource production. Figures 3-16 and 3-17 map a sustainable economic development framework that combines systems engineering with the generous investment of profits back into the community. These are conceptual models created to convey product possibilities, inputs and outputs, and flow paths for resources returning to the community.

3.4 Indicators for Success

Data from both the community assessment and the community survey provide useful indicators to help measure success. Table 3-5 lists some of the initial indicators for measuring success within the waste-to-resource framework. These are not conclusive indicators; however, as early indicators, they provide a baseline and point of reference for future work. Future work could include the analysis of the model 1, 2 and 5 years in the future, then identifying what indicators would be appropriate to measure success.

To ensure continued success, an iterative process periodically reviewing progress and conducting mid-course revisions would be important. As part of the review process, partners should frequently remind themselves and the community of their shared goals and mission, encouraging each other to remain committed to implementing them. Ironically, when prosperity comes, it could drive the group away from the original vision of what true SCD is.

Both prosperity and failure can derail a project, and partners must evaluate periodically to assure that the project is staying true to the vision, while goals may be changing in order to meet the needs of the community. The enemy of the best development is not the worst, but good-enough development, meaning development that hits some of the indicators of success listed in Table 3-5, such that the partnership vanishes prior to successful implementation of the entire development model.

Table 3-5

Indicators for Measuring Success in Line With Goals Set by Community

Indicators to check	**Initial stage (1-3 years)**	**Midway through (3-5 years)**	**Towards sustainability (5-10 years+)**
Community	New education, training, and capacity-building opportunities.	Growing in leadership opportunities.	Leading the CTP and the waste-to-resource intervention themselves.
Outside Partners Investors (socially conscious investors) Manufacturing (Dignity Partners) Technical (Essentium Materials) Business (Dignity, Essentium)	Working with the community for technical training and learning business management.	Beginning to see return on investments, ~10% .	Return on investment for all investors met: guidance met or adjusted accordingly. Outside agents continue to work in an advisory role with the community.
Infrastructure	Area mapped to understand how community could be affected by the plant.	All roads and main areas of infrastructure complete to handle plant capacity.	Main roads, electricity, and sanitation in place for long-term growth of the area.
Governance	Established good relationships with the government officials.	Working together to improve services, including meeting the needs of the community for health care, etc.	Sustainable positive relationships maintained over time.
Logistics	Secured access to ports.	Access to major ports to achieve lower shipping costs, improvement of roads.	Ability to transport 40' shipping containers.
Materials	Materials availability sufficient to global application, e.g., 5 million lbs annually.	Scale the capacity of the raw material and feedstock to 20-30 million lbs by year 5.	Diversification of waste streams. Look for new materials to add to successful applications, or scale up current waste stream.
Technical	Passed technical objects of first consumer application.	Launching 5 commercial applications with value-added pricing for waste.	Look for higher tech applications, or increase portfolio with initial or new waste stream growth. Successfully launch 1 high-end market application.
Environmental Impact	Reduced waste in the community, diverted from piling up in back yards.	Diverting waste, using it in consumer goods by 10-50%, e.g., plastic car parts.	Build landfill and waste processing facility to manage wastes that cannot yet be processed into products.
Human Impact	Increased dignity of community partners, a new place for employment that is helping the community to thrive and flourish, provide jobs to families.	300 employees and their families benefiting from working at the factory. Provisions for medical, nutritional, educational, and income needs of as many families as possible.	Equitably partnering in the profit and leadership of the plant and the model; goal could be a 50:50 partnership. Run the plant solely on profit, no longer requiring cash flow from investors.

In SCD, complex problems can change rapidly, creating both pleasant surprises and challenges. Sometimes results occur that are even more successful than was originally envisioned, and communities are transformed more quickly than anticipated. More often, groups aiming to do sustainable community development begin, become fatigued, then forget why they became involved. Sometimes, financial resources are exhausted prior to fully launching an initiative. Partners in SCD efforts should remember that success comes through a tremendous amount of work from a multi-disciplinary team and a willing community, all working united around clear goals. Also, sufficient capital is necessary; the amount required will vary depending on location, feedstock, and targeted final product.

3.5 Closing Framework Remarks and Observations

A survey of the community's perspectives on waste and wealth identified both preliminary opportunities and obstacles. Project partners need to understand the community's goals and capacity, followed by helping members frame a vision of what type of growth the community would like to achieve. Following the waste-to-resource SCD model can create profitable and sustainable enterprises by bringing development to areas in dire need.

Turning waste into a new resource is not only a good idea, it is also a realistic one. However, success parameters include more than profit and successfully scaling up the engineering processes. The essential benefits from the management of new resources should include clean water, better sanitation and health, a thriving family environment, good nutrition, local and regional peace, stability, safety, spiritual foundations, and a livelihood that brings dignity and respect, spurring access to the maximum potential of the individuals and their families. Engineering and materials science can catalyze the process. Chapter 4 demonstrates how materials testing, optimization, and environmental advancements can truly make the proposed framework a viable one for SCD.

CHAPTER IV

COCONUT SHELL POWDER POLYMERIC COMPOSITES

Materials science and engineering of new composites have a vital function as part of a systems-based approach to disrupting poverty. In particular, agricultural waste can be used as a resource in developing countries and rural communities around the world. The impact of waste-to-resource material transformation can be seen in the communities of Cagmanaba and Badian, Philippines, in this case study. In communities like these, materials science and engineering can help to disrupt rural poverty patterns by providing jobs at multiple steps in the process. In the long run, this brings equity and dignity to rural communities that may not otherwise see much economic progress.

4.1. Waste Model for New Technology

New composites derived from bio-waste such as coconut shell powder and coconut fiber can be processed via holistic manufacturing. Waste resources available in a community allow a gateway for economic development that can spur sustainable community development (SCD). In the past, resources have been extracted from their surroundings with an exploitative approach, focused solely on profit. Resources found within a given community ought to be considered birthright resources. Often these materials may have high value, but the communities that own them or live on them don't possess the technology to process them.

Over the past hundred years, the coconut tree has been known as the tree of life in the Philippines, and its fruit has been commercialized primarily for its white meat, known as copra, and the coconut oil it contains. The rest of the coconut has some minimal uses in handicrafts and animal feed, but more often the rest of the coconut becomes waste.

What if something could be done to elevate the value of this supposed waste? One such "something" is the idea for coconut shell polymeric composites (CSP). The shell is ground up into a natural powder that is incorporated into the polymer (e.g., polypropylene), and coir fiber from coconut husks can be incorporated into a polypropylene-coconut shell composite to create a more natural plastic. Natural filler and fiber-based composites can potentially substitute for glass fiber-filled composites, called GFRs, which are 100% synthetic. Here is the pivot point where a waste becomes a new material resource. Maximizing mechanical properties is the first step to creating a technology that can yield enough benefit to make a difference technically, cost-effectively, environmentally, and socially.

The community transformation plant (CTP) first aims to use the coconut oil and water, due to their high commercial value. In the beta communities of Cagmanaba and Badian, waste is collected from coconut oil and coconut water processing. Engineers and materials scientists use the waste byproduct of a CTP plant as fillers in polymeric composites, leaving very little behind. By using nearly all of the coconut, including most of what usually has been waste, there is higher profit from each coconut (Figure 4-1). The new materials just described create markets for more of the agricultural output of the coconut palms.

Making new composite materials out of waste, getting optimal value from all parts of the coconut, is a way to disrupt rural poverty. Mechanical properties have proven the benefits of using coconut shell powder as a filler in polymeric composites over conventional nonrenewable composites. The new bio-based composites, created through the incorporation of coconut shell powder, show improved stiffness and strength.

Figure 4-1: Cross-section of a mature coconut.

The green coconut is considered immature and is cut from the tree primarily for the sweet coconut water inside. The formation of oil-rich coconut meat on the inside, plus dense shell on the outside of the kernel, will take at least several months: during that time, the fibers in the husk become strong and resilient. As the nut matures, it turns brown on the tree. Inside the mature coconut, a significant amount of copra has developed, and good, although a bit less sweet, water remains. Figure 4-2 shows a mature nut that is ready for processing. The cross-sectional view of the coconut is predominantly husk fiber, pith, and coconut shell, all of which tend to be treated as waste. On average, a Philippines coconut weighs 2.6 pounds (1.2 kg).

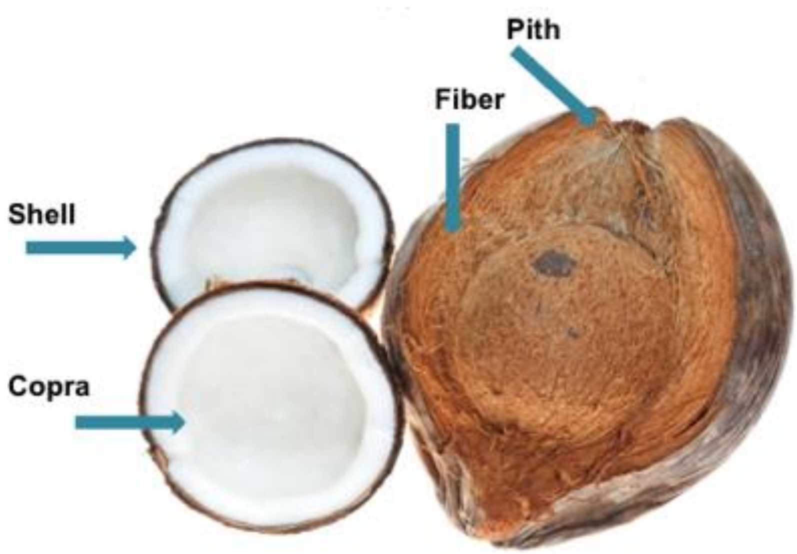


Figure 4-2: Labeled cross sectional view of coconut with husk.

4.2 Background on Mechanical and Material Properties

Incorporating natural powders and fibers into polymer composites is becoming more common. Both academic research and commercial production trials have shown that these naturally-filled composites can display increased strength, better stiffness, and lower costs, while reducing the amount of petroleum-based polymers used in the composite. CSP has been successfully used with both polyethylene and polypropylene. Results presented show the benefit of using CSP in polypropylene and polyethylene, with increases in stiffness of up to 80% observed.

The patent-pending technology platform takes coconut waste, particularly the shell, and transforms it into an innovative composite material. The unique combination of mechanical and physical properties of the coconut shell and the coconut fiber make them ideal for use as functional fillers in these polymeric composites. Additionally, by adding natural CSP, the aesthetics of these polyolefins can be enhanced.

Research on such materials has typically focused on compatibilizing the hydrophylic and polar filler surface in a bond to the non-polar polymer, as well as determining the optimum filler particle size, percent loading, and processing parameters. Studies have shown that the most significant challenges associated with natural fillers include high moisture content, low degradation temperatures, and changes to the composite's viscosity (Teipel et al., 2013). Although a vast number of materials have been considered as possible fillers for plastic composites, only materials requiring minimal specialty processing constraints and displaying consistent quality properties have found commercial success.

If a material is going to be used as natural filler in polymeric composites, it needs to be able to withstand high temperatures and high shear conditions without substantial degradation. In addition, the filler must not greatly increase the viscosity of the resin, so that the composite resin can be processed into complex shapes, similar to the processing of the pure plastic. A finer particle size will typically allow for smoother surface finishes.

CSP has unique material properties that are advantageous for use as functional fillers in thermoplastic materials. Coconut shells are high in lignin, compared to other natural materials. One effect of high levels of lignin is improved thermal stability; in other words, coconuts have a much higher degradation temperature than other natural materials. When coconut shells are processed into CSP, the particles typically have a small aspect ratio of 1 to 3, which allows CSP to flow better than high aspect ratio materials. Thus, when incorporating CSP into polymeric composites, the composite's viscosity is generally maintained or only slightly increased. These are key considerations in transforming something that was once considered waste into a value-added material that can be used in a disruptive technology.

4.2.1 Renewable fillers in polymeric composites. The most common filler currently used in thermoplastics is calcium carbonate, due to its low cost. However, calcium carbonate (specific gravity ~2.7) is much denser than polypropylene (SG ~0.91), which gives a significant increase in the SG of the composites. Increasing SG is a disadvantage in most applications, but it is tolerated for the subsequent material properties and cost improvements when using calcium carbonate. Consequently, a growing trend over the past decade has been to increase the use of bio-based fillers as alternatives to calcium carbonate because of their lower SG compared to mineral fillers. Bio-based fillers in polymeric composites enhance mechanical properties, reduce costs, and reduce the SG of the composite compared to calcium carbonate composites.

For the bio-waste based composite technology to be truly disruptive and change the way conventional composites are formulated, optimization of natural functional fillers must take place. Interfacial bonding between natural fillers such as coconut shell powder (CSP) and traditional polyolefins calls for compatibility and optimization to achieve helpful mechanical properties in compounding and injection molding applications. Compatibilizers work to strengthen interfacial bonding between the filler (coconut shell powder and coir fiber in this case) and the polymer, which is essential if the filler is to enhance mechanical properties. Maleic anhydride is a common compatibilizer used with natural fillers, in the form of maleic anhydride grafted polypropylene (MAPP). Overall, the findings show that less solid phase grafted MAPP can be used to achieve the same or better properties than melt grafted MAPP. In this research, mechanical properties were measured for unfilled polymers (generally called neat resins) as well as for bio-based composite systems that use processed agricultural waste as functional filler.

A series of tests are used in materials science and engineering to verify if a material will be useful. These tests also help to give a general indication as to whether a particular optimization technique or compatibilizer is successful in maximizing the properties of a composite. More testing can be performed once the baseline tests are conducted. At this point, the waste-to-resource model user will be working in partnership with materials scientists and engineers to help determine applications that utilize the mechanical properties of the material to best advantage. Three ASTM tests, D790 Flexural Modulus, D256 Impact Strength, and D638 Tensile Strength, are considered baseline mechanical property tests. These tests were conducted to compare the benefits of adding CSP to a resin.

As part of material characterization techniques, particle size distribution (PSD), stereomicroscopy, and scanning electron microscopy were used to study the waste material as it was transformed into an appropriate form to be used as filler in engineering plastics. Thermal gravimetric analysis (TGA) was used to determine the thermal stability of the polymeric composite material. This is particularly important when using an agricultural waste feedstock that will thermally decompose at elevated temperatures.

CSP is compounded (as described in section 4.2) and then injection molded at elevated temperatures into various shapes to make car parts and other kinds of consumer products. With bio-based fillers that are suitable for polymeric composites, there is a time-temperature processing window, in which the viscosity is reduced to a suitable fluid level for injection molding and extruding but the time and temperature do not exceed the parameters that would cause the CSP or polypropylene to thermally degrade.

4.2.2 Raw waste material conversion and initial testing results. Once a feedstock has been selected for use in polymeric composites, the material must be converted into powder or fibrous form for use in a composite formulation. As previously stated, simply adding CSP into a plastic will not work. It will not give sufficient enhancement of mechanical properties to create a value proposition. Significant research and development was conducted to optimize both the material recipe (chemistry) and the processing equipment (manufacturing), which will be discussed further.

4.3 Optimization of Coconut Shell Composites

Initially, when compounded into plastic, CSP enhances stiffness but can decrease the strength and impact properties. In order for the reclamation and transformation of coconut shell to be a successful waste-to-resource example, the material must be optimized. Required properties are dependent on the application. In order to see the technology become commercially viable, cost-effective optimization must elevate the value of the base feedstock/waste resource.

Maleic anhydride grafted polypropylene (MAPP) was the primary compatibilizer studied in this research. Different maleic anhydrides behave differently in natural composite systems. Two main types of common commercial MAPP compatibilizers exist: solid phase grafted maleic anhydride polypropylene, a newer technology in the marketplace, and melt grafted maleic anhydride polypropylene, an older technology. This research assesses the claim that solid phase grafted MAPP causes better interfacial bonding between CSP and the polypropylene matrix than melt grafted MAPP.

4.3.1 MAPP compatibilizers. As previously mentioned, one of the biggest challenges associated with natural composite systems, including CSP-polypropylene composites, is interfacial bonding between the polar filler and the non-polar matrix. Interfacial bonding is essentially the mechanism for transferring a load from the polymer matrix to the filler or reinforcement. If the interfacial bond between the coconut shell particles and the polymer matrix is weak, then the coconut shell particles will not provide a functional benefit to the mechanical properties. Instead, the poorly bonded coconut shell particles will act as stress concentration sites, which will be a hindrance to obtaining the desired mechanical properties. In order to meet this challenge, a compatibilizer is used to improve interfacial bonding between the two constituents of the composite.

Several compatibilization methods exist, breaking into two categories: physical bonding methods and chemical bonding methods. The chemical bonding methods are silane treatment, enzyme treatment, acetylation, alkaline treatment, and maleated coupling (Faruk et al., 2012). Most of the existing compatibilization methods require time-intensive batch processing, in which the natural material is left to soak for a certain length of time before it can be incorporated into the polymer. Maleated coupling agents, however, skip the soak and instead are added during compounding. Therefore, maleated coupling is a time- and cost-effective approach to compatibilization; thus, it is the focus of this research.

The most common grafting process, melt grafting, involves mixing polypropylene (PP) with a free radical initiator catalyst and a solvent in a twin screw extruder (Rengarajan et al., 1990). However, studies have shown that the graft degree achieved by this process is fairly low (Shia, 2001; Hogt, 1988). In the early 1990s, a new grafting process (Rengarajan et al., 1990) was developed that could be performed at temperatures below the melting point of the polymer using much lower levels of solvent. This new process, called solid-phase grafting, was performed by mixing powder forms of the polymer and maleic anhydride co-monomer in a reactor along with a catalyst, then adding an interfacial agent to provide reaction sites for the graft reaction (Lee, 1990). Since then, solid-phase grafting has been made commercially available, and it has been claimed to show substantial improvements over melt grafted MAPP products (BYK Kometra GmbH, 2012).

Solid phase grafting (SPG) achieves higher grafting levels than the more traditional melt grafting (MG), as reported by Kim et al. in 2007. Other claimed advantages of SPG include less thermal stress during production, because grafting takes place without melting the polymer, and lower content of volatile organic compounds (VOCs), due to a cleaning stage in the process that flushes out unbounded maleic anhydride (MAH) for high efficiency along with impurities that cause VOCs. To create a cost-effective CSP-polypropylene composite, engineers need to determine the grafting process that will allow for the best mechanical property enhancements using the smallest wt% of MAPP.

The commercial effectiveness of a coupling agent such as MAPP is measured by the improved mechanical properties it provides to the composite (Sclavons et al., 1998). These improvements create the positive cost profile needed for CSP to be used in polymeric composites.

One of the objectives in optimization is to lower the percentage of additives, which was investigated in this study. Previous research on the potential of CSP as a functional filler included a ladder study on melt grafted MAPP to determine how much was needed to optimize the CSP-filled polymer (Teipel et al., 2011). The melt grafted MAPP has a stated MAH content of 1.0% (Chemtura, 2009). These results showed that the CSP system was highly responsive to MAPP, with the highest increase in composite stiffness and strength obtained at 2wt% MAPP.

4.3.2 Material testing. This study focuses on the unique advantages of using a solid phase grafted MAPP compatibilizer rather than a melt grafted MAPP compatibilizer. The primary purpose of this study was to assess the claim that solid phase grafted MAPP causes better interfacial bonding between CSP and the polypropylene matrix than melt grafted MAPP. If these claims are true, then solid phase grafted MAPP technology will make a significant contribution to engineering better natural composite systems.

In previous studies, melt grafted and solid phase grafted MAPP compatibilizers were compared only according to their wt% of the total composite. In this study, the compatibilizers are compared as previously, based on wt% of the total composite, then the results were also normalized according to the total MA content in the composite, to discern whether the total MA content is the main factor in determining MAPP performance. Finally, this study demonstrates the application-specific advantages of using solid phase grafted MAPP compatibilizers.

4.3.2.1 Experimental procedures. Coconut shell powder sold in partnership by Dignity Products and Services, Inc. and Essentium Materials, LLC, was used in this study. The trade name for this CSP is NaturaTech™ 4112. NaturaTech™ 4112 has a top size of 150 microns and a bulk density of 0.44 g/cc. The moisture content of the NaturaTech™ 4112 used in these experiments was 7.5%. A polypropylene copolymer base resin with a melt flow of 20 g/10 min, and a density of 0.9 g/cc was used. The compatibilizers used for the composite optimization are described in Table 4-1.

Table 4-1
MAPP Compatibilizer Comparison (Solid Phase Grafted vs. Melt Grafted)

Name	Grafting Process	Total MA Content	MFI (g/10 min)	Form
Scona® TPPP 8112 FA	*Solid Phase*	1.4wt%	80	Powder
Scona® TPPP 8112 GA	*Solid Phase*	1.4wt%	80	Pellets
Polybond® 3200	*Melt*	1.0wt%	115	Pellets

4.3.2.2 Recipe formulations. The materials were compounded on a Kraus Maffei ZE 25 mm laboratory twin-screw extruder with a temperature profile centered at 190 °C. The NaturaTech™ 4112 was mixed with the PP at 20wt% and 40wt% of the total batch weight. The two SPG Scona® compatibilizers were mixed in at 0.5wt% intervals from 0% to 4%, one in pellet form and one in powder form, while the melt grafted (MG) MAPP was sampled at 1% and 2%. The pellets were then injection molded on an Arburg 55-ton Allrounder 320C Golden.

4.3.2.3 Testing mechanical properties. The samples were formed into tensile, flexural, and Izod bars, then conditioned for at least 48 hours. Mechanical property testing included tensile, flexural, and notched Izod impact: ASTM D638A, ASTM D790A, and ASTM D256 respectively, which comprise the baseline tests. An Instron 3345 load frame with a 2 kN load cell was used to perform the tensile and flexural tests. Impact testing was performed using a TMI Variable Speed Notch Cutter and a TMI Monitor/Impact Testing

Machine. The results presented in the Figures 4.3 and 4.4 show the average of 5 sample bars each.

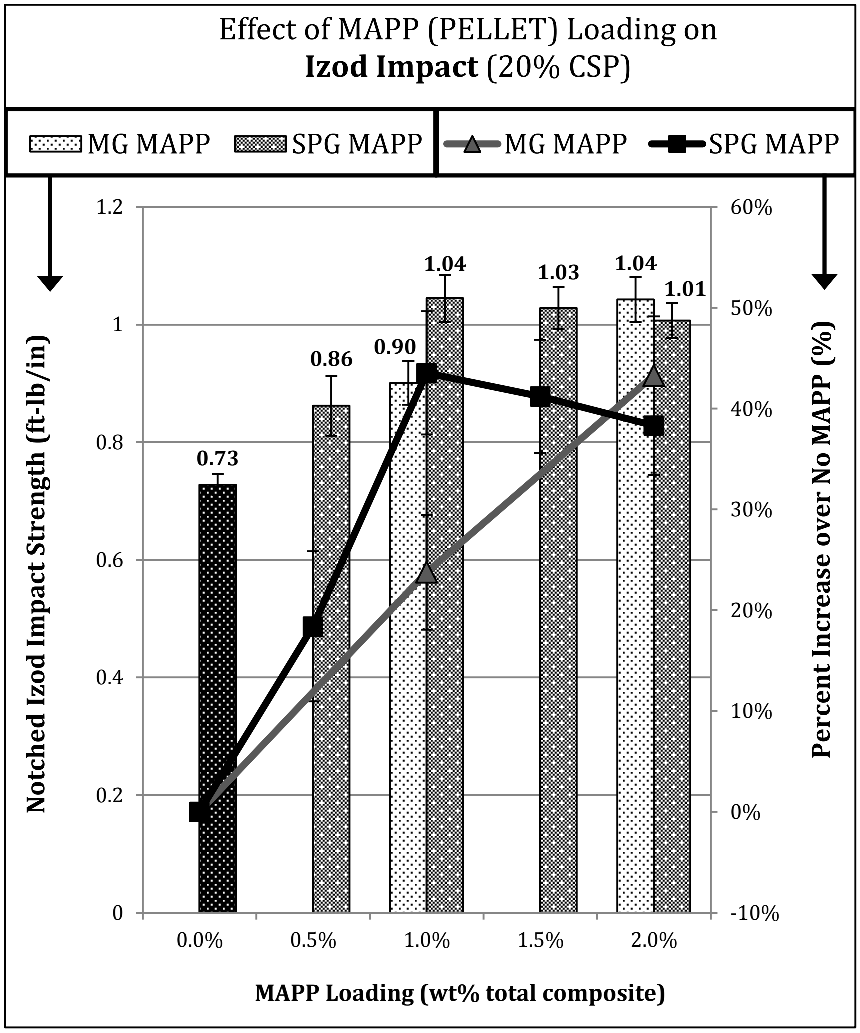


Figure 4-3: The effect of MAPP (pellet) loading on notched Izod impact strength (20% CSP—the notched Izod impact of the neat PP copolymer = 1.75 ft-lb/in).
<u>Left Vertical Axis</u>: (BARS) Notched Izod Impact Strength
<u>Right Vertical Axis</u>: (LINES) % Increase over No MAPP

4.3.2.4 Notched IZOD impact strength. The introduction of small, non-rubbery, second phase particles into a polymer matrix are effectively the introduction of stress concentration sites, which increases the likelihood of brittle crack initiation and propagation. If there is relatively no interfacial bonding between the second phase particle and the polymer matrix, then crack initiation and propagation will happen more readily. In order to reduce the likelihood of brittle crack initiation and propagation, it is necessary to use an interfacial bonding agent or compatibilizer.

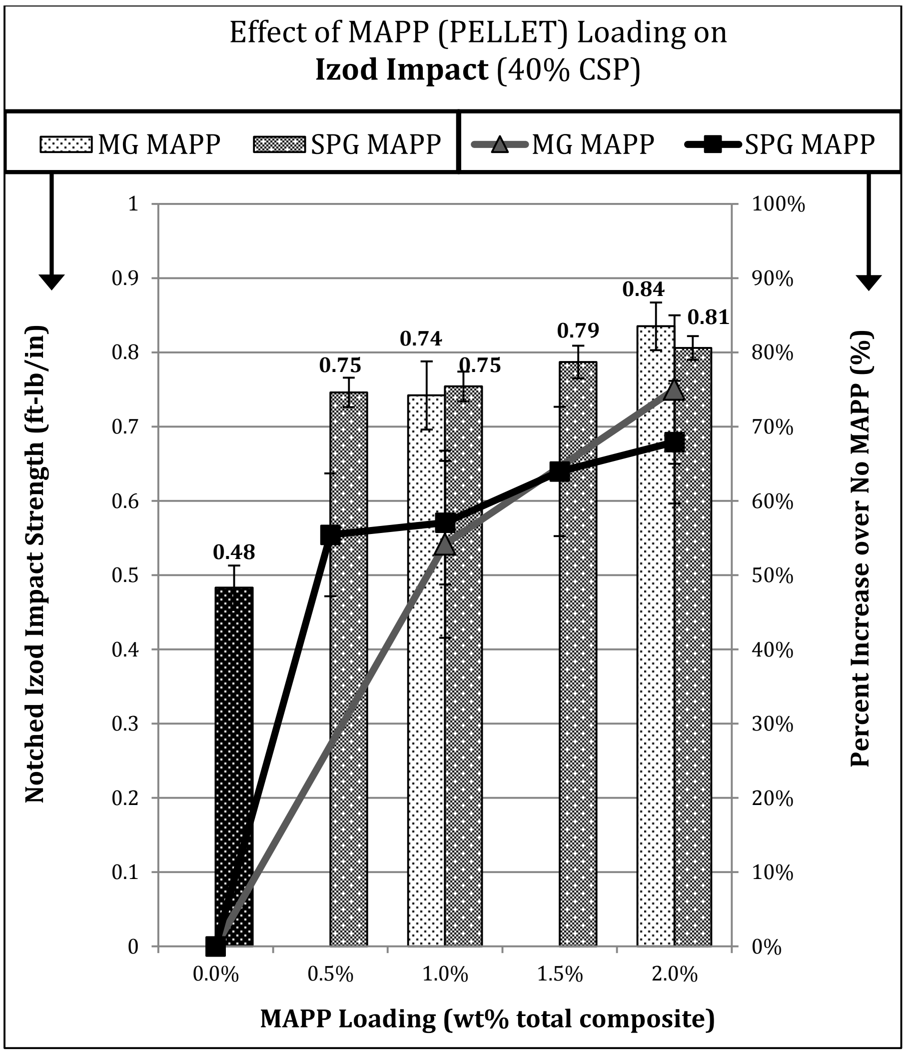


Figure 4-4: The effect of MAPP (pellet) loading on notched Izod impact strength. (The notched Izod impact of the neat PP copolymer = 1.75 ft-lb/in)
Left Vertical Axis: (BARS) Notched Izod Impact Strength
Right Vertical Axis: (LINES) % Increase over No MAPP

Compatibilizers increase the thickness of the interphase region between the second phase particles and the polymer matrix. The thicker this region is, the more gradually the stress is applied to the particle. This reduces the stress concentration at the particle. Higher levels of compatibilizer loading equate to thicker interphase regions until the saturation limit is reached. Past this point, further reduction in the stress gradients adjacent to the second phase particle is not necessary or useful.

Figures 4-3 and 4-4 show the effect of MAPP loading on notched Izod impact strength for both 20 and 40wt% CSP composites, respectively. The advantage of MAPP can clearly be seen in these figures, as the datum at 0% represents the CSP-PP composites without MAPP. With the addition of only 0.5wt% MAPP, there is as much as a 55% increase in the notched Izod impact strength, reflecting the strong positive correlation between improved interfacial bonding and mechanical properties.

Figures 4-3 and 4-4 also indicate that there is a saturation level of MAPP. For the 20wt% CSP composites, this saturation level is around 1.0wt% SPG MAPP, represented by the plateau effect seen in Figure 4-3, where increased MAPP loading does not substantially change the impact strength after 1.0wt% SPG MAPP. Based on the previous research, MG MAPP also has a saturation level at 2.0wt% loading. The MAPP saturation level indicates an optimum level of interfacial bonding. According to Figure 4-3, the SPG MAPP saturation level for 40wt% CSP composites is around 0.5wt%.

Despite the large improvements in material properties that MAPP yields compared to CSP composites without MAPP, it is important to note that there is still a disparity between the impact strength of the neat PP copolymer and the impact strength of CSP-filled composites. The notched Izod impact strength of the neat PP copolymer used in this research is 1.75 ft-lb/in. Based on the information in Figures 4-3 and 4-4, there is no statistically significant difference between MG MAPP and SPG MAPP on Izod impact strength in the materials tested.

4.3.2.5 Tensile strength. Figures 4-5 and 4-6. The effects of MAPP on the tensile strength of CSP composites are not as pronounced as they are on the impact strength.

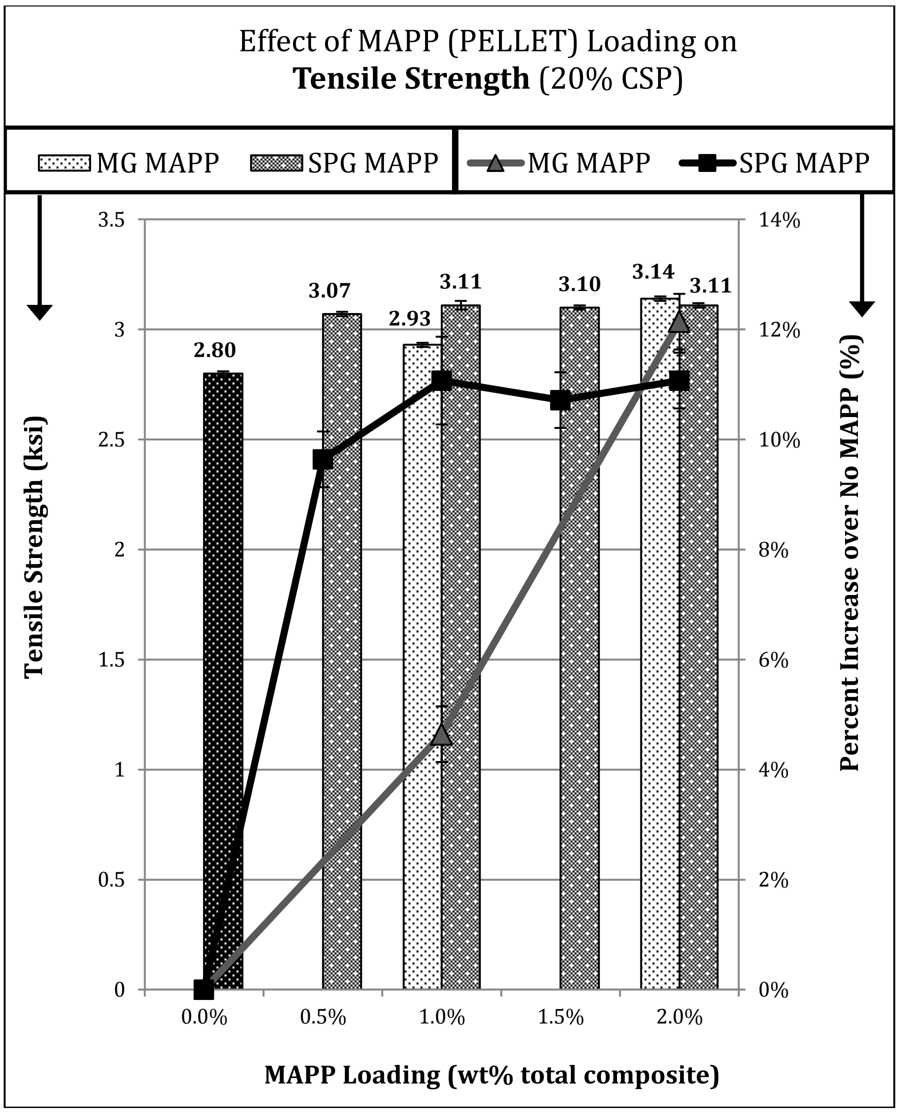


Figure 4-5: The effect of MAPP (pellet) loading on tensile strength (20% CSP). The tensile strength of the neat PP copolymer = 2.87 ksi.
<u>Left Vertical Axis</u>: (BARS) Tensile Strength
<u>Right Vertical Axis</u>: (LINES) % Increase over No MAPP

Without MAPP, the tensile strength of CSP composites has been shown to stay the same or slightly decrease compared to the neat polypropylene value. Tensile strength is a measure of local effects, and adding CSP without adequate interfacial bonding results in local stress concentrations and poor load transfer to the rigid second phase particles. Figure 4-5 and 4-6 show the effect of MAPP loading (in the pellet form) on tensile strength for both 20 and 40wt% CSP composites respectively.

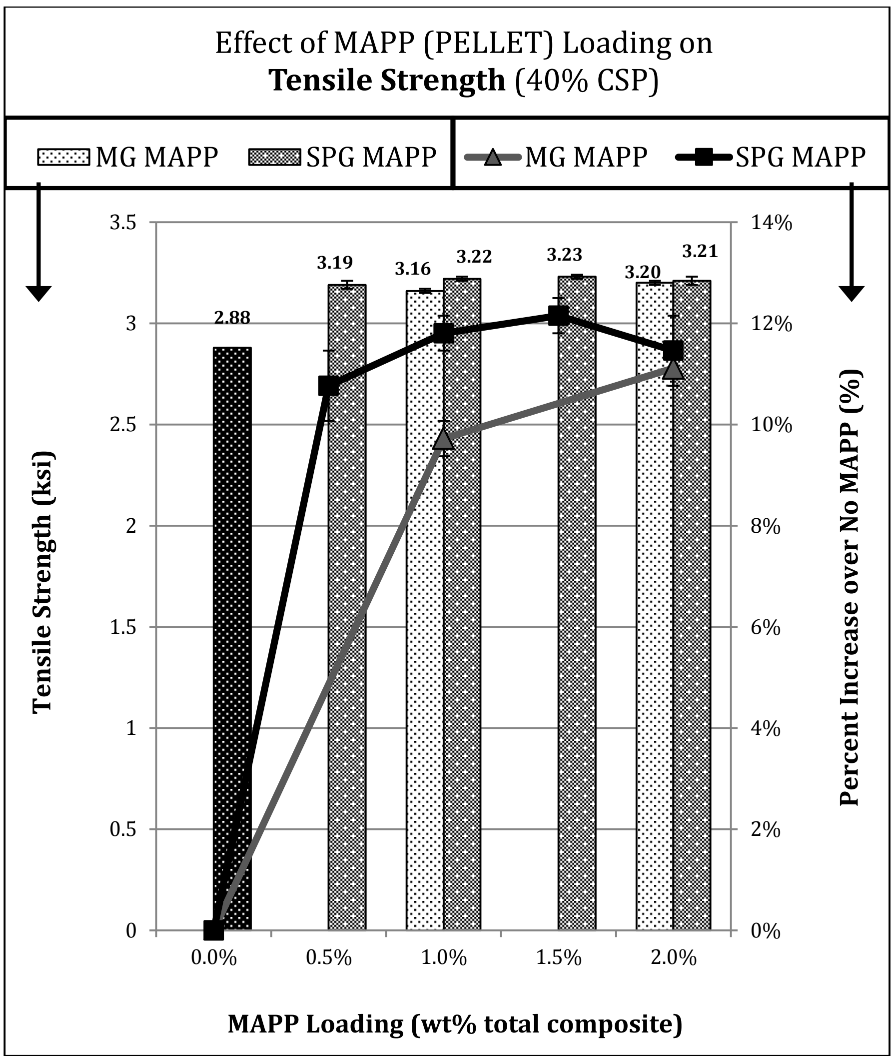


Figure 4-6: The effect of MAPP loading on tensile strength (40% CSP). The tensile strength of the neat PP copolymer = 2.87 ksi.
Left Vertical Axis: (BARS) Tensile Strength
Right Vertical Axis: (LINES) % Increase over No MAPP

A relatively large increase in tensile strength is noticed after adding only 0.5wt% SPG MAPP. After adding 0.5wt% SPG MAPP, the tensile strength of the composite shows an increase of as much as 11% over the CSP composite without MAPP. It appears that the MAPP saturation level, or the optimum level of interfacial bonding, takes place around 1.0wt% SPG MAPP loading for both 20 and 40wt% CSP composites.

Based on previous research, the saturation level of MG MAPP is around 1.5wt% loading. Also, based on Figure 4-5 and 4-6, it is apparent that less SPG MAPP is needed to achieve the same or better tensile strength results than 2.0wt% MG MAPP achieves. More specifically, the tensile strength data shows that between 0.5wt% and 1.0wt% SPG MAPP content is equivalent or, in some cases, better than 2.0wt% MG MAPP.

While optimizations are made to maximize the technical impact of the model for using the new material, it is vital to keep the cost of the composites competitive with current market composites so that the new product may be more widely used and have a larger impact in SCD.

4.3.2.6 Flexural modulus. One of the biggest advantages of using CSP and other rigid natural fillers is the increased stiffness that these functional fillers provide to the composite. CSP typically increases the stiffness by 20–100%, depending on the percent loading of CSP filler when compared to unfilled polypropylene resins. Often when an additive is used to optimize a composite, the additives will increase some properties and decrease others. However, the addition of MAPP increases both the tensile strength and the flexural modulus, between 6-10%. The flexural modulus of the neat PP copolymer used in this research is 128.20 ksi.

Since the flexural modulus is a global average measure, it is less affected by the local stress concentrations introduced by the rigid coconut shell particles in the softer PP matrix. Improved interfacial bonding can provide a slight increase in flexural modulus due to improved load transfer between the rigid CSP and the polymer matrix. However, even without MAPP, CSP provides a substantial stiffness increase over the flexural modulus of the neat PP copolymer. Figure 4-7 and 4-8 show the effect of MAPP loading on flexural modulus for both 20 and 40wt% CSP composites.

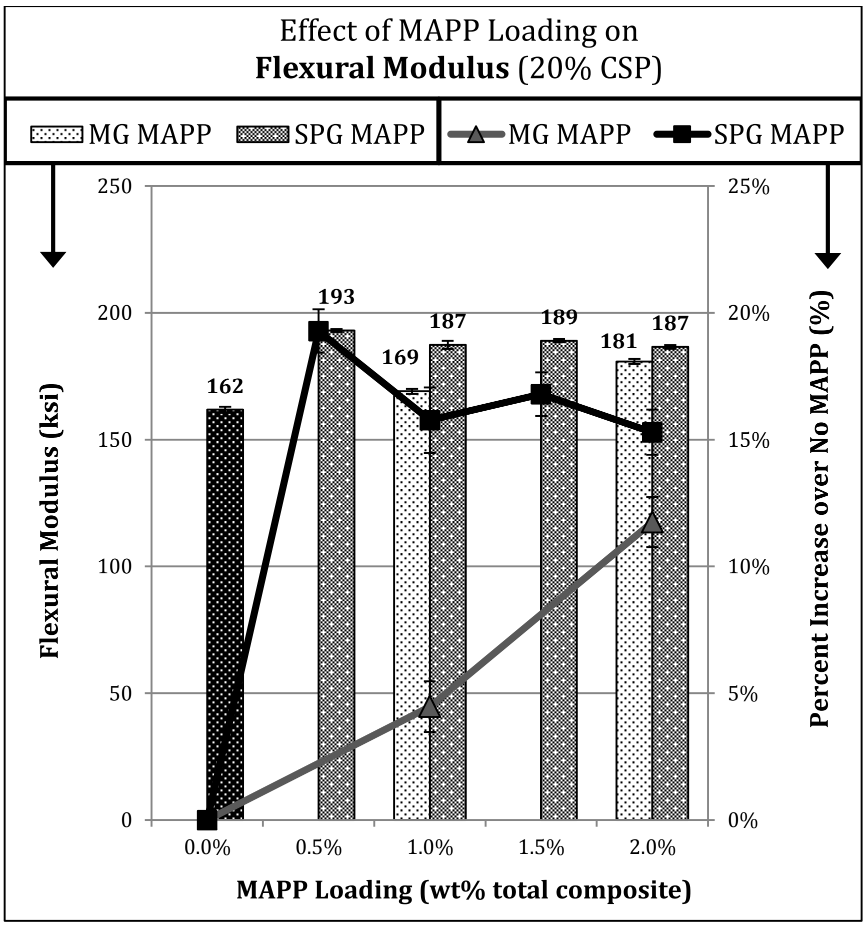


Figure 4-7: Effect of MAPP loading on flexural modulus (20% CSP). The flexural modulus of the neat PP copolymer = 128.20ksi.
Left Vertical Axis: (BARS) Flexural Modulus
Right Vertical Axis: (LINES) % Increase over No MAPP

Even without MAPP, the flexural modulus of the composite filled with 20 and 40wt% CSP resulted in a 25% and an 80% increase in the flexural modulus over the neat polypropylene copolymer, respectively.

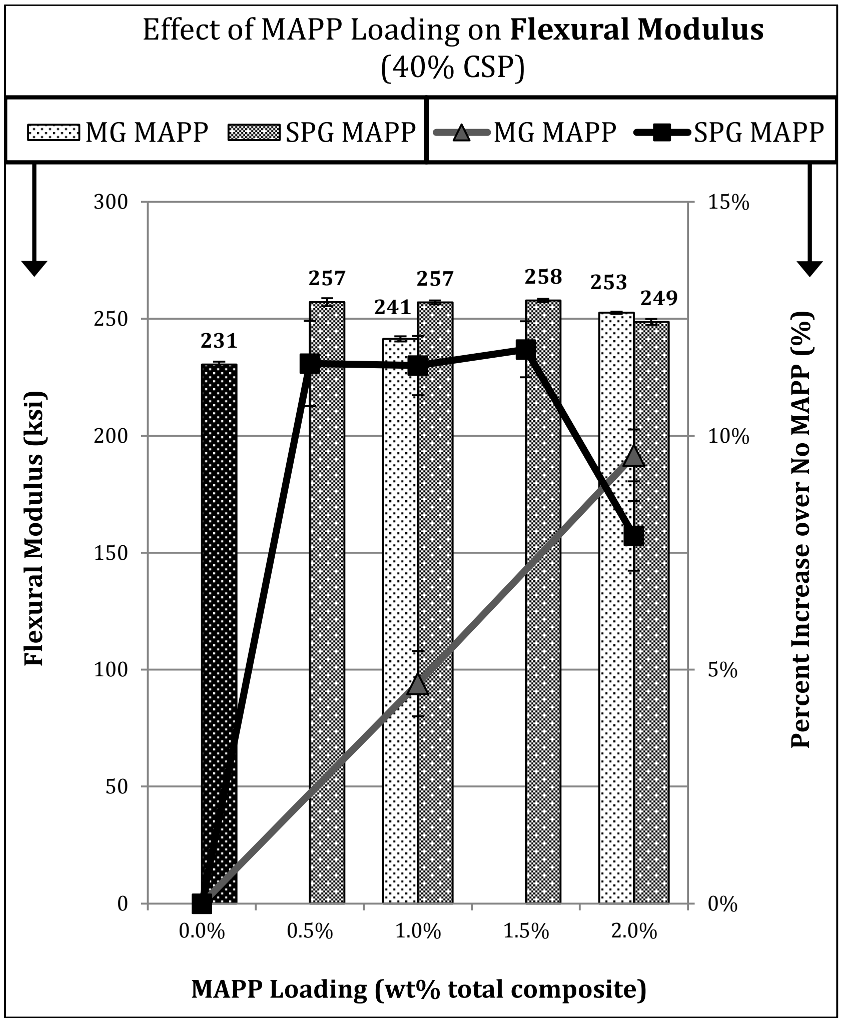


Figure 4-8: The effect of MAPP loading on flexural modulus (40% CSP). The flexural modulus of the neat PP copolymer = 128.20ksi.
<u>Left Vertical Axis</u>: (BARS) Flexural Modulus
<u>Right Vertical Axis</u>: (LINES) % Increase over No MAPP

By setting the CSP-PP composite without MAPP as the datum at 0%, the stiffness advantage that MAPP provides can be observed. With the addition of 0.5wt% SPG MAPP, the flexural modulus of the 20wt% CSP composite increases close to 20%, and the flexural modulus of the 40wt% CSP composite increases close to 12% over the CSP composite without MAPP. Also, approximately 0.5wt% SPG MAPP loading appears to be the saturation level for both 20 and 40wt% composites. MG MAPP does not reach the saturation level until around 1.5wt%, based on previous research.

Smaller amounts of SPG MAPP are needed to achieve the same or, in most cases, better flexural modulus properties than 2.0wt% MG MAPP yields. The flexural modulus results are similar to the flexural strength results, which are not shown. Overall, SPG MAPP proved to have the greatest advantage over MG MAPP in flexural properties.

4.3.3 Correlation between total maleic anhydride (MA) content and compatibilizer performance. Figures 4-9 through 4-11 show the correlation between total MA content in a 20wt% CSP-polypropylene composite and mechanical properties (notched Izod impact strength, tensile strength, and elongation at break, respectively). The solid phase grafted MAPP was dosed at 0.5, 1, 1.5, and 2wt% of the total composite. The MA grafted content for the solid phase grafted compatibilizer is 1.4wt%, which corresponds to 0.007, 0.014, 0.021 and 0.028wt% total MA content in the composite at each of the specific dosage intervals. The melt grafted MAPP was dosed at 1 and 2wt%, which corresponds to 0.01 and 0.02wt% total MA in the composite. All three figures show that an increase in total MA content results in an increase in mechanical properties.

Figure 4-9 suggests that MA content is the main factor in the notched Izod impact improvements seen when using MAPP. The normalized graph shows that the use of both the solid phase and melt grafted MAPP yields almost identical impact strength improvements based on the MA content.

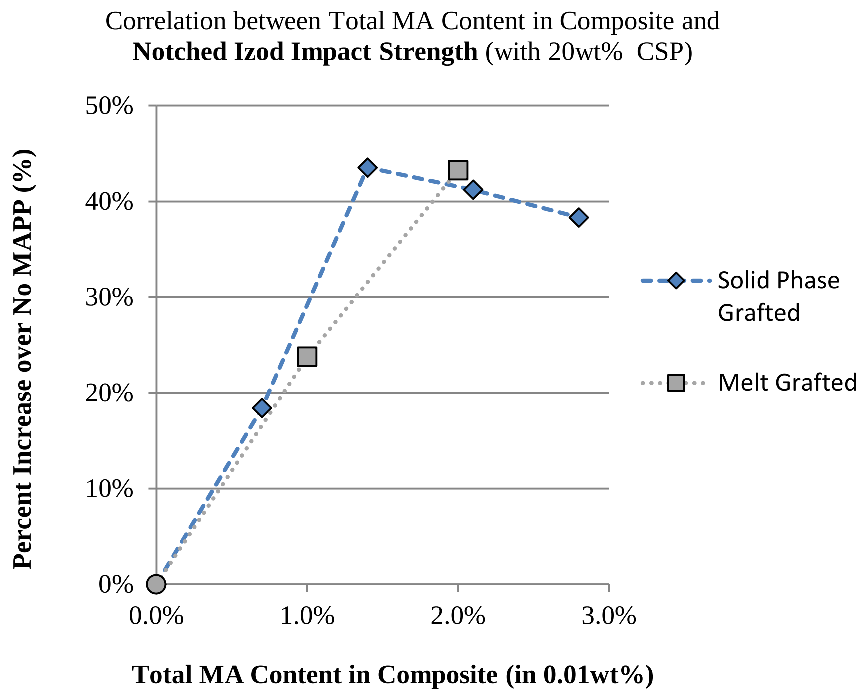


Figure 4-9: Correlation between total MA content and notched Izod impact strength in a 20wt% CSP-filled PP composite.

The results for tensile strength, Figure 4-10, are not as easy to interpret. At and around 0.02wt% total MA content, there is a negligible difference between the mechanical properties achieved with solid phase grafted and melt grafted MAPP. However, at 0.01wt% total MA content, there is roughly a 2 to 1 difference between the mechanical property improvements with solid phase and melt grafted MAPP. Due in large part to the lack of data points for the melt grafted MAPP, Figure 4-10 is inconclusive as to whether the total MA content is the controlling factor of MAPP performance.

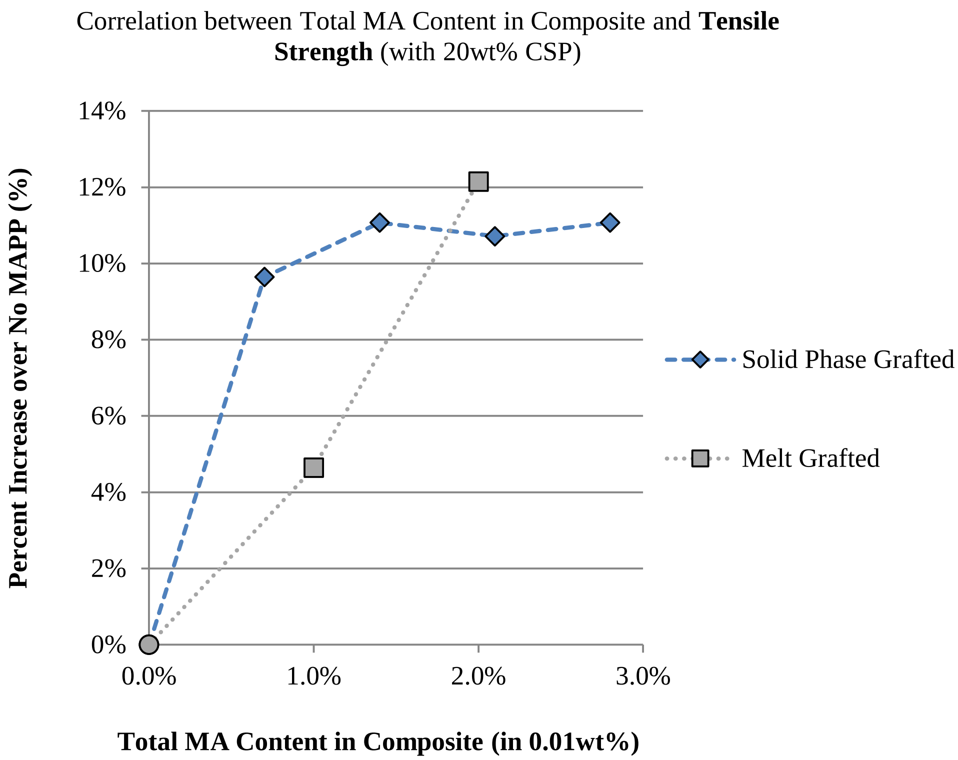


Figure 4-10: Correlation between total MA content and tensile strength in a 20wt% CSP-filled PP composite.

The results for elongation at break, Figure 4-11, are also inconclusive. At lower levels of MA content, the melt grafted and solid phase grafted MAPPs yield similar elongation at break improvements. As the total MA content increases, the elongation at break improvements for solid phase and melt grafted MAPP diverge. Solid phase grafted MAPP then provides a noticeable advantage in elongation at break improvement, even while being compared on specific MA content.

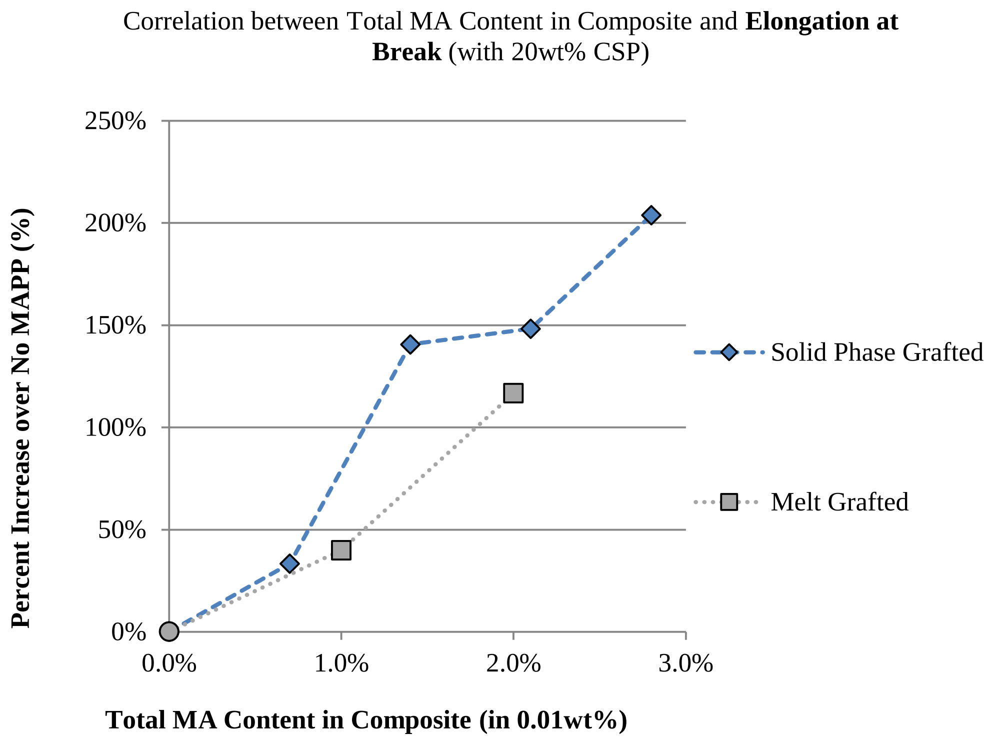


Figure 4-11: Correlation between total MA content and elongation at break in a 20wt% CSP-filled PP composite.

Overall, there is evidence to suggest that total MA content is the driving force behind the mechanical property improvements seen when using MAPP compatibilizers. More data is needed to sufficiently verify the claim that total MA content is the main factor in determining MAPP performance. There is a strong correlation between increasing MA content and increasing mechanical properties.

Figures 4-12 and 4-13 compare a 20wt% CSP-filled polypropylene composite system without MAPP to the same composite system with 1wt% solid phase grafted MAPP. By incorporating only 1wt% BYK Scona® 8112 into a polypropylene composite with 20wt% CSP, there was a noticed improvement of 11.1% and 43.5% in the tensile strength and notched Izod impact strength, respectively. These mechanical property improvements and the cost-effective compatibility solution that solid phase grafted MAPP offers allow the embodied energy savings of CSP composites to be realized in commercial applications.

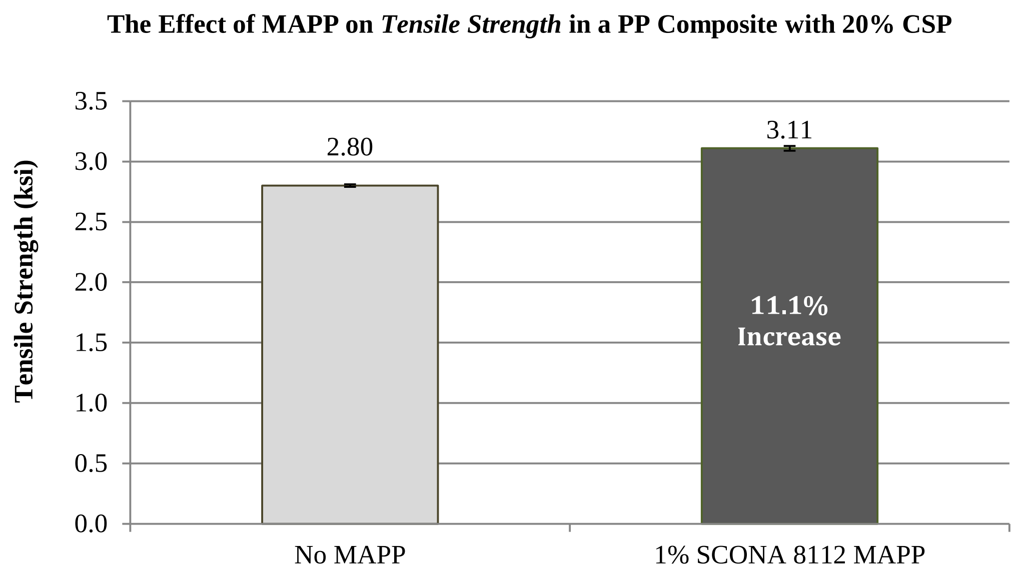


Figure 4.12: The effect of solid phase grafted MAPP on tensile strength in a PP composite with 20% CSP.

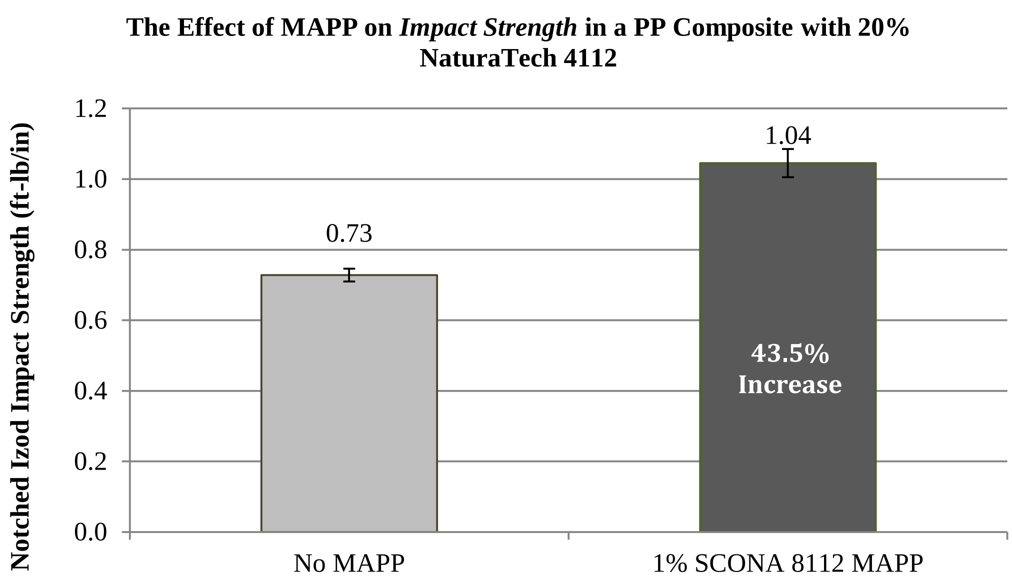


Figure 4.13: The effect of solid phase grafted MAPP on notched Izod impact strength in a PP composite with 20% CSP.

Optimization by using additive packages and compatibilizers is the type of material enhancement that helps to transform waste, like coconut shell, into a resource. Achieving optimum composite compatibility represents the engineering bridge between environmentally conscious innovation and commercial application.

4.3.4 Summary of MAPP composite optimization study. For all the mechanical properties discussed in this research, SPG MAPP appeared to reach a saturation level, or the optimum level of interfacial bonding, at lower wt%s than the MG MAPP. Specifically, lower amounts of Scona® 8112 SPG MAPP, 1.0%wt%, yielded similar or better results than typical 2.0wt% Polybond® 3200 MG MAPP for all the mechanical properties discussed in this research. The MG MAPP is the current status quo for 20wt% loaded CSP-PP composites. However, comparing 1.0wt% SPG MAPP side by side with 2.0wt% MG MAPP on a spider plot, as seen in Figure 4-14, we see that 1.0wt% SPG MAPP is a better option for compatibilizing CSP-PP composites, since less SPG MAPP can be used to achieve the same or better properties than 2.0wt% MG MAPP.

Figure 4-14 normalizes the highest value for each of the four material properties listed on the plot to 10, then bases the other values on the highest value to establish a 10-point scale. This plot is for 20wt% CSP composites. To maximize the applications that CSP composites can be used in, it is important for the composite to be well rounded, performing as well as possible in each mechanical property (flexural modulus, flexural strength, tensile strength and impact strength).

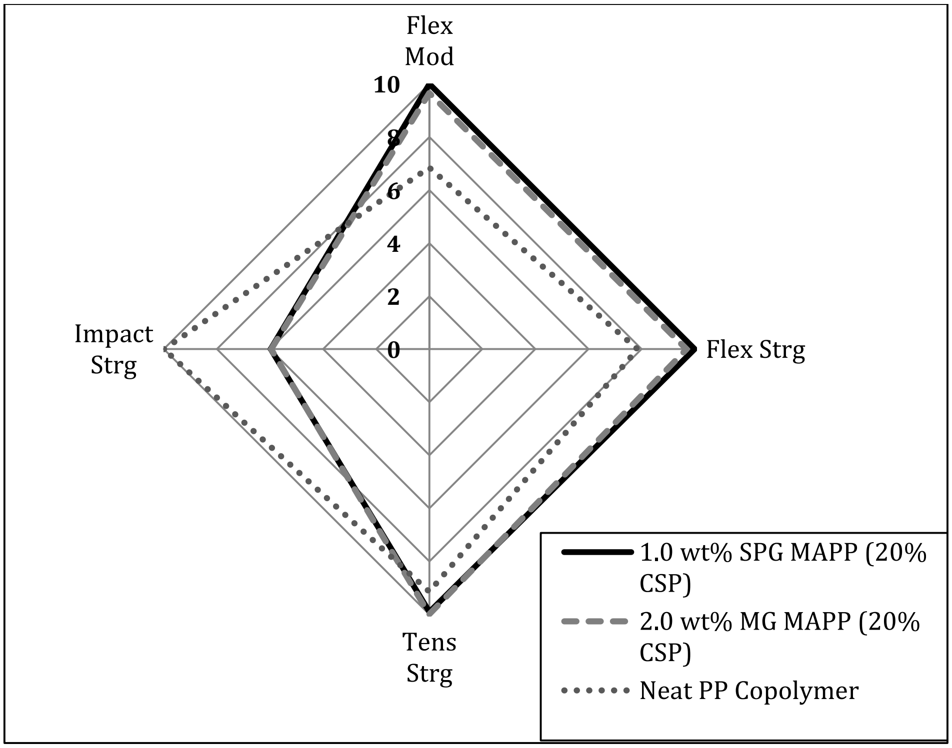


Figure 4-14: 1.0wt% SPG MAPP (pellet) compared to 2.0wt% MG MAPP (pellet) in a 20wt% CSP Composite.

4.3.5 Points of departure on MAPP. This research shows that using solid phase grafted MAPP gives better interfacial bonding between CSP and the polypropylene matrix than melt grafted MAPP provides, as proved by the increase in mechanical properties when using SPG MAPP. Using a smaller quantity or percentage of solid phase grafted MAPP achieves the same or better mechanical property results than can be achieved with greater amounts of melt grafted MAPP.

This research also confirms the evidence suggesting that total MA content is the driving force behind MAPP performance. Due to higher total MA grafting, composites made with solid phase grafted MAPP can achieve higher mechanical properties with lower dosages of MAPP. The time and cost-effective nature of these maleated anhydride coupling agents, along with the mechanical property improvements that these compatibilizers offer, make natural composite innovations like CSP feasible for SCD opportunities. Table 4-2 provides an overview of some of these results.

Table 4-2
Comparison of the Optimum MAPP Loading For MG MAPP (pellet) and SPG MAPP (pellet) for Different Mechanical Properties in 20wt% CSP Composites

20% CSP	**Previous Research with MG MAPP**	**Current Research with SPG MAPP**
Mechanical Property	Optimum **MG MAPP** (pellet) Loading for Best Property Performance (wt% Composite)	Optimum **SPG MAPP** (pellet) Loading for Best Property Performance (wt% Composite)
Impact Strength	2.0%	1.0%
Tensile Strength	1.5%	1.0%
Flexural Modulus	1.5%	0.5%

Figure 4-15 illustrates the successful implementation of a waste-to-resource framework. The primary technical variables are raw material supply, chemistry, and processing. Coconut shells can be transformed from a waste to a resource because all three primary technical variables have been successfully addressed.

Nothing is possible unless the fundamental chemistry of the material is well understood. However, fundamental chemistry is of no use if the material cannot be processed. A good understanding of processing parameters and their influence on the structure-property relationship of the material is required. Technical commercial success also depends on the raw material supply. Raw material supply and quality control is imperative for long-term successful waste-to-resource manufacturing.

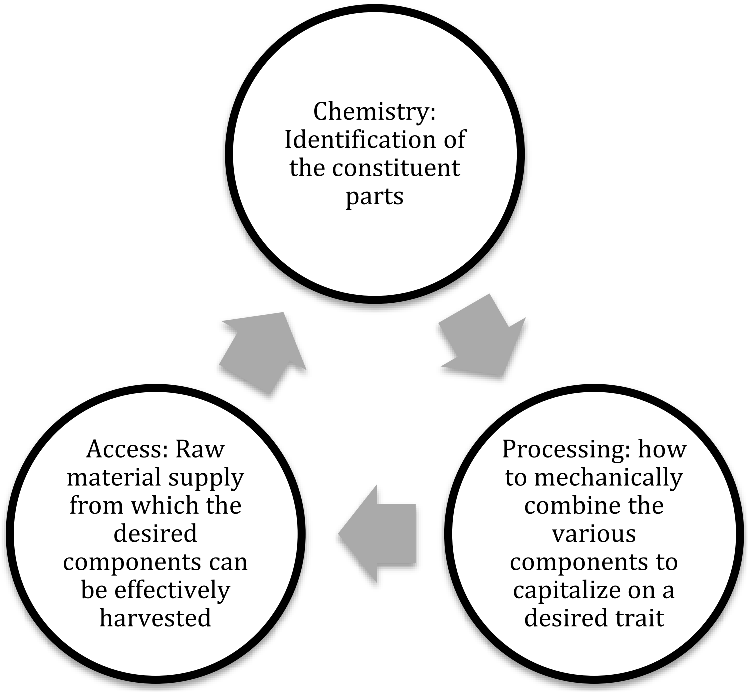


Figure 4-15: System schematic for the technical sphere.

Using a waste-to-resource model is complex, and so is sustainable community development. Building successful, long-term, sustainable communities is challenging, but with sound engineering and materials science, it can work. In addition to the technical impact, the environmental impact must be understood. Our environmental analysis of transforming waste into a new composite helps to determine if it is a viable solution or does more harm than good.

4.4 Sustainability of Natural Filler Reinforced Polyolefin Systems

The transformation of coconut shells into coconut shell powder used in plastic composite materials has not only technical considerations but also environmental and human impacts. Zero waste may be a desired ideal, but in we are not likely to practice complete zero waste because some percentage of waste generally remains at the end of any chemical process. For motivating innovation, though, zero waste remains a good target.

Recovering waste and transforming it into a new resource requires an emphasis on innovation. As the phrase "waste-to-resource" implies, this research topic is driven by an emphasis on new resource creation. Creatively using waste can reduce poverty on a community level. For successful implementation, it is responsible and vital to understand, identify, and mitigate negative impacts on the environment and human health. Using waste presents an economic opportunity for sustainable development, but the use of waste can also provide a new path for contaminants to pass into the ecosystem through land, water, or air. Human impact will be briefly addressed in this chapter and will be discussed at greater length in Chapter 5.

4.4.1 Environmental impact assessment of coconut shell as filler for polymeric composites. Many challenges and benefits come with reclaiming waste and reusing it to develop new products. An example of this is when sewage waste is transformed into a compost product; serious complexities and health issues accompany such waste reclamation (USFA, 2013). Using waste can both positively and negatively impact the environment, human health, and the economy of a community (Mahr, 2012).

Agricultural waste has good uses in composites. In the waste-to-resource framework, the first focus is to understand the available waste streams in a given community, then to map (quantify, locate) and recover them. Agricultural waste byproducts as well as recyclable materials such as glass, tires, and plastics are some of the key contenders for value-added opportunities. Using agricultural waste in combination with plastics, including post-consumer resins (PCRs), and reclaimed rubber, allows for the creation of new value-added materials for both local and global markets.

Coconut Shell Powder (CSP) has been described in previous chapters. It is a waste byproduct of processing a mature coconut. Approximately 11 million farmers in the Asian Pacific region rely on the coconut tree for their families' livelihoods (Arancon, 2010). In 2011, the United Nations estimated the global supply of coconuts to be approximately 61 million tons per year; billions of coconuts grow each year, making it an abundant natural resource, also an abundant waste product (UNCTAD, 2012). Scanning electron microcopy (SEM) images in Figure 4-16 show the intrinsic characteristics of coconut shell that lend it to successful incorporation in polymeric composites.

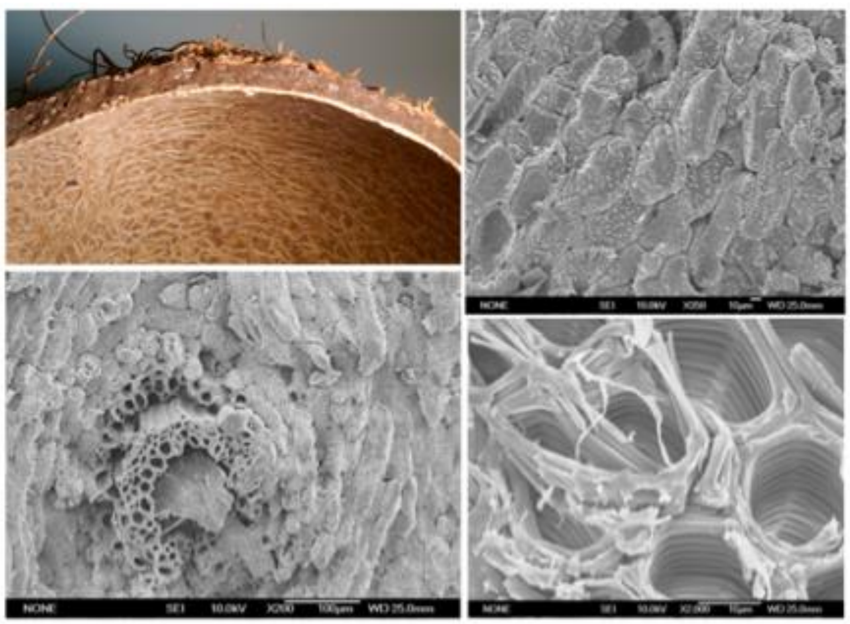


Figure 4-16: Scanning electron microscopy cross-sectional view of coconut shell.

The initial commercial application for coconut shell polymers is automotive parts. The automotive industry has a compelling reason to adopt lighter weight, more sustainable plastic composites in a fairly immediate time frame—strict government regulations that call for improved environmental sustainability and incremental increases in automotive fuel efficiency over the next several years. Using reclaimed coconut shells ground into a fine powder can reduce the amount of neat resins in automotive parts, including lightweight automotive parts, which helps to increase fuel efficiency (Durbin, 2014).

In 2011 in the United States alone, approximately 3 million vehicles were manufactured (IOMVM, 2013). Each vehicle contains approximately 300 lbs of plastic. Initially, one small North American vehicle platform (Figure 4-18) with an annual vehicle production of 22,000 could help to launch the use of CSP plastic. Using an average of 10% coconut shell powder as a functional filler in vehicle parts amounts to reducing 30 lbs of plastic per vehicle. When calculating the plastic resin savings over the entire small platform, approximately 660,000 lbs (299,370 kg) of virgin resin can be reduced.

The benefits to the environment increase when a global platform is considered. With a Ford Fiesta platform that has over 250,000 units, using coconut shell powder in plastics can help prevent the production of 37 million lbs of resin.

Figure 4-17. Example of a 22,000 EAU vehicle platform (Lincoln MKS).
Picture reference Lincoln Motor, Co, sales webpage.

The intrinsic nature of thermoplastic composites and the exceptional thermal stability of CSP together allow coconut plastics to be recycled following industrial use, then reground and reused up to 5 times (Teipel et al., 2011). Currently, most recycling operations cannot take filled plastics, so reuse would have to happen at the manufacturing plant (Tellus Institute, 2011).

4.4.2 Human health effects of reclaiming coconut shells. Reclaiming coconut shell and transforming it into a new resource has positive human health impacts within the community. In the tropics (20 degrees north or south of the equator), heavy rainfall and an abundance of coconut waste make a favorable breeding ground for mosquitoes, which carry diseases such as malaria. Recovering and processing discarded coconut husks and shells disrupts the breeding grounds for these disease-carrying mosquitoes.

Conversely, grinding coconut shell into powder can be hazardous if proper safety equipment is not used—equipment such as facemasks and facility ventilation. The powder can cause upper respiratory infections due to indoor air pollution as well as contamination of the air in surrounding areas. Communities that grow and harvest coconuts are hot and humid, so farmers and processers often neglect safety procedures for comfort.

By reclaiming and preventing coconut waste from going into a landfill or collecting in piles, a natural material enters the post-consumer recycling stream. Compounding the coconut shell powder with a polyolefin resin locks it into the plastic for its life cycle. Pros and cons must be weighed: does saving 20% plastic outweigh locking in 20% of a natural material and hindering recycling?

Another consideration is that natural based composites often require less energy to produce than traditional resin systems. The embodied energy of CSP in polypropylene has been calculated and compared to the energy required to manufacture neat polypropylene. Embodied energy calculations indicate that natural based composites can be more environmentally sustainable than neat polyolefin resin systems.

4.4.3 Embodied energy calculations. At first mention, adding CSP to plastics gains a positive response. A study of the embodied energy can help us tell if CSP is an environmentally viable solution for plastics. The embodied energy is defined to be "the total energy expenditure required to produce one kilogram of material in final form" and is generally reported in units of mega joules per kilogram. Calculating the values of embodied energy for composite materials is often one element of a full life-cycle analysis and can be used to evaluate the environmental impact of CSP composites. An estimate of the embodied energy of coconut shells milled into CSP compared to the embodied energy of other fillers and resin systems shows that less energy is required to mill the coconut into powder than is required to produce other fillers or resins.

By way of comparison, consider the embodied energy of the functional filler to the embodied energy of potential resin types (i.e., polypropylene). This comparison is presented in Figure 4-18. The embodied energy of CSP was derived from the fuel, oil, and total energy consumption of the typical circa-1970 diesel-engine-driven hammer mills commonly found in developing countries. Fuel consumption per hour over kilograms of coconut shell powder produced by the mills can be calculated and reported in MJ/kg. The mill in this study was in service through 2013. Later, this researcher working with Dignity and the community moved to more efficient machines to reduce the consumption of energy. The patent-pending processing line was commissioned in 2014, and trial runs to test for production readiness have begun.

Using modified eclectic mills could decrease energy consumption. The use of newer equipment is currently being implemented at the CTP in Cagmanaba. The system boundaries in the following embodied energy calculations are limited to the hammer mills alone, a yardstick sufficient for initial study on how the production of coconut shell powder can generate positive impacts for the environment.

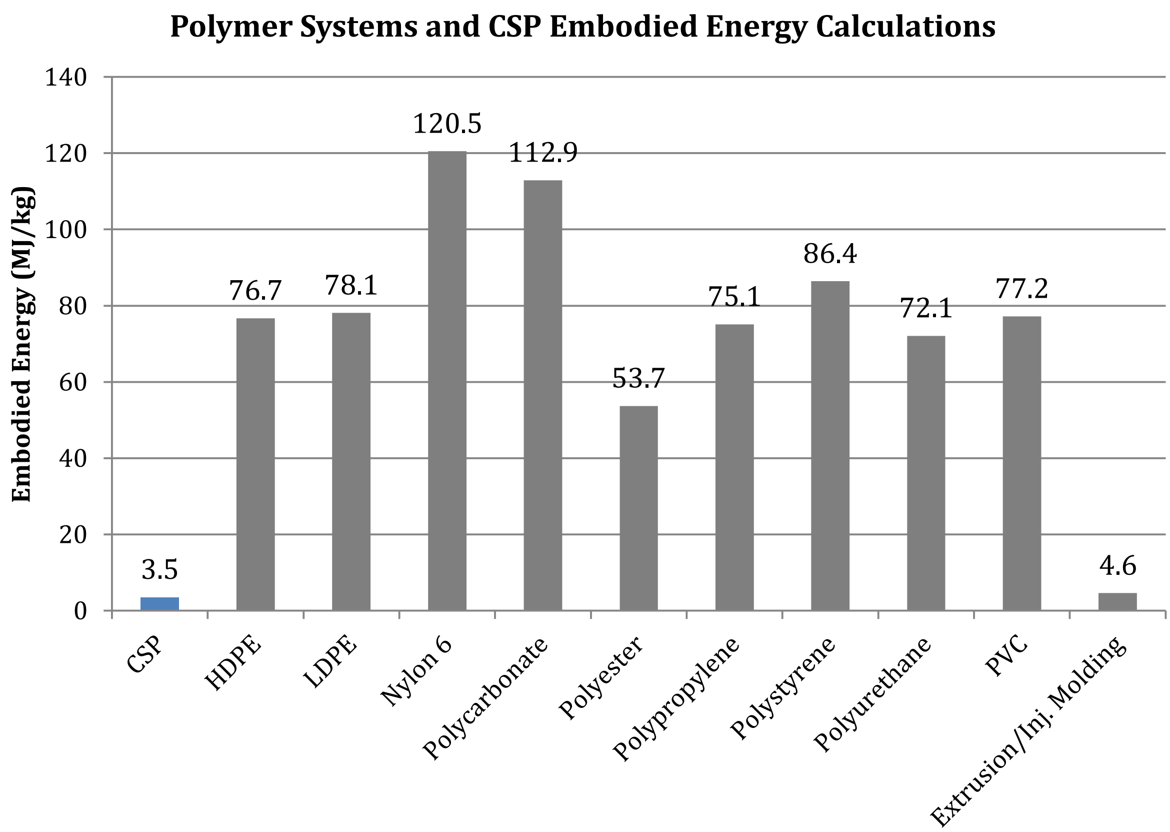


Figure 4-18: Embodied energy comparison of CSP with various thermoplastic resins.

It is useful to show how the energy efficiency of the composite could be increased by the addition of coconut shell powder. The rule of mixtures helps with calculating the embodied energy of a 20% CSP-polypropylene composite. The embodied energy of a kilogram of extruded and injection molded polypropylene is reduced by 18% with the addition of 20 wt% coconut shell powder, as seen in Figure 4-19.

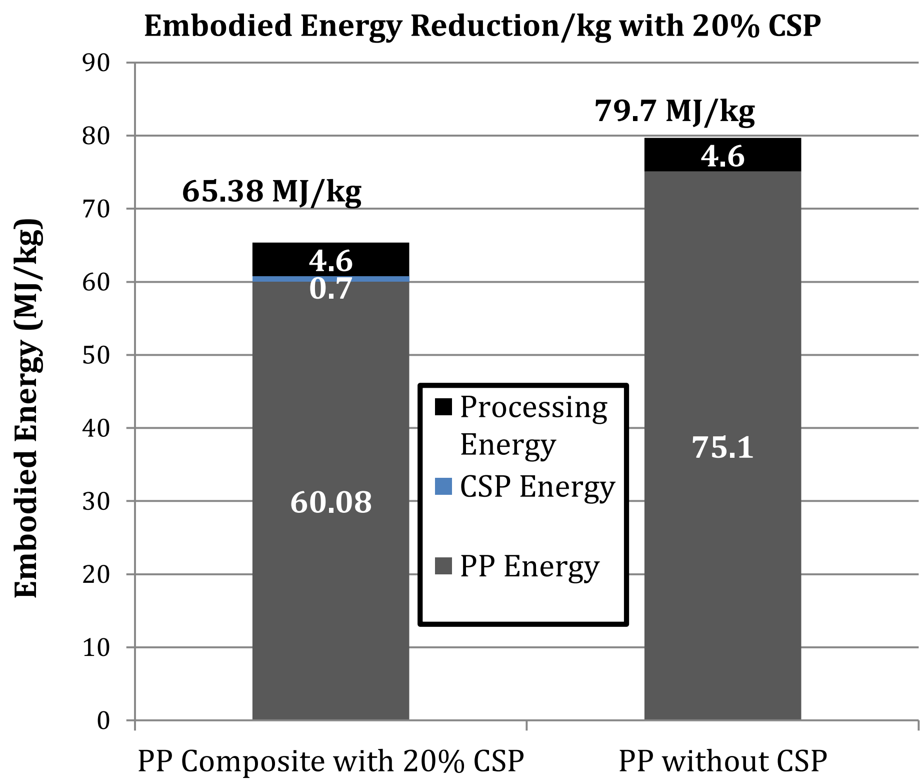


Figure 4-19: Embodied energy reduction of PP composites with the addition of 20 wt% CSP (coconut shell powder). The compounding energy used was reported in Karian et al., 2011.

4.5 Commercial Impact

As demonstrated by the positive implications for the environment, human health, and community economics, recovery and reuse of coconut shells to make composite materials demonstrates a triple bottom line approach to transforming waste into a new polymeric composite for sustainable community development. Reclaiming natural waste byproducts and engineering them to create materials such as CSP-polypropylene composites brings economic benefits with the technical innovations, while reducing the energy required to produce the final plastic products.

The positive technical and environmental benefits set the stage for positive human impacts. The three together form the bridge to creating sustainable community development solutions. Partners such as Essentium Materials and Dignity Products and Services work together within the communities of Cagmanaba and Badian. Dignity works to reclaim coconut waste, specifically shell waste, as byproducts from their coconut water and oil manufacturing operations. Essentium Materials formulates new composite materials and commercial launches of coconut plastic products.

From a combined materials innovation and social entrepreneurship platform, a new coconut-based waste-to-resource platform would be a great opportunity for SCD. Direct examples of this waste-to-resource application using coconut shell powder have launched because of the findings of this research and during the writing of this thesis. See Figure 4-20 for a structural guard used on the Ford F-250 and Figure 4-21 for a living wall planter available from Williams Sonoma. The information from the community survey provides feedback to assess what materials are available. Once a material (waste as feedstock) is selected, the next step in the process is to validate the material by mechanical property testing and material optimization.

Figure 4-20: Ford F250—Structural guard.

Figure 4-20 demonstrates an example of a material (coconut shell waste) that was chosen in part using information from the assessment reported in this thesis, which has recently launched as a commercial product. Of the polymeric composites contained in the F-250 structural guard, 10% of the total part mass is coconut shell powder. Approximately 20% of the part mass is recycled tires, with the balance of the part comprised of polyethylene resin and trace amounts of environmental stabilizers—UV, salt, and oxidative degradation resistors.

A second example that resulted from using coconut shell waste is the living wall planter seen in Figure 4-21. The living wall planter is comprised of 30% coconut shell powder, mixed into polypropylene resin, again with trace amounts of environmental stabilizers. These are two examples of products that have launched from waste into commercial applications.

Figure 4-21: Williams Sonoma living wall planter, made with coconut shell based plastic and coconut fiber moisture mats.

Even though there are some negative impacts (e.g., filling a plastic makes recycling challenging), the positives ones far outweigh the negatives (e.g., using 10-40% less plastic on potentially millions of car parts, due to filling that space with CSP). It is more straightforward to incur an environmental benefit during the manufacturing of a durable good than to count on its end-of-life solution. Based on the technical and environmental impacts, the waste-to-resource model should be considered a viable option for SCD. The final important impact, addressed in chapter 5, is the human impact. The technical and environmental impacts pave the way for an equitable solution, and the human impact assessment gives guidance on holistic ways these benefits could work together to help the communities meet their goals and needs.

CHAPTER V

HUMAN IMPACT ASSESSMENT

The system dynamics of changing wastes into resources and the human impact created by such transformation is investigated in this chapter. Polymeric composites and new materials make a positive impact in sustainable community development by mitigating rural poverty. This research closes by investigating techniques for fairly sharing the benefits from a waste-to-resource model among the various stakeholders, identifying needs for future work in the areas of equity and profit-sharing in such a development setting. An analysis and discussion of the meanings of equity and generosity in this systems-based approach to sustainable community development is included.

Using this waste-to-resource framework as an approach to sustainable community development leads considering the structure of business entities. Private for-profit entities and their non-profit counterparts are reviewed and compared. It is also helpful to discuss various profit models both to apply the new waste-to-resource approach and to consider the viability of scaling up in the future.

Further, sustainable community development (SCD) can be framed like a mathematical equation. Once the research framework, along with the technical, environmental, and commercial benefits of this agricultural waste-to-resource model are defined, adding the Human Impact factor occurs as follows:

Table 5-1
Sustainable Community Development Equations

$\mathbf{SCD_{W2R}}$	$\mathbf{= SCD_{Human\_Impact} + SCD_{Enterprise}}$	**Eq. 5.1**
	where	
$\mathbf{SCD_{Human\_Impact}}$	$\mathbf{= ICI + Equity + Dignity_{People}}$	**Eq. 5.2**
	where	
ICI	= Intentional Participatory Community Involvement	
ICI is soliciting the Community's Involvement in the following:	• Planning the product • Selecting the feedstock • Locating the facility • Considering the impacts of new wealth	
	and	
Equity	= Shared ownership	
	and	
$Dignity_{People}$	= Consideration of the whole person	
Consideration of the whole person is comprised of improvements in the areas of:	• Good working conditions • Retirement savings plan • Community program investment matching • Livelihood programs • Banking • Improvements in public health • Continuing education and vocational training	
	and	
$\mathbf{SCD_{Enterprise}}$	$\mathbf{= Dignity_{Planet} + New\ Business}$	**Eq. 5.3**
	where	
$Dignity_{Planet}$	= Environmental stewardship	
	and	
New Business	**= R&D + MFG + Sales**	**Eq. 5.4**
	therefore	
SCD	$\mathbf{= ICI + Equity + Dignity_{People} + Dignity_{Planet} + R\&D + MFG + Sales}$	**Eq. 5.5**

The different components that enter into the definition of Sustainable Community Development are presented in Equation 5.1. In order to be complete, equal weight must be given to the Human Impact and the Enterprise factors.

Equation 5.2 breaks the Human Impact factor into three components: Intentional Community Involvement, Equity and $Dignity_{People}$. Again, equal weighting of the three components is key to achieve a balanced system.

Equation 5.3 defines the Enterprise Sustainable Community Development impact factor into its components— $Dignity_{Planet}$ accounts for the environmental focus, while New Business (Eq. 5.4) contains R&D, MFG and Sales. $SCD_{Enterprise}$ depends directly on these components: if sales increase, so does the value of the Enterprise factor, for instance. $SCD_{Enterprise}$ contains the Technical, Environmental, and Commercial Impacts; this research's case study for this was presented in Chapter 4.

Finally, Equations 5.1–5.4 are combined in the form of Equation 5.5, which captures all the sub-components of SCD. Each component is additive and, if conducted well, directly increases the value of SCD, meaning that the likelihood of successful SCD occurring increases. The research framework for this thesis is represented by Equation 5.5.

5.1 What does it mean to be equitable?

Developing an understanding of equity in sustainable community development is based on the human impact assessment. Transforming coconut waste into a resource to be added to polymer resins can create collateral stresses such as excess money, stored at the home due to a lack of local banks, or increased gambling activities. Income alone will not solve all of the community members' problems. The effects of the waste-to-resource systems approach are considered as part of holistically studying equitable outcomes for those engaged in the community development partnership. Defining what it means to have equitable benefits for all the stakeholders using a waste-to-resource model is part of the human impact assessment.

According to findings in this research, higher net income is not the wealth desired by the community. Erroneously, project benefits are too often determined by what the partnering organizations assume ought to be most beneficial; instead, as a first metric, it is helpful to query community members to understand the community's context for waste and wealth (discussed in Chapter 3).

Findings from interviews with the residents of Cagmanaba and Badian show that they want community members and employees to use newly earned money to nurture their families, to love their neighbors, to invest in their communities, and by doing so to increase peace on earth. For them, part of being truly wealthy means knowing how to help others and to give back to the community.

Behavior Change Communication (BCC) is a huge component of achieving lasting change within a population that is dynamically developing—especially when new financial benefits become involved. In this sense, BCC helps develop communication strategies that promote positive behavior: for example, not squandering money. BCC methods provide a supportive context that enables individuals and communities to sustain positive behavioral outcomes (Freeman, 2012).

5.1.1 Questions the assessment seeks to address within this framework.

1. How does a waste-to-resource model impact the people in the community?
2. How does social equity affect the community?

3. What does it mean to be equitable?
4. What does it mean to share profit?
5. What are the community benefits of waste-to-resource transformation?
6. How will social equity impact the community?
7. What does the community view as waste?
8. What are the pros and cons of creating income and economic development?
9. What are the intended and unintended consequences of an income increase and new income generation?

5.1.2 Equity: elevation, not exploitation. Various societal models exist regarding the ownership of a resource in question. For example, private property owners sometimes have mineral rights to everything in the ground below their property, while sometimes these rights reside with a governmental body in the host country. Natural resources are of particular focus in this study, due to the historically exploitive nature of outside agents.

Too often outside agents, who usually own the technology to extract value from the birthright resource, grab the lion's share of profits from the sale of the material. These agents usually claim that the provision of jobs was sufficient return to the local community, and, after extracting desired resources, abandoned the locality without leaving behind any permanent jobs. Too often, such abusive development neglects investing in schools or areas of worker training such as personal financial management, leaving instead residual pollution to be endured or cleaned up by the local community.

Consider the coconut, a prime example of a natural resource, whose value can be significantly increased by utilizing 100% of the mass of the nut in commercially viable products. Through examination by a team trained in material science, engineering, and commerce, product streams can be identified to use each constituent of the nut.

Western companies have exploited much of the developing world by utilizing only a single component or a small percentage of the total material mined or manufactured. This approach supplies jobs within an area of high poverty but eventually strips the inhabitants of access to their most valuable natural resource. As an example, Bolivia had large tracts of mineral-rich lands but continues to suffer high rates of poverty.

For sustainable progress, the focus must be on elevating the importance of accompanying system needs—education; training to develop globally valuable skills, products, and services; banking; and public health, to name a few—to achieve a point where the people with the birthright resource gain improvement in *all* sectors of their lives. This can be accomplished through focusing on equity in a systems approach to sustainable community development.

Meeting the needs of the present without compromising the future is the essence of the popularly accepted definition of sustainable development (Barkemeyer et al., 2011). Through the past several decades, the term "sustainable development" has often been used broadly, without a concise understanding of the meaning or implications (Zaccai, 2012). Sustainable development by this definition takes into consideration the needs of the current population as well as planning and stewardship for future generations. However, new definitions seem to focus more on environmentalism than on equity in sustainability and human development (Barkemeyer et al., 2011; Lawson-Remner, 2013).

The UNDP's 2011 Human Development Report (HDR) on Sustainability and Equity notes that sustainable development and human development are often seen as two separate areas, but sustainable development by definition includes both human and environmental components. Though the two concepts differ, they are not unrelated, and fundamentally they should occur together to ensure that the desired outcome is truly sustainable. An overview of sustainability assessment methodologies can be seen in the literature (Singh et al., 2009; Cloutier et al., 2014; Mayer, 2008). True equity is accomplished through stewardship, instead of exploitation, of natural resources as they are harvested and processed.

5.2 Case Studies: How Access to the Global Market Benefits the Community, CTP

This research investigated how the community can benefit from resource creation that brings not only economic development but also many other facets of sustainable development. While benefit is a logical outcome from a waste-to-resource model, negative **outcomes** could also stem from this approach, so a thorough assessment must address harmful effects. Using data from two different community surveys in Badian and Cagmanaba, a list of the pros and cons of resource creation, specifically new income for a normally lower-income community, is examined and the following human impact points are summarized:

- Public Health
    - Prior to the CTP, there was no community health education. The nearest hospital, which is two hours away, was the only source for health care. With new jobs, the value of workers increases and preventive health care becomes the new focus, instead of a trip to the hospital in an emergency

- Transportation and shipping
    - The CTP provided impetus for the national, provincial, and local governments to expedite construction of a concrete highway.
    - The better road brought daily bus service all the way to Manila.
    - Packages can now be shipped on the bus, providing commercial and medical device transport opportunities.
- Access to education
    - The highway and bus system provide improved access to the local high school and regional colleges.

5.2.1 Building community capacity and resilience: true equity. What else could be done instead of simply paying people more when they have access to steady work? What types of community capacity and resilience building can be incorporated? Learning community perspectives on resource collection and new material creation helps find feasible approaches to building equity. Focus on building a positive legacy was also included in this research, to see if behavior communication change (BCC) helped the community view its wellbeing through these new methods.

Instead of merely providing higher pay to community workers who help collect and transform waste into a new material, better equity mechanisms could be established. Programs or models that could benefit the broader community, helping members of the community retain the newly created wealth instead of wasting it, are described here. To limit the impact of greed, the community and CDP partnership needs a good strategy for sharing equitably out of the profits, Not all people in a community can be offered new jobs, so beneficial social equity cannot be achieved solely through the creation of new jobs. Jobs that give a tangible opportunity to gain an ownership position in a globally active enterprise offer an excellent value proposition. Without investment from the outside, however, the global opportunities fail to come, and the same local commercial options offer limited opportunity for gaining value from solid waste. Currently, community members can sell some of their waste to a local buyer who pays in cash. In rural Philippines, the common rate per kilogram of recycled polyethylene plastic bottles is 75 pesos. Scrap iron is about 30 pesos per kilogram but commodity buyers who visit the local barangays control sales of this scrap.

The current use of agricultural waste such as coconut fiber is an example of equity that does not benefit the community. Coconut waste fiber can be made into rope, but the community is making very little income from the work. The rope is sold in 11-meter sections for 1.3 Pesos ($0.03 USD) to a Filipino businessman. When a development initiative is launched, community members need enough reward for doing the hard work. As a whole, the community and development partners need to establish a sense of fairness and justice, as opposed to taking advantage of someone's need for work.

5.2.2 The cost to the community. Turning waste into a resource can elevate a financially distressed region, but inevitably the transformation is susceptible to exposing harm as well. The risk of newly created income leading to increased wasteful spending must be considered as part of the foundation in creating a systems approach to poverty reduction. Similarly, the idea that newly created income will solve problems needs to be contextualized along with the possible life-threatening implications of simply having more money (e.g., fears of robbery or assault to plunder inadequately-guarded resources).

The purpose of a waste-to-resource transformation is to build a model that breaks poverty traps. In the rural Philippines, it is common for husbands to lose their wages gambling at cockfights. However, there are ways that community partners like Dignity could help employees and farmers use their newly created wealth wisely: i.e., to nurture their families, love their neighbors, invest in their communities, and bring peace on earth.

5.2.3 Equity, fairness, justice. Sustainable community development empowers the community members by providing a space for an active role in charting their own path forward (Onyx & Bullen, 2000; Razzaq et al., 2013). The waste-to-resource framework could transform the area into a community of innovators. The income from the value-added process contributes to livelihood, and wastes are now considered potential income sources. Also, the process of setting up the waste-to-resource model and CTP creates more than productivity in the market. Some training and education must happen to pave the way for the sustainable development that builds community capacity and resiliency.

Investors in a community transformation plant must consistently seek ways for the local community members to be the beneficiaries. A clear example of this effort was seen in the construction of the CTP in 2012. For building the CTP campus, the shareholders chose to hire 3 workers from the community to learn alongside of each more experienced builder, even though an initial assessment told them to go where the expertise was by hiring a crew from outside the community. Providing the community with this opportunity created a sense of respect, fairness and justice for a hardworking rural group of people that had never had such an opportunity before. This CTP gave the community an opportunity to showcase what they had as far as passion, skills and commitments, as shown in Table 5-2.

Table 5-2

Ways the Waste-to-Resource Model Can Provide Equity and Justice Through Job Creation

Metric	Result
Job creation—Income	Better pay than local minimum wages Allows for community to meet their own needs
Increase living standards	Community can sustain needed education, food, shelter, health, and other basics
Stimulate economic growth	Goal: To employee approximately 300 workers from the 1000 families in the area, increase income for 400 coconut farmers, and help other businesses get started in the area to spur economic growth
Fair pricing of products and new materials	Helps get the most value for stakeholders
Fair trade certification	Demonstrates commitment to stated principles and practices of the business
A use for waste in the community	Less pollution in the communities' environments
Decision making	Allowing communities to help with the decision making process Mistakes may occur; lessons learned can build capacity and resilience Because partners are willing to invest in their future, mistakes are seen as opportunities to grow and learn
Training and education	Community grows in capacity and resiliency
Voice in politics and community governance	Community grows in capacity, resiliency, self-sufficiency

The Manila-based construction manager expressed reservations regarding building a factory with farmers. However Dignity saw it as an investment opportunity for their future. The trust given to the farmers and other community members not only increased confidence, it also gave the community an opportunity for ownership plus zeal to see the project through. Construction was not just erecting a building, it was an opportunity to receive training and increase the community's capacity (resiliency). A farmer gains equity with this additional capability. He also receives dignity by learning new skills and being part of the solution. Through such intentional approaches, sustainable development replaces handouts.

5.2.4 Profit sharing and shared ownership as means to increase dignity. An examination of profit sharing leads to the conclusion that there is not a one-size-fits-all solution. Imagine that within the waste-to-resource framework, a community transformation plant (CTP) is built and employees start to receive their compensation. A shared profit approach could begin to take place as the employees are given back a certain percent, otherwise known as a share, based on the profit made in a month, quarter, or year. One approach could be that after a set-aside for reinvestment into the business, 60% of the remaining profits would go to the workers and other local stakeholders, and 40% to investors.

Profit sharing can presage shared ownership of the plant itself. By sharing ownership, the investors and leadership of a CTP are saying to the community, "The plant belongs to us all." Social entrepreneurs and socially conscious investors must profit financially from their investments. This model has embedded in its core the belief that a business not only will be profitable but also will be equitable for all involved. It is therefore critical to have discussions about the nature and distribution of equity at the outset of the venture. It is crucial to retain socially conscious investors who nurture the vision for the CTP model; otherwise investor frustration and fatigue may derail the good intentions.

It is neither common in the Philippines, nor in the more developed nations, to witness an employee-ownership model. The vision of building this first CTP and launching a waste-to-resource model through it is to encourage the communities of Cagmanaba and Badian to blossom and set a chain reaction of thriving, flourishing, and sharing with other poor communities. In sum, allowing the community members to become part-owners of the business is a strong incentive for high-quality work and robust employee retention. It also feeds sustainable growth opportunities over a long time-horizon. One aim is to make the business self-sufficient. Initially, investors may need more control because of risk; as the business becomes self-sustaining, however, the equity structure should transition in favor of increased employee ownership.

Many feel that the government should manage sustainable development, but in developing countries and communities, outside groups often lead because the government is absent from rural communities. In these cases, socially conscious investors have stepped in to make a difference. Business as a platform for SCD brings hope into the community; with the flow of new investment come new dignity and equity.

In sum, allowing the community members and stakeholders to become owners of the project or business is a good incentive for high quality work and robust employee retention. It also includes sustainable growth opportunities over a long time-horizon.

5.3 Equitable Profit Sharing Models

Nonprofit organizations around the world have not demonstrated the ability to disrupt poverty through donor-based economic conditions on a broad scale. Practices that effectively break the cycle of poverty, even in resource-rich countries, are limited in number and kind. A coalition of partnerships among for-profit entities, private/public partnerships, and nonprofit organizations should work together to build equity in a community.

A key piece of equity is developing globally competitive skills and management within the workforce: the people component (Figure 5-1). The fair distribution to all stakeholders is the most equitable fashion to share both ownership and profit. Dignity of the planet transfers equity back into the community and the region in the long term, through robust environmental stewardship.

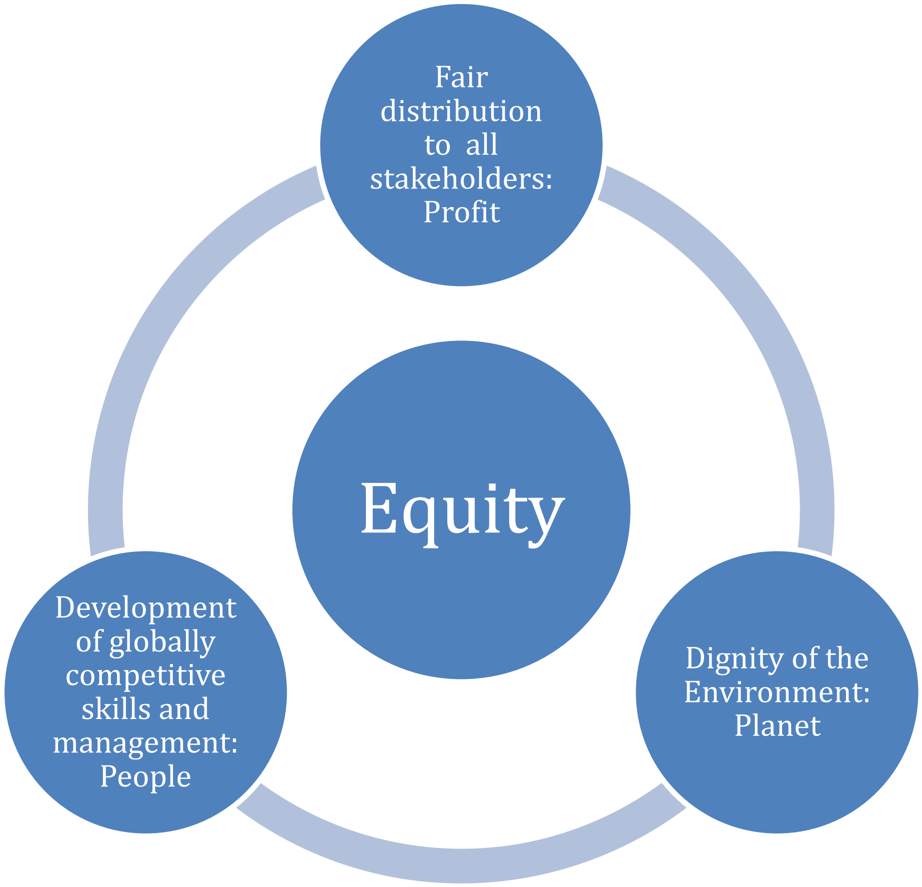


Figure 5-1: Building community equity.

In addition to the development of globally competitive skills and management, equity could involve generous investment of profits, fair distribution to stakeholders, and profit sharing targeted at community development through employee-specific programs. Table 5-3 shows possible examples developed as part of this research, followed by a more detailed description of the rationale behind each potential method of equity building.

Table 5-3

Profit Sharing Ideas Based on Human Impact Assessment and Community Survey

Method
Monthly/ Quarterly Continuing Education Mini-Courses
Monthly Giving–Match Program
An Employee Shareholder 401k Type Fund
Community Revitalization Projects
Discipleship Training Night School
Profit Sharing and Employee Ownership
Livelihood programs

5.3.1 Discussion rationales for employee-specific programs. The rationale for the profit sharing ideas is presented in this section. This rationale is based on building resources back into the community as much as possible, partnering with the employees to increase the focus on the community. The seven methods are not exhaustive but are specifically selected to allow growth of the whole community, in keeping with growth for the whole person.

5.3.1.1 Monthly and quarterly continuing education mini-courses. *Rationale:* These would be similar to the continuing education requirements of many professions. Employees must take a certain number of hours per year in order to remain eligible for working at a facility, for bonuses, or for promotions to new positions. A certain number of these courses would be required for each employee, farmer, or other stakeholder in the community.

Consider a tiered structure, such that during the employee's first year with Dignity, the employee must take one mini-course per month. This will help build positive behavior changes, and the employee has a chance to learn early on how to handle the newfound increase in income and transform it to wealth over the course of time. As the employee continues with the company, the mini-courses could be quarterly or even semi-annually.

The courses would cover a broad range of topics, and employees would have the opportunity to choose 8–12 courses for their first year, while Dignity could define the top 4 courses that all employees must take. These mini-courses will not be cumbersome, but instead offer hope and insight. If taught properly, the coursework will keep employees coming back because they will see the benefit.

Examples of topics for some courses:

a) Financial Peace—financial planning, budgeting, and saving
b) Celebrate Recovery—breaking addiction and addiction recovery
c) Cornerstone—building family foundations
d) The Richness of Marriage
e) Young Professionals—professional development for tomorrow's leaders
f) Business Communication

5.3.1.2 Monthly giving and match program. *Rationale:* In this program, Dignity could have three to five different ministries as partners (for example, Grace Christian Mission; a safe house for human trafficking victims; a community center.) Once profitable, Dignity Products and Services will match employees' giving (in addition to the proposed retirement plan). These funds could go to the partner ministry of the employee's choice.

Results from this research indicate that when asked, people will often increase giving with new income. But more often than not, people who are not familiar with giving may not know how or where to give. In this case, as part of a payroll deduction program, employees and farmers can choose to give 1–3% back to their ministry of choice from the list compiled by the Dignity community, and Dignity will match the amount. While this would not be a mandatory action for employees, it could certainly garner the interest of community members as they learn about managing their wealth through the continuing education courses.

5.3.1.3 A 401k-type retirement fund. *Rationale:* This fund could serve as part of the profit-sharing model, teaching and incentivizing employees and farmers to save. Typical matching funds are from 1–6% of an employee's income. Teaching concepts of good stewardship of the money earned would be useful. For example, matching 1–3% is a model used by Habitat for Humanity for its employees. More aggressive saving and matching plans in which employee contributions are matched up to 6% are typical of American companies such as Ford, Caterpillar, and John Deere.

5.3.1.4 Community revitalization projects. *Rationale:* A model for this type of project could be similar to that of Habitat for Humanity, where employees and farmers work together on a quarterly or semi-annual neighborhood home project for some of the neediest among them. Being part of the project crew could count as earned credit for continuing education courses.

5.3.1.5 Discipleship training night school. *Rationale:* Modeled after Antioch Community Church's night school, helping employees and farmers invest spiritually in their lives one to two times per week is a project that Dignity could provide for their employees. This can benefit the community by helping those who attend to understand a calling to fight against injustice and physical oppression. Unlike liberation theology, classes could focus on the holistic nature of the Christian message, a message that shapes and permeates every aspect of life, not just the material aspects of life.

5.3.1.6 Profit sharing and employee ownership. *Rationale:* Profit sharing is a key metric of Inclusive Capitalism. This is an emerging best-practice for conscientious business behavior, having been shown to improve the economic position across many types of enterprises. To serve employees better over the long term, shared ownership provides a robust vehicle to help build wealth (Hoffmire & Young, 2014).

5.3.1.7 Livelihood program. *Rationale:* For the livelihood program, handicraft opportunities can be offered to provide more work done in the home or elsewhere within the community. Here community members would come together to learn to make soap or crafts to sell. This is not the waste-to-resource approach, it but would provide income for those who not working at the plant. The employees who work at Dignity would have increased earnings to spend on these local products. Everyone can benefit, even the local government by increased tax revenue.

As it stands today, the CTP will be able to employ approximately 300 community members. In order to open opportunities to as many families as possible, Dignity encourages only one family member to work at the CTP to allow 300 of the approximately 1000 families access to employment and income. These livelihood opportunities also support further employment at the grassroots level in the community. Similar to microfinance, or a micro business opportunity, community members can participate in the livelihood program.

A portion of handicraft profit is reinvested into the business to purchase more material and increase the volume of the product. Some profit can be channeled into the community health education (CHE) program fund. Overall, community members work hard, both within the CTP and through livelihood programs. Some may be saving to buy their own property or start their own business one day.

5.3.2 Community health education (CHE) discussion. Both Badian and Cagmanaba each have one team of CHE volunteers. Cagmanaba is already working on some livelihood projects, but the Badian team is not, yet. The Cagmanaba team has many members who do not have full-time employment. Most of the members of the Badian team are teachers in the local schools. The teams are formed of united community members and leaders who want to learn about microenterprise opportunities in and for their community, e.g., through the livelihood programs.

5.4 Partnerships that Build Sustainable Equity

The bottom line for sustainable development to be successful requires a sound business case and value-added products or services, along with various types of capital and strong partnerships. In the case of this beta-level waste-to-resource model, the identified partners are named in Figure 5-2.

Figure 5-2: Partnership equity model.

In conclusion, how are success and failure defined in sustainable community development? Success in development means the community can perform all the project steps self-sufficiently, not relying or depending on training or supporters once the outside agents are gone. Through the process, good leaders are developed who can shepherd the community through challenges, demonstrating robustness and resiliency that was previously not present in the community.

Successful application of the waste-to-resource model requires deep knowledge of the community. It requires a willingness to develop all aspects of the community, an understanding of the community's capacity, and a desire to help frame the vision of where the community would like to be as the result of investment. A waste-to-resource model can help breathe life into sustainable enterprises, businesses that are profitable and bring development to areas that are in dire need of it. Turning waste into profit is not only a good idea but also a realistic one, providing for increasing wealth. However, it is not just about money and scale.

The essentials of true wealth are grander and more holistic. Sustainable human development includes clean water, health, sanitation, a thriving family environment, food, nutrition, peace, stability, safety, spiritual foundations, and a livelihood that brings dignity and respect to individuals and their families. Earning $0.30 for a coconut and $0.10 for its waste compared to the original $0.03 does not solely provide wealth. Wealth is about the quality of human life. Who wouldn't like to live with the freedoms and privileges present in many developed nations? Resource creation is not about affluence, comparisons, or living with every material desire met. It is about dignity.

CHAPTER VI

CONCLUSIONS, RECOMMENDATIONS, AND FUTURE WORK

In conclusion, the successful application of a waste-to-resource model as an approach to sustainable community development requires strong partnerships between outside stakeholders and an engaged community. These development agents work alongside members of the community to disrupt rural poverty patterns by bringing valuable products to market and equitably sharing the profits. To use a waste-to-resource framework and model to achieve community development, some key elements are essential. First, project partners should understand the community's capacity and then assist in framing a vision and goals that can benefit all stakeholders, especially the community. Given that local materials are transformed through the new enterprise, knowledge in materials science and engineering is necessary. Finally, business expertise from partners who have experience with successful commercialization is crucial.

Turning waste into resources is not only a good idea but also a proven one. The model has been initially tried, and new materials have been developed and gone into production. In 2012 a coconut-shell based structural guard was launched in the Ford F250. In 2013 a gardening application and a cutting board using coconut-filled polymeric composites launched in the home goods market. These applications are early stage examples of how the model is progressing.

Waste-to-resource development could also have a very positive impact on people and the planet while building a profitable business. In 2014, this researcher is looking for more ways to harness coconut and increase its use in automotive polymeric composites, consumer goods, and specialty chemical applications. Sales should increase due to a large potential market, and those sales will yield a bigger impact for the community.

Profits from the sale of coconut shell powder in polymeric composites require time to reach the community. However, profits are not the only metric by which to judge success of the model. The waste-to-resource framework is (1) not only focused on increasing net household income in rural settings, nor (2) focused solely on creating a large-scale operation that would move a developing community toward first-world standards.

The framework instead demonstrates that a combination of social and economic justice bring the most equity to all stakeholders. Conscientious, reformed capitalism, which values all stakeholders and invests generously in sustainable development for a financially depressed region, is the economic vehicle for growth. Along with jobs created in the process, environmental and human impacts become additional indicators of success.

In the case study presented, coconut shell waste serves as an example of adding value to a former waste. Cagmanaba and Badian are rural seaside villages, and they do not have access to solid municipal waste recovery. Instead, these communities historically rely on burning the waste or piling it in back yards. When the wind blows, the waste is blown across the villages, leaving behind a rural landscape that seems far behind our time.

One last example from the case study in Cagmanaba highlights plastic waste. Plastic bottles, wrappers, and donated diapers all become mounds of waste in local backyards because the community does not have a way to process it. The traditional project-based development is the most common methodology used today. Donor agencies had intended disposable diapers for good, to help mothers modernize and improve sanitation. However, the good intentions left unintended consequences sure to be poorly managed by a community that does not have access to mechanisms for disposal of solid waste. Donor projects and charity-based solutions to single issues attempt to solve complex systems problems, but often their solutions do not last.

6.1 Contributions to Sustainable Community Development

This thesis presents the successful implementation of an early stage waste-to-resource systems approach to sustainable community development. Within the practice of sustainable community development, this research also presented a framework that demonstrates how agricultural waste from developing, rural communities can be transformed into engineered products. The promising result from the initial stages of this research is the commercialization of the waste-based polymeric composite by a multinational automotive company as well as the initial order from a specialty fillers company to use coconut shell powder in their blend. Additional capital has been raised by partners to continue to build the plant and provide cash flow for the CTP to become operational in processing coconut and its waste.

The key research question in the waste-to-resource framework is: ***What are the necessary steps are to create a highly efficient, successful model for sustainable rural community development utilizing agricultural waste?*** This overarching research question was answered by addressing a subset of specific questions summarized in Table 6-1. A brief discussion on the results and conclusions follow.

Table 6-1
Research Questions Addressed (review from chapter 1)

Question no.	Research area	Specific research questions that address gaps	Chapter	Keywords
1	Factors and conditions needed for community development to become sustainable in low-income countries.	What key indicators must be identified in a community for a waste-to-resource model to be successful?	3	Community Assessment (ICI) Case Study, Indicators
2	The global market for new technologies, such as waste-based composite materials.	What are the technical benefits of using coconut shell powder (CSP) in composite materials that could accelerate the use of valuable new products to disrupt rural poverty?	4	Technical Impact Environmental Impact Commercial Impact
3	Environmental impacts of natural resources, particularly the waste from plant and fruit crops, for a waste-to-resource transformation approach for SCD.	What are the likely environmental impacts of waste-to-resource transformation?		
4	Capturing all available value streams of the limited waste-to-resources solutions while equitably treating the people who are harvesting and working the waste stream.	What does it mean to be equitable and generous when using a waste-to-resources model as a systems approach to community development?	5	Human Impact Equity Dignity
5	Engineering-based micro-businesses where profits are shared.	How could the benefits be fairly shared among the various stakeholders?		

The waste-to-resource framework and model were tried through the course of this research and will continue to be tested in the communities of Badian and Cagmanaba in the Philippines over the coming years. As a result of beginning to use the coconut and its waste streams, community members have learned new manufacturing and technical skills for processing former waste, specifically coconut shell and fiber. It will, however, be years before the full impact of the model is evident. Nevertheless, lives are currently being improved as the community gains access to economic resources from the jobs created by the community transformation plant.

The safe reclamation and processing of agricultural waste also gives families access to clean drinking water, medical attention, education, and other community infrastructure enhancements. These benefits were unreachable when their rural livelihoods were subsistence farming, fishing, and infrequent casual employment. Economic development is the backbone of sustainable community development; when coupled closely with broadly distributed equity, it can drive lasting change. A closer look at sustainable community development shows that the complexity behind such a mission is best addressed by a systems-based approach.

The initial results from the beta study presented in this research are new technologies and manufacturing capabilities that have achieved successful product launches in global markets. Also, polymeric composites made in part with waste from coconut shell have (1) reduced the impact of plastics on the environment, (2) captured greater profits than if the material were unprocessed and remained in the community, and (3) introduced new jobs and skills into a community looking for such opportunities. By sharing profit and helping to manage its use wisely within the community, as discussed in chapter 5, the beta-level CTP has created some of the holistic benefits of true SCD. In sum, this work is beginning to build equity for the community while helping its members to develop globally competitive skills.

6.2 Lessons Learned

During the process of designing and testing the waste-to-resource framework, making a viable business case was found to be one of the most challenging hurdles. However, by combining engineering breakthroughs and carefully selecting the right product applications to launch, it has become possible to see some early stages of success. The waste-to-resource model works in part because it is a systems approach to a systems problem. It supplants one traditional form of development (i.e., charity) and makes way for a new approach where commerce and innovation pave the way to new opportunities. The waste-to-resource model works because it is based on the triple bottom line of sustainability—the three Es of Equity, Environment, and Economic opportunity, also known as the three Ps: People, Planet, and Profit.

The complexity of SCD is its greatest limitation. A community cannot simply go out, reclaim waste, and then sell it in the global marketplace. New skills have to be mastered and checks and balances need to be established to protect the vulnerability of the community with its newly acquired trade. Community members must also develop the wisdom and expertise to use profit in ways that truly enhance their dignity and that of others. Additionally, because of the compounding nature of rural poverty, complexity is further intensified. It became evident in the beta testing that multi-dimensional growth, including increasing the community's resiliency, was critical so that the model could flourish over the long run.

The engineering results of this waste-to-resource model show that coconut shell waste can be pulverized and added to polymeric composite materials. The addition of the coconut shell to composite materials strengthens and stiffens the base material. Due to the lower density of the coconut shell powder compared to other common fillers such as calcium carbonate or talc, the overall composite weight is reduced, thus reducing the environmental impact of the material. By the year 2025, the US Environmental Protection Agency will likely set 45 miles per gallon as the target that new cars must meet. Perhaps the most straightforward way to do this is by lowering the weight of the car.

Lighter composites are of great interest for a variety of applications, including automotive, consumer goods, and building materials. Engineers and materials scientists and businesses such as Essentium Materials can work together to achieve the best possible mechanical properties for composite products, setting the stage for increased commercial opportunities. The properties of the optimized bio-waste composite produced in this beta research compare favorably to specifications for global applications, allowing for broad use of the new material. The highest monetary value can be realized for the composite if the mechanical properties are an improvement over those of other conventional fillers. Next, manufacturing partners such as Dignity Products and Services have been shown to help communities gain employment and access to the technologies that are needed to process the former wastes.

Reclaiming coconut shell from the community waste stream and transforming it into a new resource reduces waste in the environment. From a sanitation viewpoint, this is a health and environmental improvement. The concave shape of a split coconut shell creates a natural water collector. In the tropics, with heavy rainfall and warm temperatures, coconuts are abundant. In this same region, mosquitoes and the diseases they carry multiply rapidly. Recovering and processing discarded coconut shells disrupts the breeding ground for many disease-carrying mosquitoes. This model helps to move the perspective towards waste-recovery equality and the need for processing of waste in ways that can benefit the community.

6.2.1 The social gospel: sustainable community development and the church. The final set of lessons learned came by exploring Judeo-Christian theology in regards to sustainable community development. The Christian church over the centuries has had as its biblical command to care for the oppressed and the financially poor (Luke 12:33). The results from the community survey showed that the communities' belief in God, and the importance of their pursuit of a relationship with God, was irrespective of any socioeconomic status. This finding is invaluable to this research and its application because the many of the various stakeholders formerly considered wealth to be equivalent to development, while now they also take into account what is demonstrated to be most valuable to the community.

In "Sustainability: The Five Core Principles," Michael Ben-Eli states that there are five core principles to sustainability, and he breaks sustainability into five domains: material, economic, life, social, and spiritual (2005). These five domains set the perspective for sustainable development to also take into account about the spiritual wellness of the community members. Sustainable development therefore encompasses more than just meeting the needs of the present without compromising the future. It is based on capacity, where the human's full potential to develop is a function of the environment's full capacity to sustain this growth.

6.2.2 Further implications. In sum, the original pre-implementation analysis, from a materials science and innovation viewpoint, showed that coconut waste was not effectively being utilized. The coconut wastes' mechanical properties were not being leveraged, nor were environmental and health benefits being realized. From a materials innovation and social entrepreneurship platform, the coconut waste material represents additional value-added opportunity, if viable products get developed for final applications. This research reveals that introducing a new, more profitable model could give rise to community tensions in unexpected areas.

The value proposition of a waste-to-resource product model and methodology could create marginalization and greed—from where there was once nothing, now suddenly trash has value. One of the most valuable lessons learned from the survey results was that potentially having more money concerned some community members. Specifically, the survey results showed that community members had fears of being robbed and of money bringing strife into the home. These results prove the importance of considering the unintended consequences before implementing the model. Even so, there may still be unpredictable factors that can affect the system.

Overall, the positive impacts and opportunities outweighed the concerns. In the end, the community felt a spirit of enterprise and conscientious capitalism as a result of using the model.

6.3 Recommendations and Future Work

Traditional project-based methods for community development have proven to be unsustainable. For example, developing communities are often in desperate need of clean water; however, installing a well for the community does not actually secure clean water for the community over a long time-horizon. The community will continue to rely on outside help to maintain the well.

What if community members instead had employment opportunities that increased their technical capacity? They would then be more able to generate the funds to maintain the well, proactively providing their own solution. Partner organizations may still be required to train and provide updated clean water solutions as new technology emerges, but the community could become financially and technically responsible for managing clean water production in time.

Sustainable community development includes clean water, health, sanitation, a thriving family environment, healthful nutrition, local and regional peace, stability, safety, spiritual foundations, and a livelihood that enhances dignity and respect for individuals and their families. It is not merely about earning more money from the coconut crop itself. True SCD is much more than money; it is about the quality of human life.

The waste-to-resource model must go further than the triple bottom line, defined by the three Ps as follows: People—providing jobs and equity, Planet—environmental stewardship by respecting the worth of materials and resources, Profit —wealth building, including more than just money. In terms of equity for people, there must be a move towards human sustainable development including building capacity and resiliency. This systems-based approach to sustainable development has demonstrated the potential of mitigating and disrupting rural poverty. Where a coconut shell once had almost zero value, through engineering and materials science the price can be raised to between $0.40–$1.20 per lb, depending on the process and optimization.

In order to maximize profits and be able to service a fast-paced global materials market, the ability to scale up is necessary. Documenting the pros and cons of increasing scale could represent ongoing and future work. Research could be conducted to analyze the effect of scaling up in a rural community. Modeling the future impact of development for years to come, including its effects on the community, would be of great benefit.

Additionally, introducing economic development into a community that was lacking even its basic infrastructure will affect the present and future systems. Therefore, the dynamics of changed levels of wealth in a community could be a follow-up thesis to this body of work. Continued research in the area of waste-to-resource transformation could investigate how much sustainable community development has taken place. It would be revealing to re-survey the Cagmanaba and Badian communities to hear their story at 2, 5, and 10 years into the model being in place.

In the end, engineering for waste-to-resource creation has demonstrated the potential to transform agricultural waste into composite materials. This system was modeled and tested in a community transformation plant (CTP) in Cagmanaba, Philippines. Successful implementation of this strategy can provide new opportunities to create CTPs in developing communities worldwide, each capitalizing on its own particular waste resource streams, helping to sustainably disrupt poverty cycles in developing communities.

In addition to the technical and environmental impacts and benefits of the waste-to-resource model are the human impacts. New composites derived from bio-waste such as coconut shell powder can be processed via holistic manufacturing. The technical, commercial, social, and environmental benefits make the platform truly disruptive. Economic development, built upon a model delivering human dignity as its main output, is shown to be the backbone of sustainable community development. When coupled closely with broad and fair distribution of stakeholder equity, SCD can drive lasting change.

REFERENCES

Adeyemi, A. S., Olorunfemi, J. F., & Adewoye, T. O. (2001). Waste scavenging in Third World cities : A case study in Ilorin, Nigeria. *Environmentalist, 21,* 93–96.

Adrados, A., de Marco, I., Caballero, B. M., López, A., Laresgoiti, M. F., & Torres, A. (2012). Pyrolysis of plastic packaging waste: A comparison of plastic residuals from material recovery facilities with simulated plastic waste. *Waste Management*, *32*, 826-832. doi:10.1016/j.wasman.2011.06.016

Ahmed, S. A. & Ali, S. M. (2006). People as partners: Facilitating people's participation in public–private partnerships for solid waste management. *Habitat International*, *30*, 781–796. doi:10.1016/j.habitatint.2005.09.004

Allen, C., Gokaldas, V., Larracas, A., Minot, L., Morin, M., Tangri, N., Tyler, B., & Walker, B. (2012). On the road to zero waste: Successes and lessons from around the world. Barcelona, Spain: Global Alliance for Incinerator Alternatives. Retrieved from http://no-burn.org/downloads/On%20the%20Road%20to%20Zero%20Waste.pdf

Allen, J., Jr. (2000). Key principles of liberation theology. *National Catholic Reporter, 36*(31), 16. Retrieved from http://natcath.org/NCR_Online/archives2/2000b/060200/060200i.htm

Amadei, B. & Wallace, W.A. (2009). Engineering for humanitarian development. *Technology and Society Magazine, 28*(4), 6-15.

Amplified Bible. (1987). Grand Rapids, MI: Zondervan.

Arancon, R. N., Jr. (2010). *Asian and Pacific Coconut Community.* Retrieved from www.apccsec.org

Aronson, D. (1996), Overview of systems thinking. Retrieved from http://www.thinking.net/Systems_Thinking/OverviewSTarticle.pdf

Ash, P. (2012). Food waste to resource in India. *BioCycle Magazine, 53*(7), 26-27. doi:10.1109/MTS.2009.934940

Ashokkumar, M., Narayanan, N. T., Gupta, B. K., Reddy, A. L. M., Singh, A. P., Dhawan, S. K., & Thanikaivelan, P. (2013). Conversion of industrial bio-waste into useful nanomaterials. *ACS Sustainable Chemistry & Engineering*, *1*, 619-626. doi:10.1021/sc3001564

Assis, C. (2014). Is Tesla the most important car company in the world? Morgan Stanley thinks so. *Marketwatch.* Retrieved from: http://blogs.marketwatch.com/energy-ticker/2014/06/19/is-tesla-the-most-important-car-company-in-the-world-morgan-stanley-thinks-so/

Baillie, C., Matovic, D., Thamae, T., & Vaja, S. (2011). Waste-based composites—poverty reducing solutions to environmental problems. *Resources, Conservation and Recycling, 55*, 973-978. doi:10.1016/j.resconrec.2011.05.006

Barkemeyer, R., Holt, D., Preuss, L., & Tsang, S. (2011). What happened to the "development" in sustainable development? Business guidelines two decades after Brundtland. *Sustainable Development, 22*, 15–32. doi:10.1002/sd.521

Barrientos, M. (2013). Coconut oil monthly price—US dollars per metric ton. Retrieved from ww.indexmundi.com/commodities/?commodity=coconut-oil

Becker, W. W. (2000). Neighbors in time: development and use of some values for intergenerational justice from the Jewish and Christian religious traditions. *Risk Analysis*: *An Official Publication of the Society for Risk Analysis*, *20*(6), 801–20. Retrieved from http://www.ncbi.nlm.nih.gov/pubmed/11314730

Bell, D. M. (2003). What gift is given? A response to Volf. *Modern Theology, 19*, 271–280. doi:10.1111/1468-0025.00221

Ben-Eli, M. (2005). Sustainability: The five core principles. Retrieved from http://www.sustainabilitylabs.org/page/sustainability-five-core-principles

Benítez, S. O., Lozano-Olvera, G., Morelos, R. A., & Vega, C. A. (2008). Mathematical modeling to predict residential solid waste generation. *Waste Management, 28, Supplement 1*, S7-S13. doi:10.1016/j.wasman.2008.03.020

Berkhout, F., Verbong, G., Wieczorek, A. J., Raven, R., Lebel, L., & Bai, X. (2010). Sustainability experiments in Asia: Innovations shaping alternative development pathways? *Environmental Science & Policy, 13*, 261–271. doi:10.1016/j.envsci.2010.03.010

Bernache, G. (2003). The environmental impact of municipal waste management: The case of Guadalajara metro area. *Resources, Conservation and Recycling, 39,* 223–237. doi:10.1016/S0921–3449(03)00029–6

Bernstein, J. (2004). *Toolkit: Social Assessment and Public Participation in Municipal Solid Waste Management.* Washington, DC: The World Bank.

Brasileiro, G. A. M., Vieira, J. A. R., Barreto, & L. S. (2013). Use of coir pith particles in composites with Portland cement. *Journal of Environmental Management, 131,* 228-238. doi:http://dx.doi.org/10.1016/j.jenvman.2013.09.046

Braun, W. (2002). The System Archetypes. Retrieved from http://www.albany.edu/faculty/gpr/PAD724/724WebArticles/sys_archetypes.pdf

Broitman, D., Ayalon, O., & Kan, I. (2012). One size fits all? An assessment tool for solid waste management at local and national levels. *Waste Management*, *32,* 1979–1988. doi:10.1016/j.wasman.2012.05.023

Buenrostro, O., Bocco, G., & Cram, S. (2001). Classification of sources of municipal solid wastes in developing countries. *Resources, Conservation and Recycling, 32,* 29–41. doi:10.1016/S0921–3449(00)00094-X

Burns, P. (1992). The problem of socialism in liberation. *Theological Studies; 53*, 493–516.

BYK Kometra GmbH. (2012). High Performance Polymer Modifier for the Plastic Industry. Retrieved from http://eltexco.com/resources/Kometra_product_overview_engl.pdf

Casiello, F. A., & Villarruel, J. M. (2011). The acceptance and progress in Argentina of multi-modal systems thinking for community development. *Systemic Practice and Action Research, 24,* 523–531. doi:10.1007/s11213-011-9205-9

C-Change. (2012). *Social Behavior Communication Toolkit.* Communication for Change. Retrieved from https://c-changeprogram.org/resources/sbcc-toolkit

Chalmin, P., Gaillochet, C. (2009). *From waste to resource: An abstract of "2006 World Waste Survey."* Paris, France: Veolia Environmental Services. Retrieved from http://www.agro.uba.ar/users/semmarti/RSU /From%20Waste%20to%20Resource.pdf

Chan, S., Huang, S. (2004). A systems approach for the development of a sustainable community—The application of the sensitivity model (SM). *Journal of Environmental Management, 72,* 133–47. doi:10.1016/j.jenvman.2004.04.003

Chan, Z. C. Y. (2011). How has liberation theology influenced my practice? *International Journal of Nursing Practice, 17,* 330–5. doi:10.1111/j.1440-172X.2011.01946.x

Chemtura. (2009). Polybond 3200 polymer modifier technical information sheet. Retrieved from www.chemtura.com

Cloutier, S., Jambeck, J., & Scott, N. (2014). The Sustainable Neighborhoods for Happiness Index (SNHI): A metric for assessing a community's sustainability and potential influence on happiness. *Ecological Indicators, 40,* 147–152. doi:10.1016/j.ecolind.2014.01.012

Cornwall, A., & Jewkes, R. (1995). What is participatory research *? Social Science and Medicine, 41,* 1667-76. Retrieved from http://www.ncbi.nlm.nih.gov/pubmed/8746866

Corscadden, K. W., Biggs, J. N., & Stiles, D. K. (2014). Sheep's wool insulation: A sustainable alternative use for a renewable resource? *Resources, Conservation and Recycling, 86,* 9–15. doi:10.1016/j.resconrec.2014.01.004

Da Cruz, N. F., Simões, P., & Marques, R. C. (2012). Economic cost recovery in the recycling of packaging waste: The case of Portugal. *Journal of Cleaner Production, 37,* 8-18. doi:http://dx.doi.org/10.1016/j.jclepro.2012.05.043

Davis, G. & Song, J. H. (2006). Biodegradable packaging based on raw materials from crops and their impact on waste management. *Industrial Crops and Products*, *23*(2), 147–161. doi:10.1016/j.indcrop.2005.05.004

De Graaf, H. J., Noordervliet, M. a. W., Musters, C. J. M., & de Snoo, G. R. (2009). Roadmap for interactive exploration of sustainable development opportunities: The use of simple instruments in the complex setting of bottom-up processes in rural areas. *Land Use Policy, 26,* 295–307. doi:10.1016/j.landusepol.2008.03.006

Deakin, M. (2011). Meeting the challenge of learning from what works in the development of sustainable communities. *Sustainable Cities and Society, 1,* 244–251. doi:10.1016/j.scs.2011.07.006

DiDero, M. (2012). Cairo's informal waste collectors: A multi-scale and conflict sensitive perspective on sustainable livelihoods. *Erdkunde, 66,* 27–44.

Dignity Products and Services. (2013). Retrieved from http://dignitycoco.com

Dos Santos, R. M., Flauzino Neto, W. P., Silverio, H. A., Martins, D. F., Dantas, N. O., & Pasquini, D. (2013). Cellulose nanocrystals from pineapple leaf, a new approach for the reuse of this agro-waste. *Industrial Crops and Products, 50,* 707-714. doi:10.1016/j.indcrop.2013.08.049

Durbin, D. (2014). Auto industry gets serious about lighter materials. *Research and Development Magazine*, 1–4. Retrieved from http://www.rdmag.com/news /2014/06/auto-industry-gets-serious-about-lighter-materials

Eco-Cycle. (2011). About us. Retrieved from http://ecocycle.org/aboutus.

Fahmi, W. S. (2005). The impact of privatization of solid waste management on the Zabaleen garbage collectors of Cairo. *Environment and Urbanization*, *17*(2), 155–170. doi:10.1177/095624780501700212

Faruk, O., Bledzki, A. K., Fink, H., & Sain, M. (2012). Biocomposites reinforced with natural fibers: 2000–2010. *Progress in Polymer Science, 37,* 1552–1596. doi:10.1016/j.progpolymsci.2012.04.003

Freeman, E. (2012) Conscious culture. Retrieved from http://www.consciouscapitalism.org/purpose

García, D., López, J., Balart, R., Ruseckaite, R. A., & Stefani, P. M. (2007). Composites based on sintering rice husk–waste tire rubber mixtures. *Materials &* Design*, 28,* 2234–2238. doi:10.1016/j.matdes.2006.06.001

Giovannini, M. (2012). Social enterprises for development as *buen vivir*. *Journal of Enterprising Communities: People and Places in the Global Economy, 6,* 284–299. doi:10.1108/17506201211258432

Gutiérrez, G. (1990).Toward a theology of liberation. In: Hennelly, A. T. (Ed.), *Liberation Theology: A Documentary History* (pp. 67-69)*.* Maryknoll, NY: Orbis Books.

Hennelly, A. (1990). *Liberation Theology: A Documentary History,* (p. 335)*.* Maryknoll, NY: Orbis Book.

Ho, M., Wang, H., Lee, J., Ho, C., Lau, K., Leng, J., & Hui, D. (2012). Critical factors on manufacturing processes of natural fibre composites. *Composites Part B: Engineering, 43*, 3549–3562. doi:10.1016/j.compositesb.2011.10.001

Hoffmire, J. & Young, B. (2014, June 9). Wage economy vs. employee ownership economy. *Deseret News.* Retrieved from http://www.deseretnews.com/article/865604778/Wage-economy-vs-employee-ownership-economy.html?pg=all

Hogt, A. (1988). Modification of polypropylene with maleic anhydride. *ANTEC '88 Proceedings*.

Hoornweg, D., & Bhada-Tata, P. (2012). *What a waste: A global review of solid waste management.* Washington, D.C.: The World Bank. Retrieved from http://web.worldbank.org/WBSITE/EXTERNAL/TOPICS/EXTURBANDEVELOPMENT/0,,contentMDK:23172887~pagePK:210058~piPK:210062~theSitePK:337178,00.html

Ibrahim, M. M., El-Zawawy, W. K., Juettke, Y., Koschella, A., & Heinze, T. (2013). Cellulose and microcrystalline cellulose from rice straw and banana plant waste: Preparation and characterization. *Cellulose, 20,* 2403-2416. doi:10.1007/s10570-013-9992-5

Imam, A., Mohammed, B., Wilson, D. C., & Cheeseman, C. R. (2008). Solid waste management in Abuja, Nigeria. *Waste Management, 28*, 468–472. doi:10.1016/j.wasman.2007.01.006

IOMVM (International Organization of Motor Vehicle Manufacturers). (2013). Cars produced this year. *Worldometer.* Retrieved from www.worldometers.info/cars

Jiang, Y., Marang, L., Tamis, J., van Loosdrecht, M. C. M., Dijkman, H., & Kleerebezem, R. (2012). Waste to resource: Converting paper mill wastewater to bioplastic. *Water Research, 46,* 5517-5530. doi:http://dx.doi.org/10.1016/j.watres.2012.07.028

Jorgetto, A. O., Silva, R. I. V., Saeki, M. J., Barbosa, R. C., Martines, M. A. U., Jorge, S. M. A., & Castro, G. R. (2014). Cassava root husks powder as green adsorbent for the removal of cu(II) from natural river water. *Applied Surface Science, 288,* 356-362. doi:10.1016/j.apsusc.2013.10.032

Juwana, I., Muttil, N., & Perera, B. J. C. (2012). Indicator-based water sustainability assessment - a review. *The Science of the Total Environment, 438,* 357–71. doi:10.1016/j.scitotenv.2012.08.093

Karamchandani, A., Kubzansky, M., & Frandano, P. (2009). *Emerging Markets, Emerging Models: Market-based solutions to the challenges of global poverty.* Mumbai: Monitor Group. Retrieved from http://www.mim.monitor.com/index.html

Karian, H. G., Preston, J., Hopkins, A. (2011). Comparative life cycle assessment (LCA) of bio-fibers, mineral and glass fiber reinforced polypropylene composites. Society of Plastics Engineers - Global Plastics Environmental Conference 2011.

Karunasena, G., Amaratunga, D., Haigh, R., & Lill, I. (2009). Post disaster waste management strategies in developing countries: Case of Sri Lanka. *International Journal of Strategic Property Management, 13*, 171–190.

Kim, H. S., Lee, B. H., Choi, S. W., Kim, S., & Kim H. J. (2007). The effect of types of maleic anhydride-grafted polypropylene (MAPP) on the interfacial adhesion properties of bio-flour-filled polypropylene composites. *Composites: Part A, 38,* 1473-1482.

Kofoworola, O. F. (2007). Recovery and recycling practices in municipal solid waste management in Lagos, Nigeria. *Waste Management, 27*, 1139-1143. doi:10.1016/j.wasman.2006.05.006

Lacey, S. (2012, June 24). Waste expert: 'it's madness' that waste isn't a bigger international priority. *Nation of Change.* Retrieved from http://www.nationofchange.org/waste-expert-it-s-madness-waste-isn-t-bigger-international-priority-1340548396

Lawson-Remner, T. (2013, August 12). Rethinking the meaning of development. *Development Channel.* Council on Foreign Relations. Retrieved from blogs.cfr.org/development-channel/2013/08/12/rethinking-the-meaning-of-development/

Lebel, L., Mungkung, R., Gheewala, S. H., & Lebel, P. (2010). Innovation cycles, niches and sustainability in the shrimp aquaculture industry in Thailand. *Environmental Science & Policy, 13,* 291–302. doi:10.1016/j.envsci.2010.03.005

Lee, S. (1990). Solid phase graft copolymerization: Effect of interfacial agent. *Journal of Applied Polymer Science, 41,* 1891-1894.

Li, G., Stubblefield, M. A., Garrick, G., Eggers, J., Abadie, C., & Huang, B. (2004). Development of waste tire modified concrete. *Cement and Concrete Research, 34,* 2283–2289. doi:10.1016/j.cemconres.2004.04.013

Litonjua, M. D. (1998). *Liberation Theology: The Paradigm Shift.* Lanham, MD, USA: University Press of America.

Mahr, K. (2012, December 5). Why the coconut craze isn't helping farmers: Americans are demanding all-things-coconut, but it's unclear how the boom will benefit farmers in foreign countries. *Time.* Retrieved from http://business.time.com/2012/12/05/why-the-coconut-craze-isnt-helping-farmers/

Mayer, A. L. (2008). Strengths and weaknesses of common sustainability indices for multidimensional systems. *Environment International, 34,* 277–91. doi:10.1016/j.envint.2007.09.004

McCornack, A. (2012). Strengthening local governance through effective waste management : The " Sustainable Environmental Practices and Policies " program in South Lebanon and the Bekaa Valley. *Consilience: The Journal of Sustainable Development, 8,* 188–199. Retrieved from http://www.consiliencejournal.org/index.php/consilience/article/viewFile/278/124

Meadows, D. (1999). *Leverage Points Places to Intervene in a System.* Norwich, VT: Donella Meadows Institute.

Meadows, D. (2008). *Thinking in Systems: A Primer.* White River Junction, VT: Chelsea Green Publishing.

Medina, M. (2000). Scavenger cooperatives in Asia and Latin America. *Resources, Conservation and Recycling, 31,* 51–69. doi:10.1016/S0921–3449(00)00071–9

Mohamad, Z. F., Idris, N., & Mamat, Z. (2012). Role of religious communities in enhancing transition experiments: a localised strategy for sustainable solid waste management in Malaysia. *Sustainability Science, 7,* 237–251. doi:10.1007/s11625-012-0169-1

Mori, K., & Christodoulou, A. (2012). Review of sustainability indices and indicators: Towards a new City Sustainability Index (CSI). *Environmental Impact Assessment Review, 32,* 94–106. doi:10.1016/j.eiar.2011.06.001

Noel, C. (2010). Solid waste workers and livelihood strategies in greater Port-au-Prince, Haiti. *Waste Management, 30*, 1138–1148. doi:10.1016/j.wasman.2010.01.029

Onyx, J., & Bullen, P. (2000). Measuring social capital in five communities. *The Journal of Applied Behavioral Science, 36,* 23–42. doi:10.1177/0021886300361002

Oosterveer, P. (2009). Urban environmental services and the state in East Africa; between neo-developmental and network governance approaches. *Geoforum, 40,* 1061-1068. doi:10.1016/j.geoforum.2009.08.009

Pasang, H., Moore, G. a, & Sitorus, G. (2007). Neighbourhood-based waste management: a solution for solid waste problems in Jakarta, Indonesia. *Waste Management, 27,* 1924–38. doi:10.1016/j.wasman.2006.09.010

Peredo, A. M., & Chrisman, J. J. (2006). Toward a theory of community-based enterprise. *The Academy of Management Review, 31,* 309–328. Retrieved from http://www.jstor.org /discover/10.2307/20159204?uid=3739704&uid=2&uid=4&uid=3739256&sid=21 104341398157

Philippe, F., & Culot, M. (2009). Household solid waste generation and characteristics in Cap Haitien city, Republic of Haiti. *Resources, Conservation and Recycling, 54,* 73–78. doi:10.1016/j.resconrec.2009.06.009

Rashid, A., Asif, F. M. A., Krajnik, P., & Nicolescu, C. M. (2013). Resource conservative manufacturing: An essential change in business and technology paradigm for sustainable manufacturing. *Journal of Cleaner Production, 57,* 166-177. doi:10.1016/j.jclepro.2013.06.012

Razzaq, A. R. A., Mohamad, N. H., A.Kader, S. S. S., Mustafad, M. Z., Ab.Hadi, M. Y., Hamzah, A., & Khalifah, Z. (2013). Developing human capital for rural community tourism: Using experiential learning approach. *Procedia - Social and Behavioral Sciences, 93,* 1835–1839. doi:10.1016/j.sbspro.2013.10.126

Rengarajan, R., Vicic, M., & Lee, S. (1990). Solid phase graft copolymerization. I. Effect of initiator and catalyst. *Journal of Applied Polymer Science, 39,* 1783-1791.

Richmond, B. (1993). Systems thinking: Critical thinking skills for the 1990s and beyond. *System Dynamics Review, 9,* 113–133. doi:10.1002/sdr.4260090203

Richmond, B. (1994). Systems thinking/system dynamics: Let's just get on with it. *System Dynamics Review, 10,* 135–157. doi:10.1002/sdr.4260100204

Richmond, B. (2002). *Introduction to Systems Thinking, STELLA.* Iseesystems.com. Retrieved from http://www.iseesystems.com/resources/Articles/STELLAIST(ch1).pdf

Robinson, S. C., Tudor, D., MacDonald, G., Mansourian, Y., & Cooper, P. A. (2013). Repurposing mountain pine beetle blue wood for art through additional fungal colonization. *International Biodeterioration & Biodegradation, 85,* 372-374.

Rowland, C. (2007). *The Cambridge Companion to Liberation Theology.* Cambridge: Cambridge University Press.

Sardinha, I. D., Craveiro, D., & Milheiras, S. (2013). A sustainability framework for redevelopment of rural brownfields: stakeholder participation at SÃO DOMINGOS mine, Portugal. *Journal of Cleaner Production, 57,* 200–208. doi:10.1016/j.jclepro.2013.05.042

Schneider, J., Leydens, J. a., & Lucena, J. (2008). Where is "Community"?: Engineering education and sustainable community development. *European Journal of Engineering Education, 33,* 307–319. doi:10.1080/03043790802088640

Schneider, J., Lucena, J., & Leydens, J. a. (2011). Making the human dimensions of sustainable community development visible to engineers. *Proceedings of the ICE - Engineering Sustainability, 164,* 13–23. doi:10.1680/ensu.1000014

Sclavons, M., Carlier, V., DeRoover, B., Franquinet, P., Devaux, J., & LeGras, R. (1998). The Anhydride Content of Some Commercial PP-g-MA: FTIR and Titration*. Journal of Applied Polymer Science, 62,* 1205-1210.

Sembiring, E., & Nitivattananon, V. (2010). Sustainable solid waste management toward an inclusive society: Integration of the informal sector. *Resources Conservation and Recycling, 54,* 802–809. doi:10.1016/j.resconrec.2009.12.010

Shia, D., Yang, J., Yao, Z., Wang, Y., Huang, H., Jing, W., Yin, J., & Costa, G. (2001). Functionalization of isotactic polypropylene with maleic anhydride by reactive extrusion: mechanism of melt grafting. *Polymer, 42,* 5549-5557. Retrieved from http://www.sciencedirect.com/science/article/pii/S0032386101000696

Sianipar, C. P. M., Yudoko, G., Adhiutama, A., & Dowaki, K. (2013). Community empowerment through appropriate technology: Sustaining the sustainable development. *Procedia Environmental Sciences, 17,* 1007–1016. doi:10.1016/j.proenv.2013.02.120

Singh, R. K., Murty, H. R., Gupta, S. K., & Dikshit, a. K. (2009). An overview of sustainability assessment methodologies. *Ecological Indicators, 9,* 189–212. doi:10.1016/j.ecolind.2008.05.011

Starling, V. (2010). *Faith-based Social Venture Enterprise: A Model for Financial Sustainability.* ProQuest: Walden University.

Stone, W. (2001). Measuring social capital and community: life towards a theoretically informed measurement framework for researching social capital in family and community life. Melbourne, Australia: Australian Institute of Family Studies. doi:ISSN 1440-4761

Sullivan, D. (2011, July). Zero waste on San Francisco's horizon. *BioCycle Magazine*, *28*. Retrieved from http://www.biocycle.net/2011/07/18/zero-waste-on-san-franciscos-horizon/

Szitar, M.A. (2014). Learning about sustainable community development. *Procedia - Social and Behavioral Sciences, 116,* 3462–3466. doi:10.1016/j.sbspro.2014.01.784

Taylor, B. (2004). A green future for religion? *Futures, 36,* 991–1008. doi:10.1016/j.futures.2004.02.011

Teipel, E., Conroy, S., & Bradley, W. (2011). Polymeric composites reinforced with natural powders and fibers from renewable resource by-products / agricultural waste. Society of Plastics Engineers International Polyolefin Conference, Houston, TX. Available from the author.

Teipel, E., Kirby, M., Conroy, S., & Teipel, B. (2013). Optimization of natural functional fillers created from bio-waste in polymeric composites using coconut shell powder and MAPP Scona. Society of Plastics Engineers International Polyolefin Conference, Houston, TX. Available from the author.

Tellus Institute. (2011). *More jobs, less pollution: Growing the recycling economy in the U.S.* (Business).Tellus Institute with Sounds Resource Management. Retrieved from http://docs.nrdc.org/globalwarming/files/glo_11111401a.pdf

Tesla Motor Co. (2014). Tesla Motor Company. Retrieved from: http://www.teslamotors.com/ on 6/19/14

Thamae, T., Marien, R., Chong, L., Wu, C., & Baillie, C. (2008). Developing and characterizing new materials based on waste plastic and agro-fibre. *Journal of Materials Science, 43*, 4057–4068. doi:10.1007/s10853-008-2495-3

Thorneloe, S. A., Weitz, K., & Jambeck, J. (2007). Application of the US decision support tool for materials and waste management. *Waste Management*, *27*(8), 1006–20. doi:10.1016/j.wasman.2007.02.024

Tourism In the Philippines. (2008). Philippine Jeepney. http://www.tourisminthephilippines.com/transport/jeepney/philippine-jeepney-history.html retrieved 9/2013

Tremblay, C., Gutberlet, J., & Peredo, A. M. (2010). United we can: Resource recovery, place and social enterprise. *Resources Conservation and Recycling, 54*, 422–428. doi:10.1016/j.resconrec.2009.09.006

Troschinetz, A. M., & Mihelcic, J. R. (2009). Sustainable recycling of municipal solid waste in developing countries. *Waste Management, 29,* 915–23. doi:10.1016/j.wasman.2008.04.016

UNCTAD. (2012). Commodity Profile—Coconut. *United Nations Conference on Trade and Development (UNCTAD)*. Retrieved March 03, 2014, from http://www.unctad.info/en/Infocomm/AACP-Products/COMMODITY-PROFILE---Coconut2/

UNDP. (2011). *Summary: Human development report 2011—Sustainability and equity: A better future for all.* New York, NY: United Nations Development Programme.

US EPA, United States Environmental Protection Agency. (2012, November 15). Municipal solid waste. Retrieved from http://www.epa.gov/epawaste/nonhaz/municipal/index.htm

USAID. (2013). Grand Challenges. Retrieved from http://www.usaid.gov/grandchallenges

USFA, United Sludge-Free Alliance. (2013). Farm risks and issues. Retrieved 5/20, 2013, from http://www.usludgefree.org/risk.html

Vandevall, T. (2013). Blank fishbone diagram template and cause and effect graphic organizer. Dutch Renaissance Press. Retrieved from http://timvandevall.com/fishbone-diagram-template/

Vitali, F., Parmigiani, S., Vaccari, M., & Collivignarelli, C. (2013). Agricultural waste as household fuel: Techno-economic assessment of a new rice-husk cookstove for developing countries. *Waste Management*, *33*, 2762-2770. doi:10.1016/j.wasman.2013.08.026

Volf, M. (2003). Liberation theology after the end of history: An exchange. *Modern Theology; 9,* 261–269.

Wallace, B. (2005). In ACEC (Ed.), *Becoming part of the solution: The engineer's guide to sustainable development* (p. 39). Washington, DC: American Council of Engineering Companies.

Warner, J. F. (2006). More sustainable participation? Multi-stakeholder platforms for integrated catchment management. *International Journal of Water Resources Development*, *22*, 15–35. doi:10.1080/07900620500404992

Wible, B. (2012). Rio+20. Science for sustainable development. *Science, 336(6087),* 1396. doi:10.1126/science.1223968

Wilson, D. C., Velis, C., & Cheeseman, C. (2006). Role of informal sector recycling in waste management in developing countries. *Habitat International, 30,* 797–808. doi:10.1016/j.habitatint.2005.09.005

Zaccai, E. (2012). Over two decades in pursuit of sustainable development: Influence, transformations, limits. *Environmental Development, 1,* 79-90. doi:http://dx.doi.org/10.1016/j.envdev.2011.11.002

APPENDIX A

Survey Questionnaire

Waste

1. What is useless and could be considered waste?
   Ano ang hindi na mapapakinabangan at dapat ituring na basura?

2. Do you see something when you look around here that you think is not being used well?
   May nakikita ka ba sa paligid na sa tingin mo ay hindi napapakinabangan ng maayos?

3. Do you have anything that you could make better use of?
   Meron ka bang bagay na nakikita na sa tingin mo ay mas mapapakinabangan pa?

4. Currently what happens to waste in the community?
   Sa ngayon, ano ang ginagawa ninyo sa basura sa komunidad?

Material Resources

5. What could be done with the waste in the community?
   Ano ang pwede gawin sa basura dito sa komunidad.

6. Do you think it would be a good idea to reclaim waste in the community to create new materials?
   Sa inyong palagay, mabuti bang ibalik sa maayos na kalagayan ang basura sa komunidad para makagawa ng bagong mga materyales?

7. How could new materials created from waste help the community, and specifically your family?
   Paano makakatulong sa komunidad, at higit sa lahat sa inyong pamilya, ang pag gawa ng mga bagong materyales mula sa basura?

Building Resources and Legacy in a Community

8. What does it mean to you to be rich or to have financial resources?
   Para sa iyo, ano ang ibig sabihin ng pagiging mayaman o pagkakaroon ng salapi o kayamanan?

9. If you had more resources such as money, what would you do with it?
   Kung meron kang mas madaming kayamanan tulad ng pera, ano ang gagawin mo dito?

10. Does having more money bring problems?
    Ang pagkakaroon ba ng madaming pera ay nagdudulot ng mga problema?

11. What types of problems does more money bring?
    Anong klaseng mga problema ang nadudulot ng pagkakaroon ng madaming pera?

12. Is there anything that you think could make (Cagmanaba or Badian) better?
    Meron ka bang naiisip na bagay na pwedeng gawin para sa ikabubuti ng Cagmaba o Badian?

Waste to Resource Survey: Staff Questions in English

These questions are asked only to the staff members of Dignity Products and Services because the researcher wants to better understand the viewpoints of the partners on the ground in Cagmanaba and Badian, Philippines. Answers will help researcher backup the waste-to-resource framework. The questions are asked in English and translation is not necessary as there are only 5-10 staff members all of which speak English fluently.

1. What are key indicators identified for a waste-to-resource model to be successful in a community in order for a success?

2. What are environmental impacts of waste-to-resource transformation?

3. What is equity using a waste-to-resources model?

4. What are techniques for profit sharing-benefits between the various stakeholders?

5. In Community Development how do you define success and failures? What have you seen work? What has not worked?

APPENDIX B

Definitions, Acronyms, and Abbreviations

BCC: Behavior Change Communication

BYK Scona® 8112: solid phase grafted MAPP

CSP: a coconut shell powder based natural reinforcement

CTP: Community Transformation Plant

embodied energy: a summation of all the energy required to manufacture a material or final product

MAPP: Maleic Anhydride Polypropylene

MG: Melt Grafted

PAR: Participatory Action Research

PP: polypropylene

Polybond® 3200: melt grafted MAPP

SCD: Sustainable Community Development

SPG: Solid Phase Grafted

SWOT: Strengths, Weaknesses, Opportunities, Threats

total MA content: total maleic anhydride grafted content

W2R: Waste to Resource

APPENDIX C

IRB Protocol Exemption

Institutional Review Board
563 UCB
Boulder, CO 80309
Phone: 303.735.3702
Fax: 303.735.5185
FWA: 00003492

APPROVAL

15-May-2014

Dear Elisa Teipel,

On **15-May-2014** the IRB reviewed the following protocol:

Type of Submission:	Initial Application
Review Category:	Exempt - Category 2
Title:	Identifying Waste in Communities to Assist in Modeling a Waste-to-Resource Framework.
Investigator:	Teipel, Elisa
Protocol #:	14-0275
Funding:	None
Documents Approved:	14-0275 Protocol (15May14);
Documents Reviewed:	Local Review Letter; HRP-211: FORM - Initial Application;

The IRB approved the protocol on **15-May-2014**.

Click the link to find the approved documents for this protocol: Approved Documents. Use copies of these documents to conduct your research.

In conducting this protocol you must follow the requirements listed in the INVESTIGATOR MANUAL (HRP-103).

Sincerely,
Douglas Grafel
IRB Admin Review Coordinator
Institutional Review Board

APPENDIX D

PowerPoint Summary Slides

Elisa Teipel's selected slides from her dissertation defense on July 7, 2014 are appended following this page.

Civil, Environmental, and Architectural Engineering
UNIVERSITY OF COLORADO BOULDER

Mortenson Center in Engineering for Developing Communities

From Waste-to-Resource:

A Systems-Based Approach to Sustainable Community Development

through equitable enterprise and agricultural waste-based polymeric composites

Elisa Guzman Teipel
Final Examination
Monday July 7th, 2014

Partners and Research Sponsors

Civil, Environmental, and Architectural Engineering
UNIVERSITY OF COLORADO BOULDER

Mortenson Center in Engineering for Developing Communities

DIGNITY PRODUCTS&SERVICESINC.

National Science Foundation
WHERE DISCOVERIES BEGIN

GDC, INC.

ESSENTIUM
Building the next generation of essential materials

Elisa Teipel Dissertation Defense 7/7/14 2

Acknowledgements

- Research Committee:
  - Dr. Bernard Amadei
  - Dr. Walter Bradley
  - Dr. Don Byker
  - Dr. Paul Chinowsky
  - Dr. Rita Klees
  - Dr. Sarah Sterling

- My undergraduate professors that helped my engage in engineering and purse the career with passion:
  - Dr. Bryan Willson and Dr. Omnia El-Hakim

- My Family:
  - My husband Blake, Dad Rey, Mom Brenda, Sister Rosemary and grandmothers

Elisa Teipel Dissertation Defense 7/7/14 3

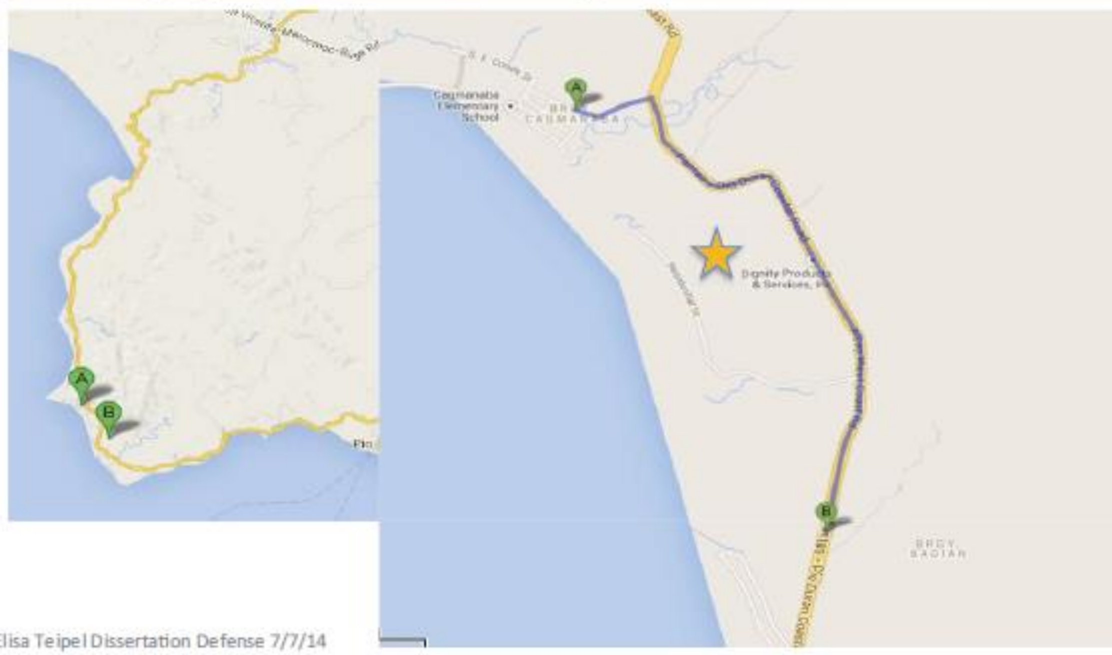
Outline: From Waste-to-Resource

Elisa Teipel Dissertation Defense 7/7/14 4

Case study location: Luzon Island – Philippines

Elisa Teipel Dissertation Defense 7/7/ 5

Barangays Badian and Cagmanaba



Elisa Teipel Dissertation Defense 7/7/14 6

Framework: Observed Problem

Rural communities in developing countries often require repeated infusions of charitable aid.

Despite various attempts to solve this problem, a lingering question remains: how can community development become sustainable in low- and middle-income countries?

Solution:

Sustainable community development can materialize through economic development when a **robust framework combines engineering solutions** with the **generous investment of profits back into the community**.

What are the steps necessary to create a highly efficient, successful model for sustainable rural community development utilizing agricultural waste?

Elisa Teipel Dissertation Defense 7/7/14 8

No.	Research Area	Specific Research Questions that Address Gaps	Chp	Keywords
1	There is little research on factors/conditions needed for community development to become sustainable in low- income countries.	What key indicators must be identified in a community for a waste-to-resource model to be successful?	3	Community Assessment (ICI); Case Study, Indicators
2	The global market is open and looking for new technologies such as waste-based composite materials.	What are the technical benefits of using coconut shell powder (CSP) in composite materials that could accelerate the use of valuable new products to disrupt rural poverty?	4	Technical Impact Environmental Impact Commercial Impact
3	Environmental impacts are not well documented for a waste-to-resource transformation approach for SCD. Natural resources, particularly the waste from plant and fruit crops, are available and accessible in developing communities.	What are the likely environmental impacts of waste-to-resource transformation?		
4	There are limited waste-to-resources solutions that capture all available value streams while equitably treating the people who are harvesting and working the waste stream.	What does it mean to be equitable and generous when using a waste-to-resources model as a systems approach to community development?	5	Human Impact: Equity, Dignity
5	Engineering-based micro-businesses where profits are shared are limited.	How could the benefits be fairly shared among the various stakeholders?		

Elisa Teipel Dissertation Defense 7/7/14 9

No.	Research Area	Specific Research Questions that Address Gaps	Chp	Keywords
1	There is little research on factors/conditions needed for community development to become sustainable in low- income countries.	What key indicators must be identified in a community for a waste-to-resource model to be successful?	3	Community Assessment (ICI); Case Study, Indicators
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Elisa Teipel Dissertation Defense 7/7/14 10

No.	Research Area	Specific Research Questions that Address Gaps	Chp	Keywords
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5	Engineering-based micro-businesses where profits are shared are limited.	How could the benefits be fairly shared among the various stakeholders?		

Framework: Sustainable Community Development

The concepts of sustainability, sustainable development, and human development are mentioned several times in this dissertation. The following definitions have been adopted:

1. The Brundtland Commission Report contends development is "stable" when: "The needs of the present are met without compromising the ability of future generations to meet their own needs" (1987).

2. In "Sustainability: The Five Core Principles," Michael Ben-Eli suggests that there are five core principles to sustainability (2005):

He defines Sustainability as: "A dynamic equilibrium in the processes of interaction between a population and the carrying capacity of an environment, such that the population develops to express its full potential without adversely and irreversibly affecting the carrying capacity of the environment upon which it depends" (2005).

3. According to a recent Human Development Report (UNDP Human Development Report , 2011): Human development is the fundamental framework that promotes the expansion of people's freedoms and ability to "lead lives that they value and have reason to value. It's about expanding choices" (UNDP Human Development Report , 2011).

Framework: Systems Thinking

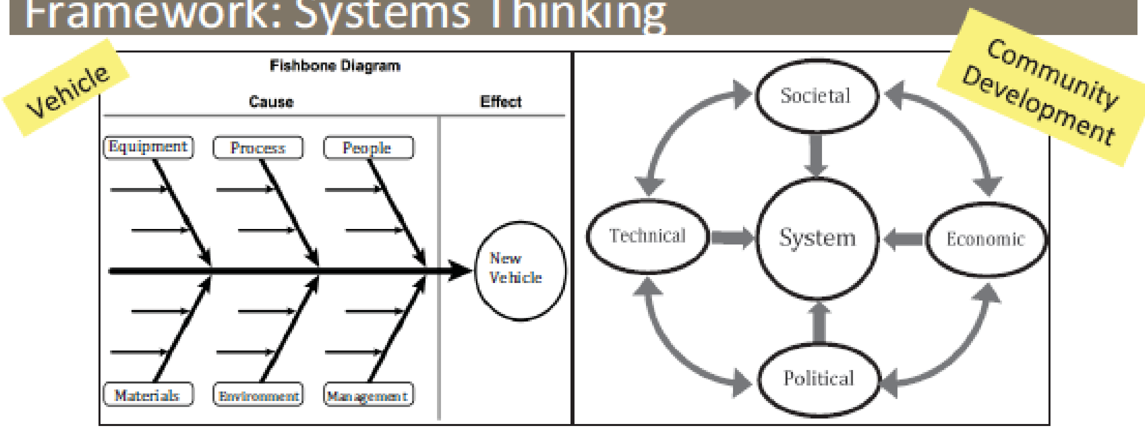


Figure 1-1: Complicated system (via Fishbone, or Ishikawa Diagram) [LEFT] (Vandevall, 2013); Complex system diagram [RIGHT].

A system organizes its elements in a **contextual, interwoven manner**. Analyzing **interconnection between** the parts helps **capture the complexity** that has to be addressed when trying to solve a **systems problem such as poverty.**

Elisa Teipel Dissertation Defense 7/7/14 13

Waste-to-Resources Framework for Sustainable Community Development

	Method	Action	Description	
Community Assessments, Case Study and Indicators	Stakeholder Assessment	SWOT analysis	Strengths, weaknesses, opportunities, threats Review capacity and vulnerability	Chapter 3
		Stakeholder identification and recruitment	Roles and responsibilities within partnerships	
	Primary and Secondary Data Collection	Collect primary and secondary data for all categories in the community assessment	Location	
			Education and livelihood	
			Governance	
			Vulnerability to natural disasters	
			Infrastructure	
			Family structure	
			Capacity and resiliency	
	Community Survey	Conduct and administer questionnaire	Waste questions	
			Resources questions	
			Legacy questions	
	Materials Assessment	Identify materials	Investigate what is available in the area through community survey – link to possible materials science applications	
	Causal Analysis	Problem tree	Map problems in community	
	Model and Transform the Waste Stream	In partnership with Community Transformation Plant (CTP), begin transforming waste.	Process waste stream and begin assessment. STELLA Model	
	Indicators for Success	Review partners, indicators and impacts	All stakeholders, infrastructure, Governance, logistics, materials, technical, environmental, and human	

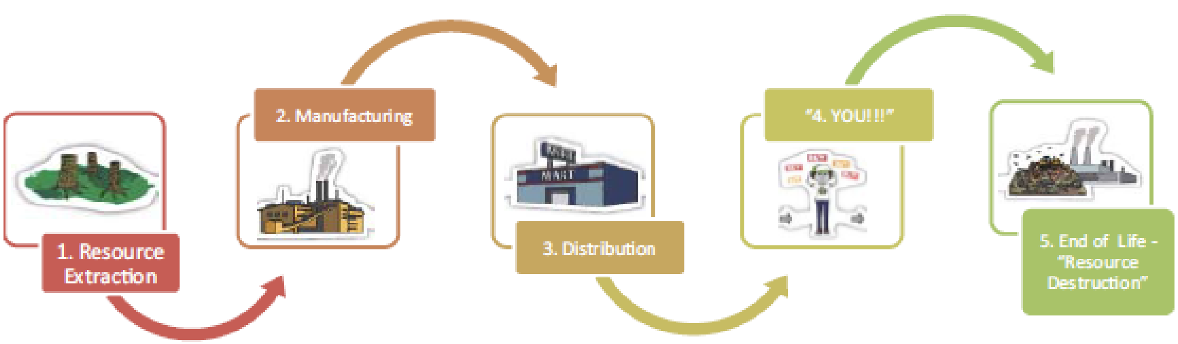
Elisa Teipel Dissertation Defense 7/7/14 14

Waste-to-Resources Framework for Sustainable Community Development

	Method	Action	Description	
Enterprise Impact Factors	Technical Assessments	Measure technical Impact	Material and mechanical property validation	Chapter 4
	Environmental Assessment	Measure environmental impact	Embodied energy calculations	
	Commercial Assessment	Sell initial waste product to client	Work with partner companies (product sales)	
Human Impact Factors	Human Assessment	Measure human impact	Review community impact	Chapter 5
	Profit sharing	Build equity in community, sharing profits from waste-to-resource sales	Monthly giving-match Employee Shareholder 401k, continuing education, Community Revitalization Projects, Livelihood programs, etc.	

Elisa Teipel Dissertation Defense 7/7/14 15

Literature: Current Examples



Scavengers & waste-pickers:

- Zabaleen *Egypt*
- Cartoneros *Argentina*
- Binners *Canada, Europe*

Elisa Teipel Dissertation Defense 7/7/14 http://ecocycle.org/zerowaste/overview 16

Literature: Waste Composition

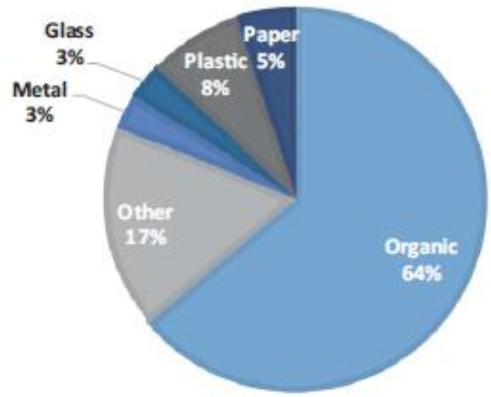


Figure 2-1: Low-income country waste composition. (World Bank Report, "What a Waste: A Global Review to Municipal Solid Waste" 2012

Waste in the Barangay


Outline: From Waste-to-Resource
Waste-to-Resource
Introduction
Framework
Literature Review
Community Assessment
Material Creation
Equity
Conclusions
Elisa Teipel Dissertation Defense 7/7/14
19


Waste? Or Resource?
Elisa Teipel Dissertation Defense 7/7/14
20

Question (1): What is useless and could be considered waste?

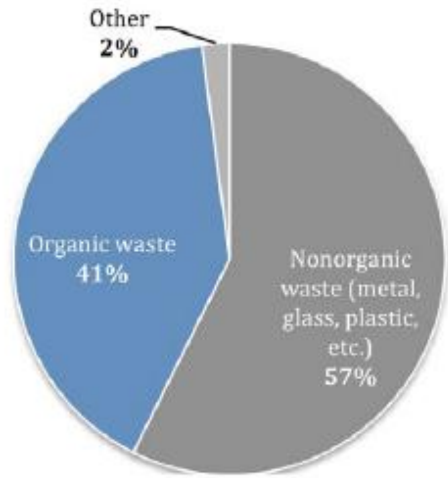


Figure 3-6: Materials considered useless by the communities of Cagmanaba and Badian.

Elisa Teipel Dissertation Defense 7/7/14 21

(1) Continued: Organic waste by type

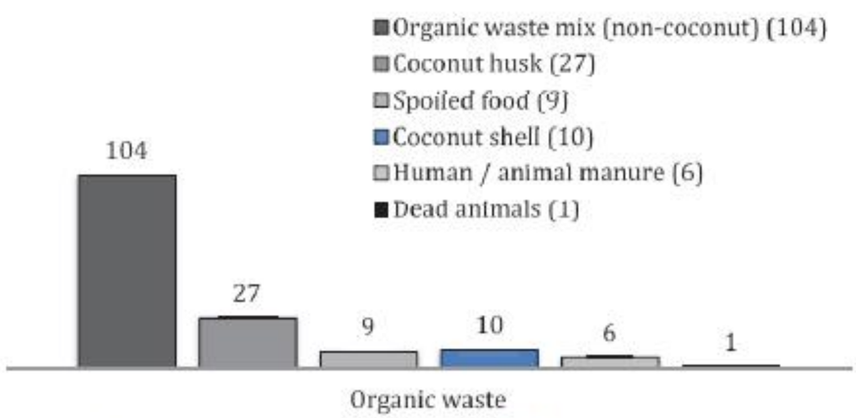


Figure 3-7: Types of organic waste identified by the communities of Cagmanaba and Badian.

Elisa Teipel Dissertation Defense 7/7/14 22

Questions (2) and (3)

(2) Do you see something when you look around here that you think is not being used well?

(3) Do you have anything that you could make better use of? If "yes" what could you do with it?

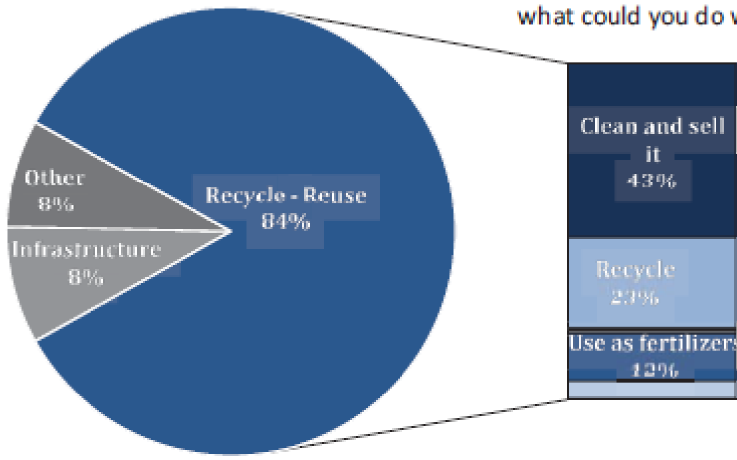


Figure 3-9: Better use of materials.

Elisa Teipel Dissertation Defense 7/7/14 23

(4) What does it mean to be rich? (Table 1 of 2)

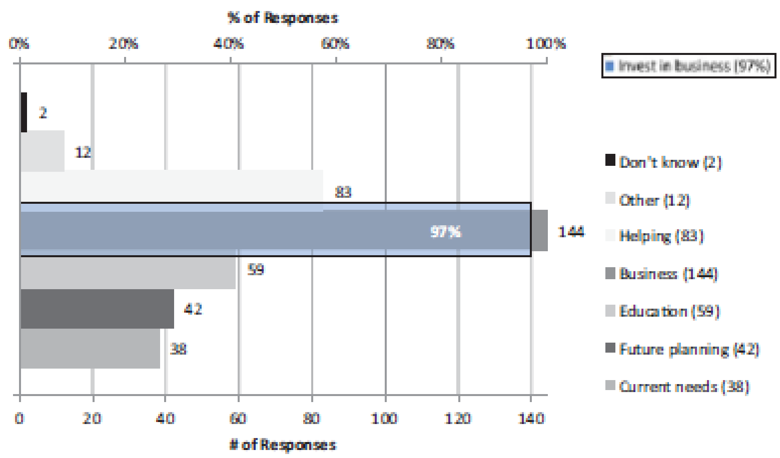
Category	Response	# of Responses	Percentage	Total Responses
Money	To have money (plenty of money)	108	86%	126
	To have big savings/savings in the bank	13	10%	
	To be free from debts	2	2%	
	Can afford anything	3	2%	
House and Properties	To have nice house	50	60%	83
	Many Real Estate properties	33	40%	
Transportation	To have car	17	50%	34
	To have many cars	17	50%	
Work	Employed (To have regular work/ employment)	31	26%	119
	To have business	43	36%	
	To have many businesses	45	38%	
Education - Experience	Degree holder	1	25%	4
	To have children finished their studies/college	1	25%	
	To have worked abroad	2	50%	

Elisa Teipel Dissertation Defense 7/7/14 24

(4) What does it mean to be rich? (Table 2 of 2)

Category	Response	# of Responses	Percentage	Total Responses
Relationships	Have faith in God / To have God in life	7	25%	28
	To have good family relationship / bond	4	14%	
	To have good public relationships	17	61%	
Basic Needs	To have abundant food	15	94%	16
	Physical health	1	6%	
Intangible Needs	Love	1	10%	10
	Peace	1	10%	
	Happy and worry free	8	80%	
Others	Complete with material needs	2	6%	35
	Successful in lfie / as a result of hard work	3	9%	
	To have plenty of jewelry	11	31%	
	In the way people dress & talk	10	29%	
	Generous	2	6%	
	Diligent, work hard to get rich	3	9%	
	It depends on the lifestyle / changed	2	6%	
	Not having any problems	1	3%	
	Other	1	3%	

(5) If you had more money, what would you do with it?



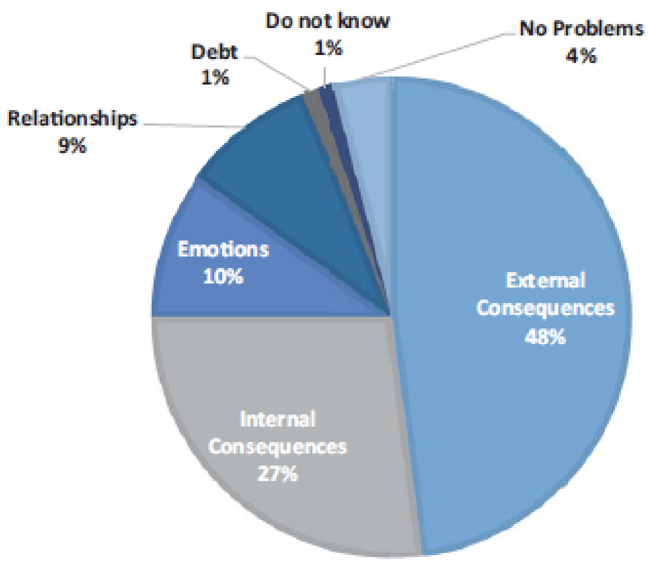
(6) Does having more money bring problems?

Table 3-4: *Community Response Regarding Problems*

Does having more money bring problems?	Response
Yes	256
It depends on how you use it	10
If not used in good ways	1
No	24
Maybe	7

Elisa Teipel Dissertation Defense 7/7/14 27

(7) What type of problems does more money bring?



Elisa Teipel Dissertation Defense 7/7/14 28

Question (7) continued: Consequence type

External

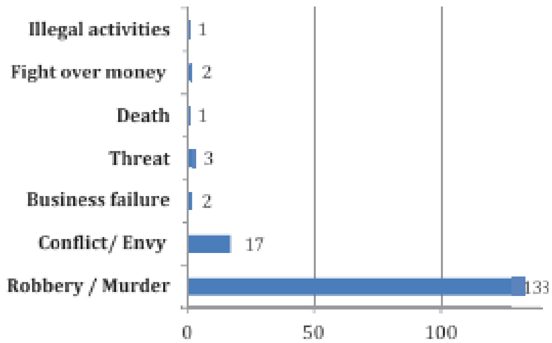


Figure 3-12: External consequences reported by participants.

Internal

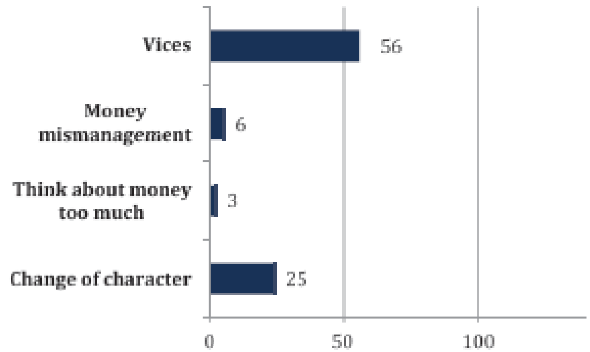


Figure 3-13: Internal consequences reported by participants.

Elisa Teipel Dissertation Defense 7/7/14 29

(8) Is there anything that you think could make (Cagmanaba or Badian) better?

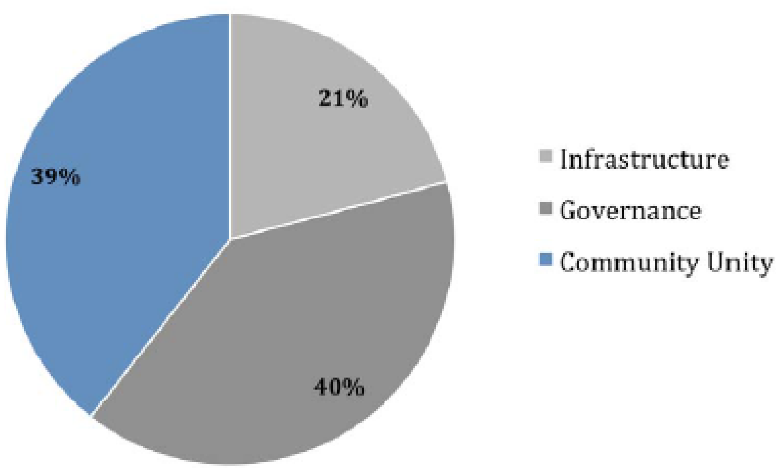


Figure 3-14: Communities' focus regarding improvements.

Elisa Teipel Dissertation Defense 7/7/14 30

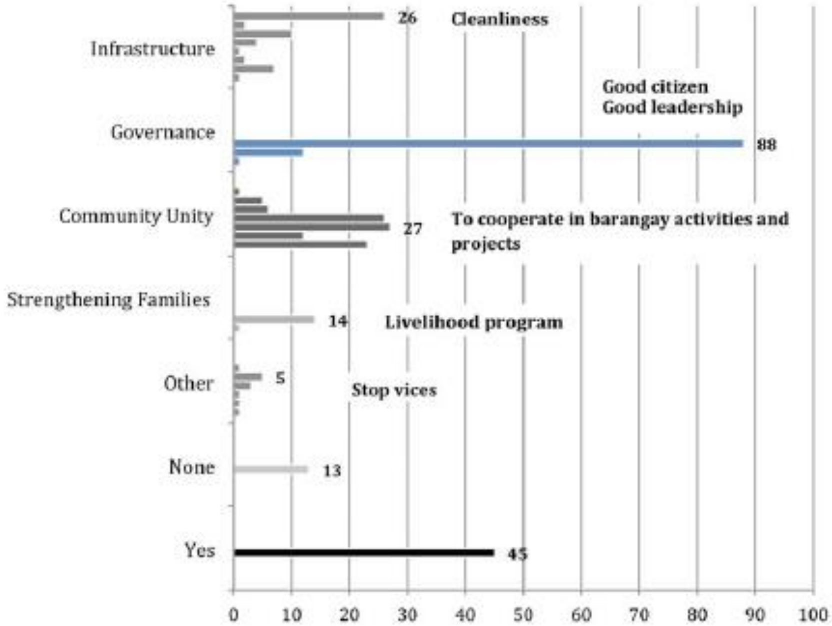
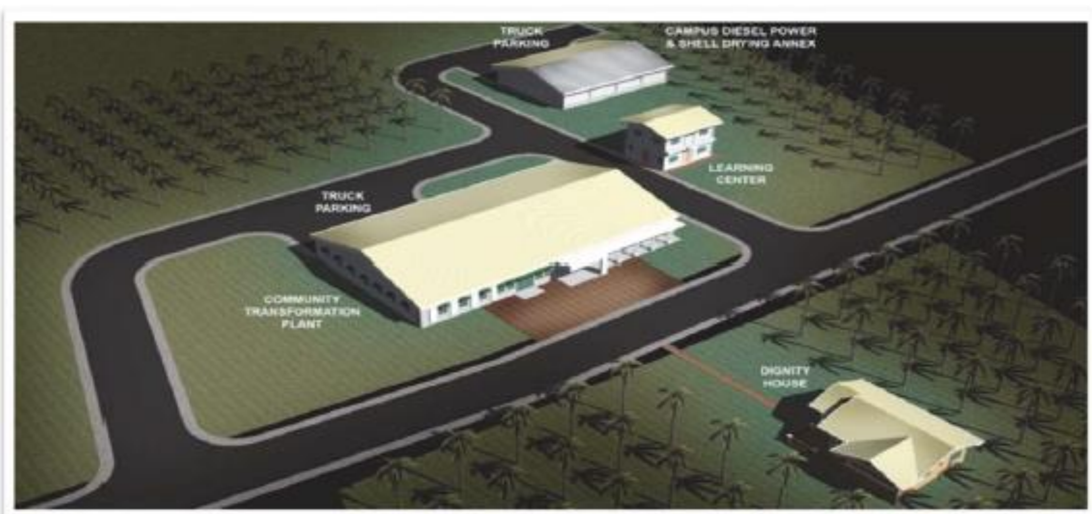


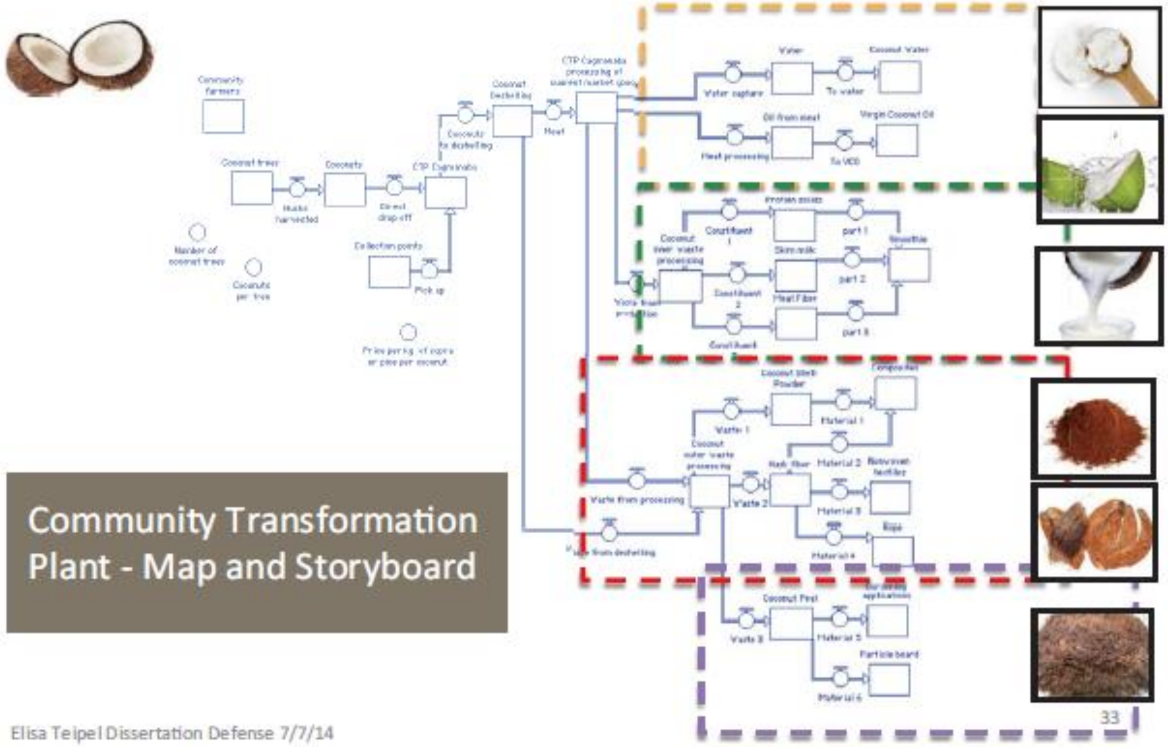
Figure 3-15: Legacy building.

Elisa Teipel Dissertation Defense 7/7/14 31

Community Transformation Plant



Elisa Teipel Dissertation Defense 7/7/14 32



Community Transformation Plant - Map and Storyboard

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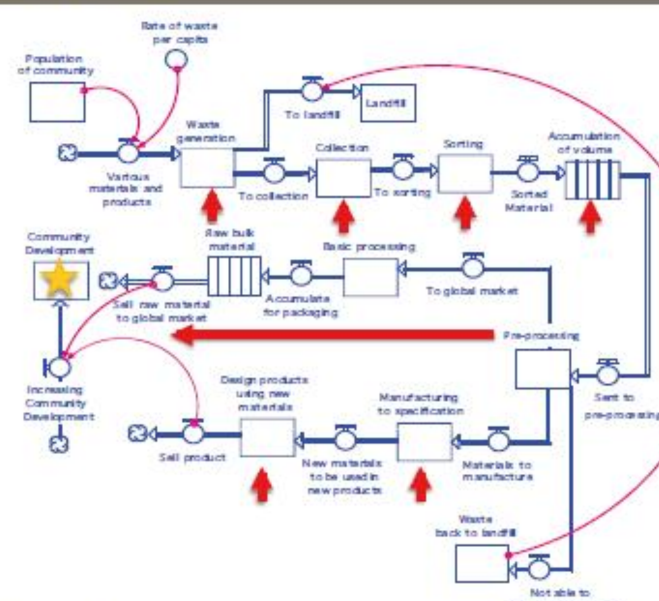
33

Reclaimed Waste



Elisa Teipel Dissertation Defense 7/7/14

34

Indicators of Success 1 of 2

Indicators to check	Initial stage (1-3 years)	Midway through (3-5 years)	Towards sustainability (5-10 years+)
Community	Provided new education, training, and capacity-building opportunities	Growing in leadership opportunities	Leading the CTP and the waste-to-resource intervention themselves
Outside Partners: **Investors** **Manufacturing** **Technical** **Business**	Worked with community to train technically and for business management	Beginning to see return on investments, ~10%	Return on investment for all investors met: guidance met or adjusted accordingly. Outside agents continue to work in advisory role with the community.
Infrastructure	Area mapped to understand how community would or could be effected by plant	All roads and main areas of infrastructure complete to handle plant capacity	Main roads, electric and sanitation in place to allow long term growth of area
Governance	Established good relationships with the government officials	Working together to improve services including meeting the needs of the community including health, etc.	Sustainable positive relationships maintained over time
Logistics	Secured access to ports	Continued access to major ports to achieve lower shipping costs, Improvement of roads	Ability to transport 40 foot shipping containers with little issue

Indicators of Success 2 of 2

Indicators to check	Initial stage (1-3 years)	Midway through (3-5 years)	Towards sustainability (5-10 years+)
Materials	Materials availability sufficient to global application 5 million lbs. annually	Scale the capacity of the raw material and feedstock to 20-30 million lbs. by year 5	Diversification of waste streams, Look for new materials in area to add to successful applications or continue to grow and scale up current waste stream
Technical	Passed technical objects of first customer application	Launching 5 commercial applications with value- added pricing for waste	Look for higher tech applications or increase portfolio with initial waste stream or new waste stream growth Successfully launch 1 high market application
Environmental	Reduced waste in the community, diverted from piling up in back yards	Diverting waste and using to reduce waste in consumer goods by 10-50% - example: plastic car parts, consumer goods	Form landfill, waste processing facility for all the waste that cannot be processed through the waste-to-resource framework
Human	Increased dignity of community partners, offered a new place for employment that is able to help the community thrive and be encouraged to flourish, provided jobs to families	300 employees and their families benefiting from their working at the factory Provisions for medical, nutritional, educational, and income needs of as many families as possible	Equitably partnering in the profit and the leadership of the plant and the model - goal could be a 50:50 Partnership Grow the plant to be running solely on profit and not requiring cash flow from investors


Outline: From Waste-to-Resource
Waste-to-Resource
Introduction
Framework
Literature Review
Community Assessment
Material Creation
Equity
Conclusions
Elisa Teipel Dissertation Defense 7/7/14
37

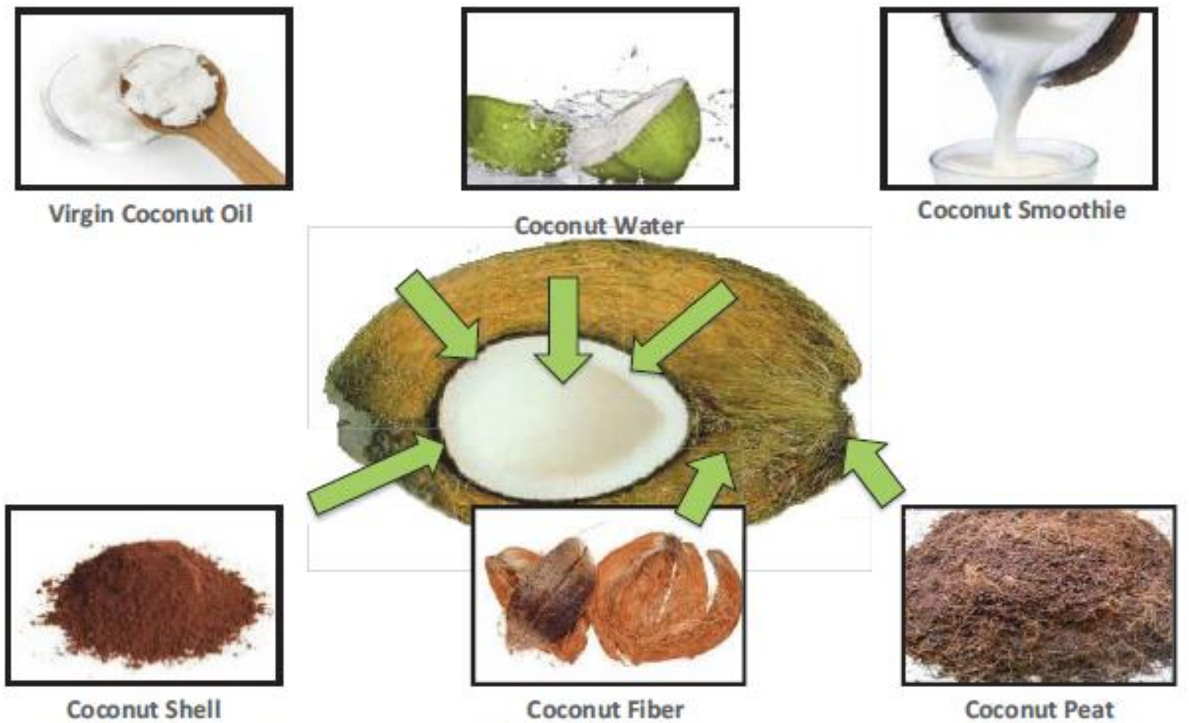

Waste? Or Resource?
38

Where Do Coconuts Grow?

Elisa Teipel Dissertation Defense 7/7/14 39

Constituent Parts of the Coconut

Elisa Teipel Dissertation Defense 7/7/14 40



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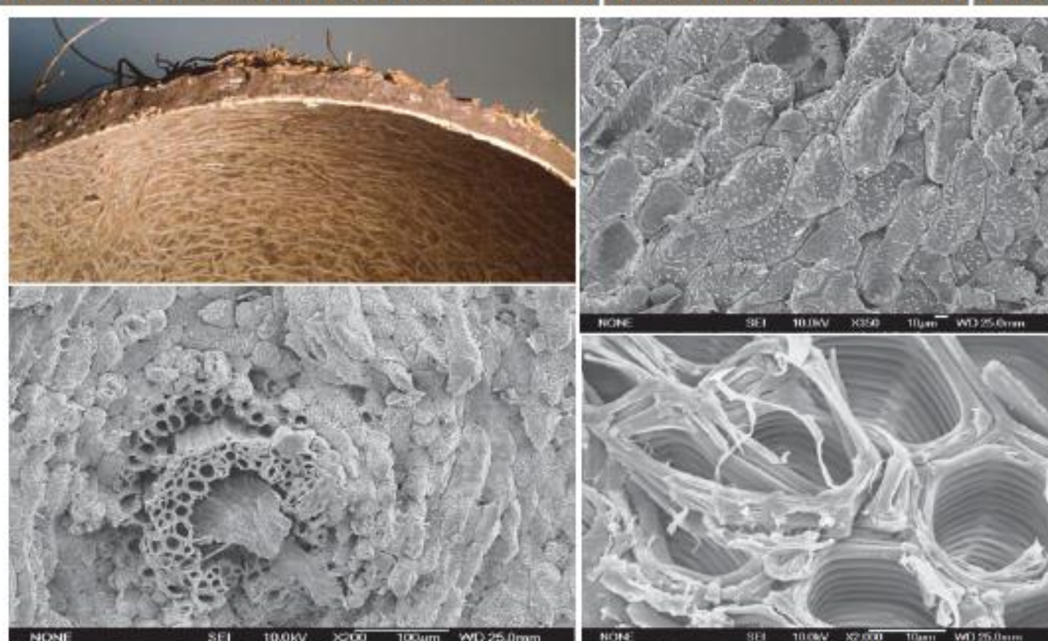
41

The Science of Waste: A Complex Natural Composite



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42

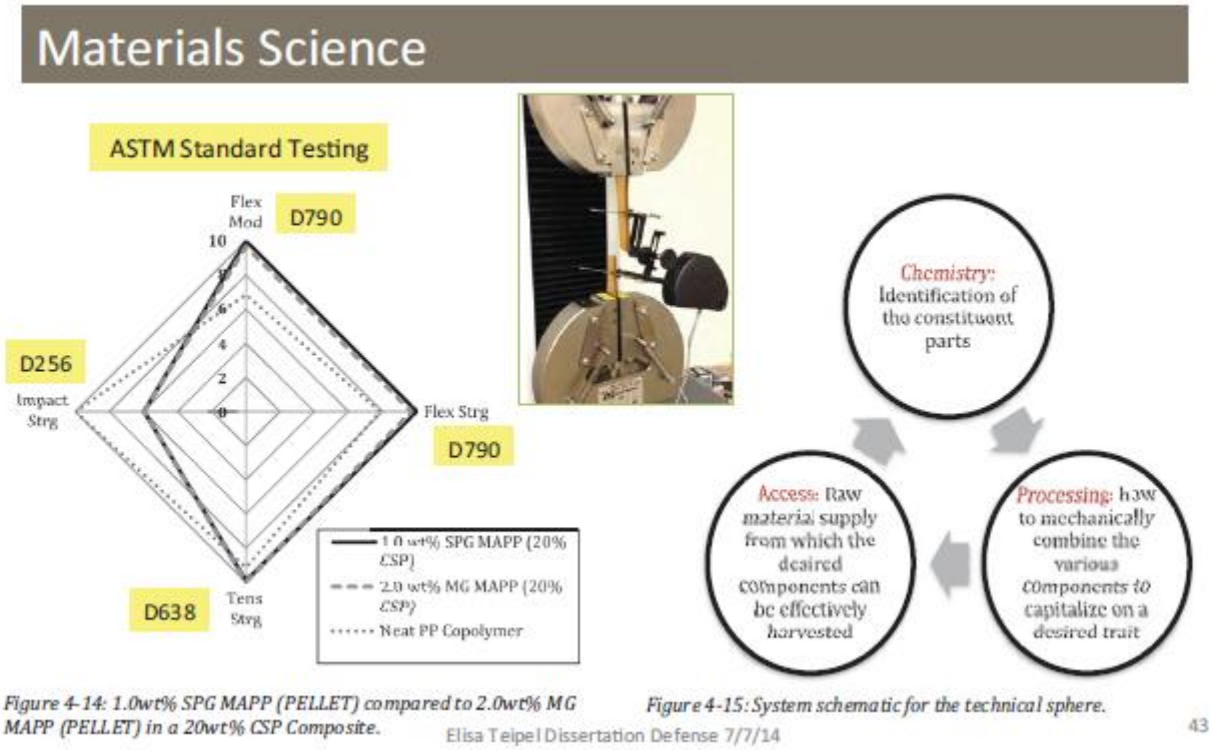


Figure 4-14: 1.0wt% SPG MAPP (PELLET) compared to 2.0wt% MG MAPP (PELLET) in a 20wt% CSP Composite.

Figure 4-15: System schematic for the technical sphere.

Environmental Impact: Embodied Energy

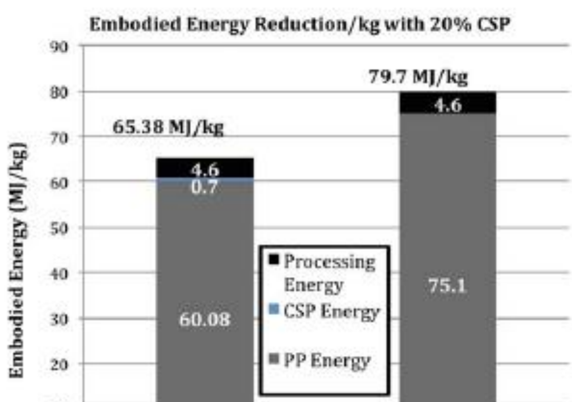
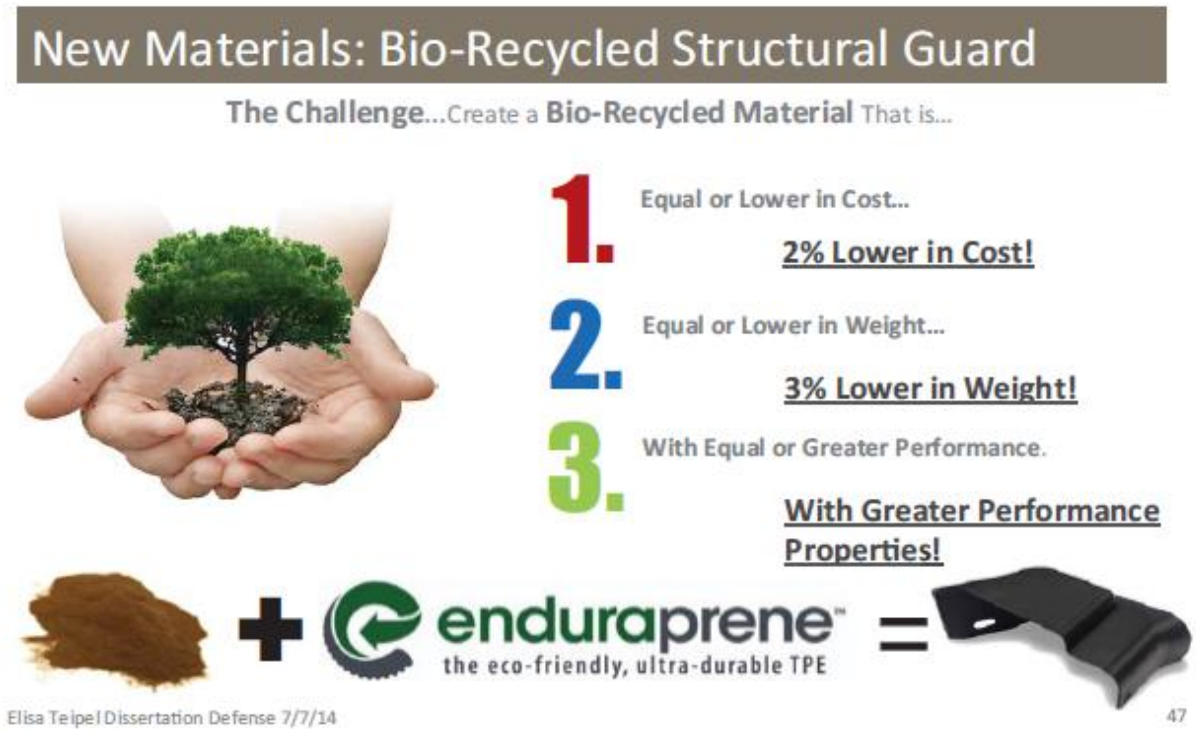


Figure 4-19: Embodied Energy Reduction of PP Composites with the Addition of 20 wt.% CSP Coconut Shell Powder. The compounding energy used was reported in Karian, et al.

Elisa Teipel Dissertation Defense 7/7/14 46


New Materials: Bio-Recycled Structural Guard
The Challenge...Create a Bio-Recycled Material That is...
1. Equal or Lower in Cost...
2% Lower in Cost!
2. Equal or Lower in Weight...
3% Lower in Weight!
3. With Equal or Greater Performance.
With Greater Performance Properties!
+ enduraprene™ =
the eco-friendly, ultra-durable TPE
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47


Waste-to-Resource Products
THE HOME DEPOT
Ford
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48


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Outline: From Waste-to-Resource
Waste-to-Resource
Introduction
Framework
Literature Review
Community Assessment
Material Creation
Equity
Conclusions
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50

Waste? Or Resource… SCD potential

Sustainable Community Development (SCD) as described by this research

$$SCD_{W2R} = SCD_{Human\_Impact} + SCD_{Enterprise} \quad \text{Eq. 5.1}$$

where

$$SCD_{Human\_Impact} = ICI + Equity + Dignity_{People} \quad \text{Eq. 5.2}$$

where

ICI = **Intentional Community Involvement**

ICI is soliciting the Community's Involvement in the following:

- **Planning the product**
- **Selecting the feedstock**
- **Locating the facility**
- **Considering the impacts of new wealth**

and

Equity = Shared ownership

and

$Dignity_{People}$ = Consideration of the whole person

Consideration of the whole person is comprised of improvements in the areas of:

- Good working conditions
- 401k savings plan
- Community program investment matching
- Livelihood programs
- Banking
- Improvements in public health
- Continuing education and vocational training

and

$$SCD_{Enterprise} = Dignity_{Planet} + New\ Business \quad \text{Eq. 5.3}$$

where

$Dignity_{Planet}$ = Environmental stewardship

and

$$New\ Business = R\&D + MFG + Sales \quad \text{Eq. 5.4}$$

therefore

$$SCD = ICI + Equity + Dignity_{People} + Dignity_{Planet} + R\&D + MFG + Sales \quad \text{Eq. 5.5}$$

Community Benefits

Metric	Result
Job creation – Income	Better pay than local minimum wages Allows for community to meet their own needs
Increase living standards	Community can sustain needed education, food, shelter, health, and other basics
Stimulate economic growth	Goal: To employee approximately 300 workers from the 1000 families in the area, increase income for 400 coconut farmers, and help other businesses get started in the area to spur economic growth
Fair pricing of products and new materials	Helps get the most value for stakeholders
Fair trade certification	Demonstrates commitment to stated principles and practices of the business
A use for waste in the community	Less pollution in the communities' environments
Decision making	Allowing communities to help with the decision making process Mistakes may occur; lessons learned can build capacity and resilience Because partners are willing to invest in their future, mistakes are seen as opportunities to grow and learn
Training, education	Community grows in capacity and resiliency
Voice in politics and community governance	Community grows in capacity, resiliency, self-sufficiency

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Human Impact: Equity

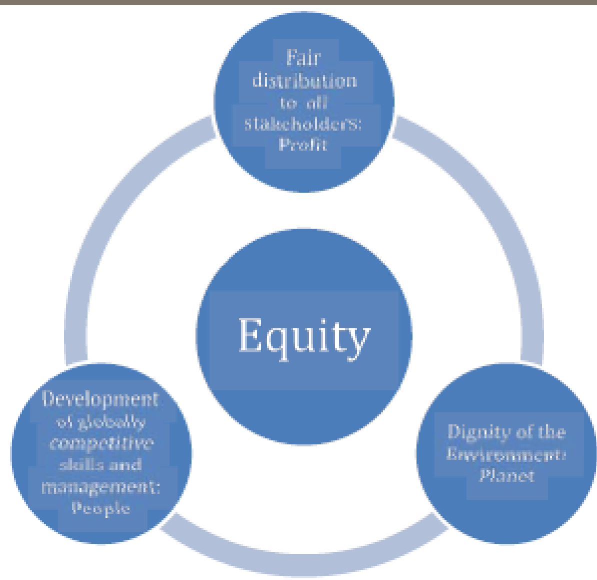

Figure 5-1: Building community equity.

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Mechanisms for Profit Sharing

Method
Monthly/ Quarterly Continuing Education Mini-Courses
Monthly Giving–Match Program
An Employee Shareholder 401k Type Fund
Community Revitalization Projects
Discipleship Training Night School
Profit Sharing and Employee Ownership
Livelihood programs

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Waste-to-Resource is a multi-pronged approach: Livelihood programs

Think BIG... Start Small... Act Now

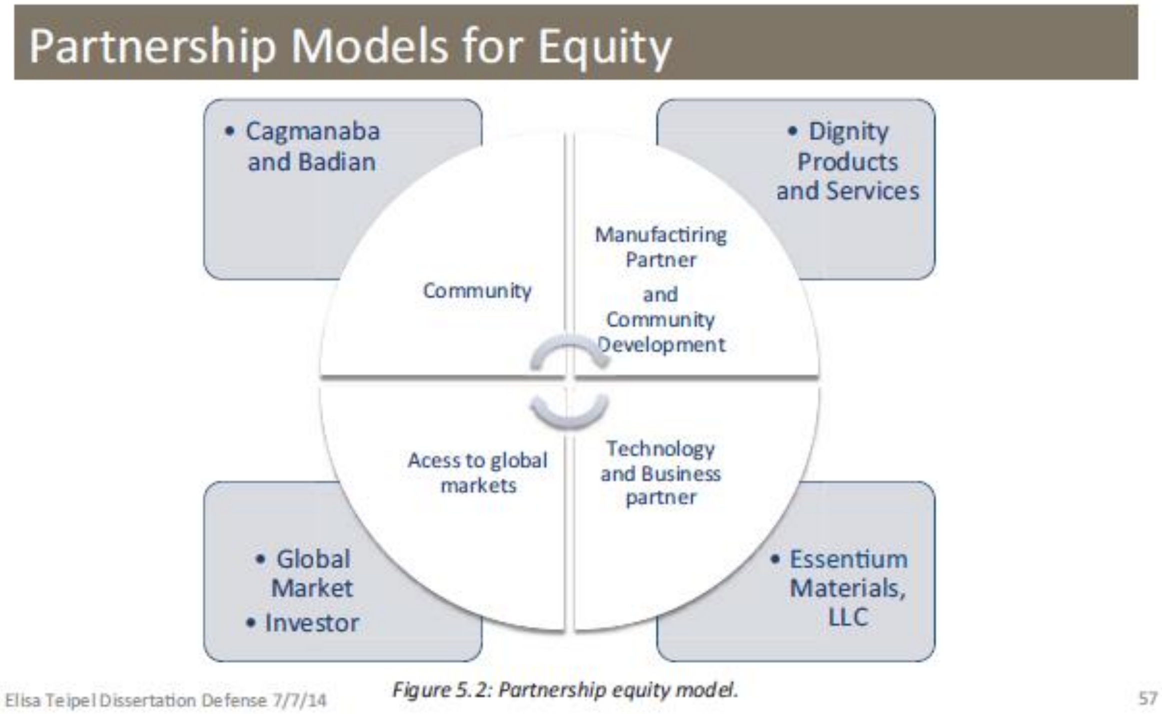

Figure 5.2: Partnership equity model.


The Question Behind the Framework
What are the steps necessary to create a highly efficient, successful model for sustainable rural community development utilizing agricultural waste?
– A waste-to-resource framework, utilizing a CTP, provides a robust solution to the complex systems problem.
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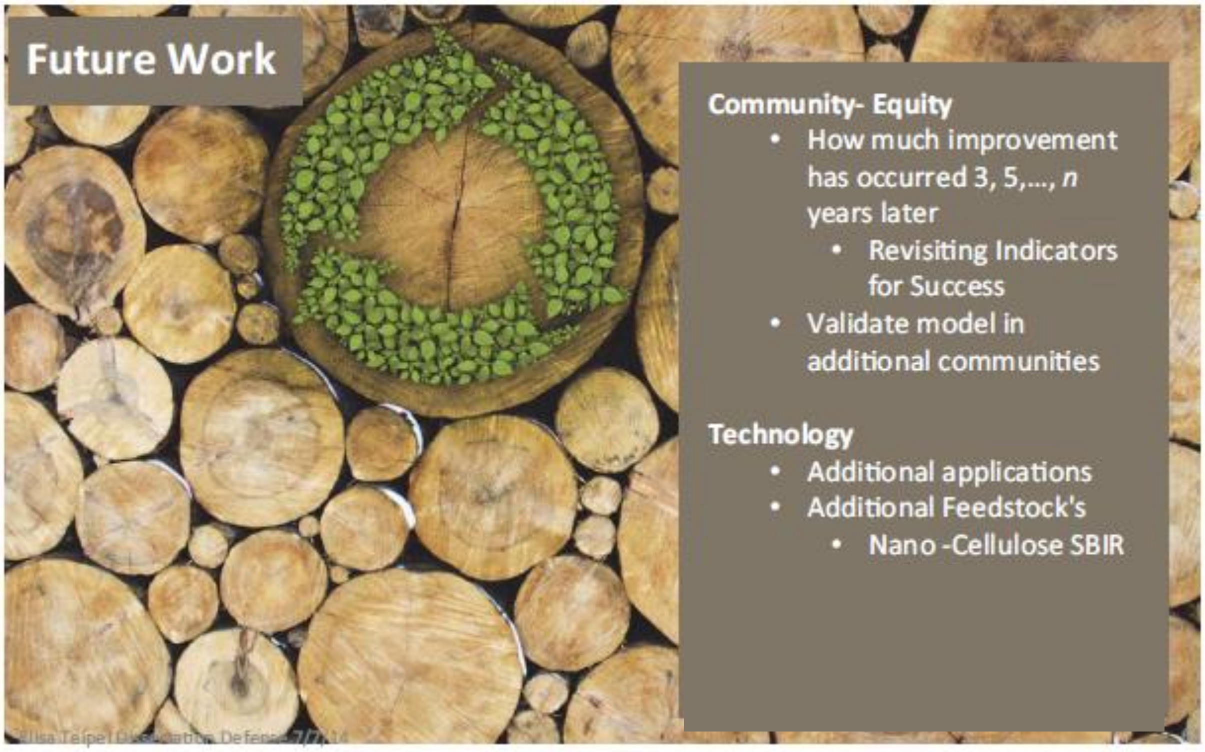
59


Lessons Learned
Waste-to-Resource Framework is a Catalyst for Sustainable community Development
– Utilizing materials destined for landfills
– Creating materials that can be used again and again
– Job opportunities created for raw material production and manufacturing, engineering
Partners are key including all stakeholders (community, and all outside partners)
Community
Environment
Technology, Business case
Equity



Selected 2012-2014 Publications and Conferences

- January 2013 ACMA – runner up coconut design Pinnacle award for: **Spray-Cast Coconut-Stone Eco-Friendly Vanity, hybrid composite using renewable bio-materials with traditional materials.**
- February 2013 Bloomberg CNBC news story – Planet Forward story title, **"A tropical treat turns into plastic."**
- March 2013 International Polyolefins conference paper – Title **"Optimization of Natural Functional Fillers Created from Bio-waste in Polymeric Composites** using Coconut Shell Powder and MAPP SCONA.
- October 2013 - Composite World Magazine – New material upcoming story December 2013: **"Natural Fiber Composites | DRIVING SUSTAINABILITY"**
- February 2014 – Society of Plastics Engineers International Polyolefins Conference, **"The Sustainability of Natural Filler Reinforced Polyolefin Systems"**
- April 2014 US Science and Engineering Festival – Selected by National Science Foundation to display waste-to-resource new materials **"The Next Generation of Essential Materials."**
- **May 2014 Granted NSF-SBIR Phase I, PI on: "High Performance Structural Composites with Cellulosic Nanoparticles"**

Papers

- Draft in Progress: **"A Community's Perspective on the Waste-To-Resource Transformation of Materials"** Future journal submission: Journal of Resources, Conservation and Recycling
- Draft in progress: **"Waste-to-Resource: Polymeric Composites"** Future journal submission: Journal of Material Science

Elisa Teipel Dissertation Defense 7/7/14 62


Resource!
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63