Biodiesel Energy in Small Island Developing States:

Addressing Challenges to Development

by

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Author's Declaration

I hereby declare that I am the sole author of this thesis. This is a true copy of the thesis, including any required final revisions, as accepted by my examiners. I understand that my thesis may be made electronically available to the public.

Abstract

Petroleum-based fuel dominates the global energy system despite the fact that this resource is diminishing. Additionally, Small Island Developing States (SIDS) face a number of challenges to development such as resource scarcity, locational isolation, and uneven development. These challenges make it difficult for these nations to compete in the global market for fuel. Incidentally, biodiesel, made from waste cooking oil, can be used in automotive diesel engines or diesel generators for electricity. Currently, these two areas: development in SIDS and biodiesel, are separate topics in the literature and a relationship between the two has yet to be developed.

This research will describe how a biodiesel-based energy system can address some of the challenges to development faced by SIDS. One such system in Barbados is used as a case study. Informal interviews and participant observation reveal the benefits and challenges of setting up and maintaining a biodiesel energy system. Also, the potential to scale-up the biodiesel energy system to the national level is assessed. An evaluation framework, derived from the literature, is used to rate the success factors of the existing biodiesel operation and as well as the steps required for scaling up.

The results of this study prove the numerous and interconnecting benefits of a biodiesel-based energy system. Biodiesel produced on the island using locally-generated waste cooking oil creates a new local resource, addressing the challenge of resource scarcity, and reduces the demand for imported petroleum-based diesel. The biodiesel system addresses the issue of uneven development by connecting different communities across the island through public participation. However, funding difficulties in the biodiesel operation arose after a change of ownership. This made obtaining methanol, an ingredient in biodiesel production, problematic and ultimately halted production.

Based on the findings, it is recommended that community biodiesel-based energy systems include the use of a locally-produced alcohol as a substitute for methanol.

Also, operations should be scale-up through decentralization in order to keep equipment costs down and better address the challenge of uneven development faced by SIDS. With proper management and sufficient funding and community support, a biodiesel-based energy system is able to contribute to sustainable development in light of the unique situation present in SIDS.

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Chapter 1. <u>Introduction</u>

Across the globe, efficient, inexpensive, and reliable energy resources are in demand. Certainly, this is the reason why oil and gas dominated the energy market for so long and why most of our infrastructure now depends on these fuels. However, this resource is no longer efficient nor inexpensive and political unrest surrounding this resource makes reliability questionable (see for example Farrell, Zerriffi, & Dowlatabadi, 2004; Campbell & Lahere, 1998; Kemp, 2006). In addition, there has been growing awareness about the use of these petroleum based fuels and their contribution to global climate change.

In consideration of energy resources and the effects of global climate change, there is a special case for Small Island Developing States (SIDS). First, these areas face many unique challenges to development including resource scarcity, locational isolation, and uneven development (Douglas, 2006; Koonjul, 2004; Read, 2002; Vallega, 2007). These challenges are ever present when considering energy in SIDS; these communities have limited energy infrastructures, and access to high-capacity generation units is expensive to develop. Also, the price of energy increases as a result of the remote area and smaller demand as energy is not provided 'in bulk' (Stuart, 2006). Second, "there is a strong consensus among scientists that unless emissions of greenhouse gases are reduced SIDS will experience losses of land, economic losses, cultural disruptions and some may ultimately cease to be habitable" (Barnett & Dessai, 2002, p.233). Therefore, not only are these countries still developing, they must learn to do so in a way that will not contribute to the complications they will experience as a result of climate change. Sustainable development is needed and this is especially true for SIDS energy systems.

Biofuels have great potential to meet specific energy needs while remaining a renewable resource with less net emissions (UNEP, 2009; Kemp 2006). Unfortunately, there has been much criticism of biofuels which stem from the negative environmental and social impacts of the way certain biofuels are created. Specifically, it is argued that growing crops to create biofuels has detrimental effects to arable land, uses more energy than it creates, and redirects global food sources away from those who need it (UNEP, 2009). These are valid arguments, however they are greatly reduced when using a waste product as the prime feedstock for biofuel production.

Biodiesel is a proven and successful example of turning waste into energy (see for example Cetinkaya & Karaosmanoglu, 2005; Kemp, 2006; Zhang, Dubé, McLean, & Kates, 2003). Most commonly it is waste vegetable oil that is turned into biodiesel which can then be directly used in diesel engines. The 'recycle' aspect of biodiesel is one of its many benefits; it can improve environmental and human health through less toxic emissions and a biodiesel system can contribute to local economic growth and development. Therefore, a biodiesel energy system is of particular interest to island communities as it has the potential to addresses the development challenges faced by SIDS in a sustainable way.

1.1. Research Gap

The literature on development in SIDS is extensive. The challenges faced by SIDS are often identified, but there is also literature focusing on international agreements and policies, the notion of sustainability, and energy in SIDS (see for example United Nations Division for Sustainable Development, 1994; Haraksingh, 2001, and Stuart, 2006). More closely related to this thesis is the literature that focuses on renewable energy development in SIDS. This collection of literature, however, focuses primarily on solar energy development.

There is also a vast amount of literature on the topic of biodiesel. Most of the peer reviewed, academic studies are very technical, reporting experiment results for making and using the fuel (see for example Al-Widyan & Sl-Shyoukh, 2002a; Cetinkaya & Karaosmanoglu, 2005; Gomez et al., 2000). There are many non-governmental organization reports and books that include all aspects (i.e. social, environmental, economic, and technical) of biodiesel production and use (see Boyd, Murray-Hill, & Schaddelee, 2004; Kemp, 2006), however no study this comprehensive could be found in the academic journals. There is also a large online community for do-it-yourself biodiesel found in forums, blogs, and anecdotal 'manuals.'

The only evaluation framework specifically for a biodiesel operation was found in a non-government organization report (see Boyd et al., 2004) and applied to a developed nation's commercial biodiesel operation. An evaluation framework related to scaling-up an alternative energy system could not be found in the literature.

Theoretically, a biodiesel system could address some of the development challenges in SIDS, however, this has yet to be explored in the literature along with a framework for evaluating its success.

1.2. Problem Statement

Although there have been many studies on the topics of sustainable development challenges in SIDS, applications of alternative energy, and production and uses of biodiesel, what has been underexplored is a combination of these fields: the use of biodiesel for sustainable energy development in SIDS. Also, the benefits and challenges of setting up and maintaining community-based biodiesel energy systems has not yet been documented in the literature nor has the topic of scaling up such systems to national levels in order to address the challenges faced by SIDS.

1.3. Research Purpose

This research has two purposes: an academic purpose and a practical purpose. The topics herein are examined through the lens of political ecology, which can be described as "empirical, research-based explorations to explain linkages in the condition and change of social/environmental systems" (Robbins, 2004, p. 12). While reviewing the literature through the political ecology lens, theoretical links between a biodiesel energy system and development challenges that face SIDS can be uncovered. Bridging the gap between these two topics is the first contribution to academia.

Next, a case study is used to gain concrete information on this topic. The case study to be examined is in Barbados where a community-scale biodiesel system is in operation.

Alternative energy forms in SIDS in the Caribbean are used to help these countries with the challenges to development that they face. Barbados faces the same challenges to development as many SIDS such as remote geographic location, small size, expensive imports, and scarce natural resources (see Section 2.1). Though many islands in the Caribbean have small-scale solar panel and wind turbine energy systems, Barbados is home to a less common alternative energy system: biodiesel. This operation has been recognized as a contribution to local energy production as well as community environmental education.

The case study is also analyzed using the political ecology lens and will further contribute to academia by reporting real-world circumstances and considerations to the theories revealed in the literature review.

Koonjul (2004) states "the recognition of SIDS as a group of countries with specific and unique vulnerabilities needs to be translated into concrete action which will ensure their survival upon the further integration of the global economy" (p. 156) which leads to the practical purpose of this research. First, the case study report will act as a guide on how to set-up and maintain a community-scale biodiesel operation. Next, the benefits and challenges of such a system will be identified. Finally, opportunities to 'scale up' the system so as to better address the challenges faced by SIDS and increase benefits can be discovered. Therefore, this research will not only help to improve an existing community-based biodiesel energy system, but will act as a guide to other SIDS wishing to develop their own system.

Through both the literature review and case study observations, an evaluation framework for community biodiesel and scaling-up activities will be developed. In summary, this research will both fill a gap in the literature, thereby contributing to academia, and provide a practical guide for a biodiesel system operation, contributing to real-world applications.

1.4. Research Objectives

This research has four main objectives:

1. Develop an evaluation framework for a community-scale biodiesel operation and scaling-up activities based on the literature.
2. Document the activities of a community-scale biodiesel operation.
3. Identify the benefits and challenges of the operation as well as the opportunities to scale up the operation as per the evaluation frameworks.
4. Provide recommendations for the biodiesel operation as well as methods for scaling up.

Through reaching these objectives, the overall goal of this research is to demonstrate how a biodiesel energy system can address and help some of the challenges to development faced by SIDS.

1.5. Organization of Thesis

This thesis is organized into six chapters. The first chapter has outlined the context, research gap, and research objectives. Chapter 2 describes the literature that relates to development in SIDS as well as biodiesel and combines these fields into an evaluation framework. Chapter 3 describes the research methods and introduces the case study for this thesis. In Chapter 4, the case study findings are reported. Chapter 5 analyzes the findings and evaluates the use of a biodiesel energy system as a method to address the challenges faced by SIDS. Finally, Chapter 6 provides recommendations for community-based biodiesel energy as well as scaling-up activities and concludes this thesis.

Chapter 2. <u>Literature Review and Conceptual Framework</u>

2.1. <u>Development in Small Island Developing States</u>

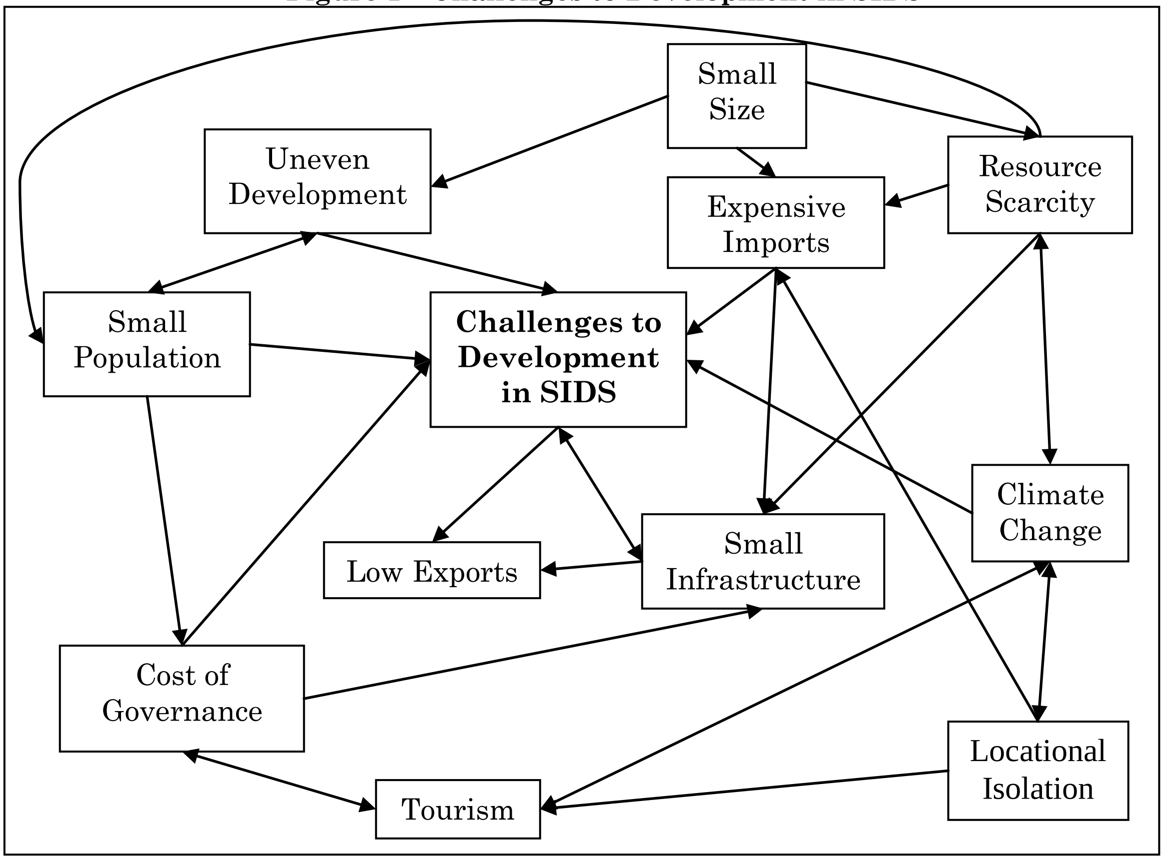
Developing countries play a significant role in the use of global resources and in the international economy. Although they are not popularized in the media, "three out of four of the world's small developing countries are island states" (Douglas, 2006, p. 75.). These small island developing states, or SIDS, are found in the Africa, Caribbean, Indian Ocean, Mediterranean, Pacific, and South China Sea and, together, make up five percent of the world's population (Alliance of Small Island States, 2007). Yet, it has only been in the last 20 years that these areas have been of academic concern along with the idea of sustainable development. These countries face an array of unique development challenges which are described in the following section.

2.1.1. <u>Development Challenges facing SIDS</u>

Due to their geographical sizes and locations, SIDS face an array of development challenges. The United Nations (2004) has recognized this stating: "they are ecologically fragile and vulnerable. Their small size, limited resources, geographic dispersion and isolation from markets, place them at a disadvantage economically and prevent economies of scale."

Figure 1 below, is a visual summary of the challenges facing SIDS as described through the literature found. These challenges stated with general headings and are described in detail in the following paragraphs.

Figure 1 – Challenges to Development in SIDS



Sources: Douglas, 2006; Koonjul, 2004; Read, 2002; Vallega, 2007

First, the amount of goods and services that small states can provide for themselves is very limited due to their small amount of land (stated in Figure 1 as 'small size') and, as a result, many goods are imported. Importing goods is very costly due to their remote location coupled with a lack of more economical 'bulk' shipments (stated in Figure 1 as 'expensive imports'). Also, it is very difficult for SIDS to offset the costs of their imports with exports. Indeed, they

> …will not be able to implement export-led strategies through the production of goods or services, partly because the advice provided and regulations imposed on them by multilateral institutions are still based on the paradigm of development through expansion of the gross domestic product (Koonjul, 2004, p. 155) (stated in Figure 1 as 'low exports').

This leads to another challenge facing SIDS: the generally small populations (stated in Figure 1 as 'small population') of SIDS and the resulting impact this has on the per capita cost of social services (stated in Figure 1 as ‘cost of governance’). The ‘advice’ mentioned above by multilateral institutions is problematic as SIDS already face higher per capita costs for governance and infrastructure due to their small population (Koonjul, 2004). Koonjul (2004) argues that in order for SIDS to have a place in the global economy, their own economies must first develop which can only be done by the population paying for national government services and development. For many SIDS, tourism is the primary, if not single, industry of source of revenue and, “growth success in terms of high per capita incomes is found to be associated with a rich natural resource base and a strong service sector, notably in financial services and tourism” (Read, 2002, p. 176). Therefore, one could conclude that small island states with a strong tourism industry could have a strong economy. However, Douglas (2006) maintains that “tourism inflow effects and management,… external dependency, international debts, unemployment, social change, cultural shifts and low capacities in administration and governance” (p.76-77) are strong sustainable development constraints (stated in Figure 1 as ‘tourism’).

There are further complications in SIDS once goods and services reach these islands since typically, though they are small, SIDS characteristically have uneven development within and across borders which makes for complex resource management and governance (Douglas, 2006) (stated in Figure 1 as ‘uneven development’). This is to say that the islands are typically not uniform in their development, but rather, have varying economic structures often with one large, rich, urban centre while the rest of the country is rural and poor (Douglas, 2006). It is common for the major port of island states to also be the country’s capital and most populated and developed centre. It is from this centre that goods and services are distributed. However transportation, communications, and inter-island equity are problematic (Koonjul, 2004) and so distribution is not equal and internal markets are limited.

Resource management is difficult in SIDS due to the lack of infrastructure and prevalence of poverty, the impacts of which are compounded by the already scarce availability of resources (stated in Figure 1 as ‘small infrastructure’ and ‘resource scarcity'). "Problematic sustainable development issues abound in areas relating to … poor water resources and availability, waste generation, disposal and management programmes and access to energy and health impact problems" (Douglas, 2006, p. 76).[1]

Vallega (2007) presents the idea that SIDS are not only geographically (and perhaps practically) 'remote' and 'isolated' but that these terms can apply existentially and refer to remoteness in terms of cultural differences across the island (thus, leaving out the time and distance aspect of the word 'remote'). This concept may relate back to the fact that many small island states have uneven development, causing an 'isolation' not only in terms of economic interaction and development, but in micro-cultures and attitudes towards community development (stated in Figure 1 as 'locational isolation').

A more recent challenge facing SIDS is climate change (stated in Figure 1 as 'climate change'). This phenomenon has exacerbated already extreme weather (Koonjul, 2004; Vallega, 2007) increasing the amplitude or frequency of events such as droughts, hurricanes, and sea level rise. These events are particularly common in SIDS (Koonjul, 2004; Douglas, 2006; Stuart, 2006, Haraksingh, 2001; Vallega, 2007) and often destroy valuable infrastructure and resources (Barnett, 2002). In these cases, these events are referred to as natural disasters due to the negative impacts they have on communities. It is for this reason that SIDS have a vested interest in climate change mitigation and adaptation options and, as such, energy is arguably one of the most complex challenges facing SIDS not only in terms of emissions and climate change, but in terms of development.

2.1.1.1. <u>Energy Challenges</u>

Among the many imports of SIDS is energy. This is very costly due to delivery to a remote area, small population that means there is no need for high volume or

[1] In contradiction, Read (2002) explains that small states that do have access to abundant natural resources tend to avoid larger scale resource management problems as these areas possibly have greater social cohesion which makes them "more effective in sharing any such gains" (p. 176). If true, this holds much potential for small community-based initiatives.

‘bulk’ fuel and electricity, and limited storage areas (Stuart, 2006). These challenges combine to make electricity very expensive, especially on a per capita basis. Unfortunately, as the world’s oil reserves are depleted, the cost of petroleum-based energy will rise. SIDS are unlikely to be able to compete with the world market for these expensive fuels. Not only will the cost of fuel itself be expensive, but obtaining it may become difficult too as multinational oil corporations concentrate efficiency and technological advancements (as they relate to distribution) between major ports as these generate the highest revenue. As well, distribution to smaller, remote areas, such as SIDS, is often done with inefficient and unsafe equipment leading to environmental and well as human hazards (Stuart, 2006).

While obtaining fuel and electricity presents several obstacles and hazards, maintaining and delivering energy presents a new set of challenges. Ensuring security of supply can be difficult as storage facilities are often limited (Stuart, 2006). Therefore, supply must continually change with demand. However, since there are fewer storage facilities, larger capacity margins are required to supply electricity reliably in the event that a generator is unavailable (Stuart, 2006). Equally, islands’ fuel storage systems must be able to hold sufficient fuel reserves between deliveries. Energy maintenance and delivery challenges are further complicated by lack of capital and hard currency, inadequately trained manpower, and limited transfer of technology (Haraksingh, 2001). Also, according to Stuart (2006), there is the ‘Virgin islands paradox’ where energy consumption in SIDS often grows larger and faster than the prosperity that resulted from the energy system that was installed in the first place. In this situation, demand increases as a result of the installed energy system, but it continues to increase beyond the supply capabilities of the installed system.

In addition to the financial and logistical challenges, the challenges to energy systems in SIDS also relate to a lack of human capital. Stuart (2006) suggests that energy systems reform should not influence an island’s sense of identity or self-reliance. In a country that is already low in human resources, community members may be reluctant to reform the energy system. Furthermore, the typical lack of internal and external institutional support is a barrier to appropriate energy system development or reform (Stuart, 2006). Financiers, in the form of aid agencies and development banks, prefer funding short term projects as opposed to long term projects that reform energy systems. At the same time, officials and decision makers are often educated outside the island, where they gain experience only with large-scale, conventional energy systems. Therefore, they tend to favour the development and maintenance of traditional energy systems and, as a result, energy policies that are specifically tailored to the needs of SIDS are slow to materialize (Stuart, 2006).

2.1.2. International Regulations and Policies related to SIDS Development

The challenges faced by SIDS, as described in the previous section, make them on the whole more vulnerable than other countries to 'shocks' (e.g. changes in global weather, global economic or market changes). According to Koonjul (2004), studies by various organizations show that "…the best response to vulnerability is to build resilience" (p. 156). This resilience is said to come, in part, through proper decision making and management of resources in a way that maintains diversity, "…requiring that all products and services be obtained in a synergistic manner" (p. 156). Organization is required for this cooperation to occur, which is why there are many international regulations and policies regarding the development of small island states.

Douglas (2006) states that "the objectives of working programmes, projects and sustainable development initiatives in many island states and territories reflect the concerns for the environment" (p. 76). These environmental concerns and subsequent sustainable development projects arise from a variety of circumstances. Such projects may result from an instance where an area or environment has already been damaged or overused from malpractice. They can also be implemented as policies: setting limits as to how much of the resource can be used at a given time in areas that are low in natural resources. Unfortunately, there are also those situations where global economic and political power struggles have created a need for sustainable development which cannot be put into practice until the struggles are resolved. This is a common scenario in many developing countries where resource exploitation is done by external multinational corporations.

The notion of sustainable development has come about from the recent, global awareness of the concept of sustainability. Douglas (2006) states that the sustainability concept involves two key assumptions “that influence the governance, policy strategies and response outcomes in small island states and territories” (p. 77). The first assumption is that there is homogeneity within the community: a common understanding and societal consensus on the causes of environmental problems as well as on resource use and management. The second assumption addresses inter-generational equity as described in the report *Our Common Future* from the World Commission on Environment and Development; also known as the Brundtland report. This report defines sustainable development as “development that meets the needs of the present without compromising the ability of future generations to meet their own needs” (United Nations, n.d.). While the first assumption is difficult to measure and achieve especially within a small state that has characteristically uneven infrastructure development, the second acts as a guide for development and resource management policy and programs. The Brundtland report articulated the idea of sustainable development and paved the way for future international development policies and organizations. More specifically, it displayed a need for more in-depth discussion of global environmental issues.

The Earth Summit in Rio de Janeiro in 1992 provided an international forum for these discussions. This had an important impact on island sustainable management as it produced Agenda 21, a program made through international collaboration outlining actions to be taken in order to improve the way humans interact with the environment. As small island states became part of the UN, they began to participate in these discussions of ‘environment and development’ and were able to bring their specific needs into focus. Indeed, Chapter 17, section G of

Agenda 21 describes how SIDS present a special case for environment and development and "from that time, the use of island resources has become more articulated, not only because the external decision-makers, such as multinational companies, and the local authorities have been increasingly interacting, but also because the resource uses have been expanding, and they have been included in global economic mechanisms" (Vallega, 2007, p. 285).

As a result of Chapter 17 of Agenda 21, the UN established the Barbados Program of Action (BPoA, formally known as the United Nations Programme of Action on the Sustainable Development of Small Island Developing States) in 1994 (Koonjul, 2004). This is a more comprehensive report that addresses economic, environmental, and social challenges of SIDS and provides national, regional, and international development strategies (United Nations Division for Sustainable Development, 1994).

2.1.2.1. International Energy Frameworks for SIDS

The first policy that specifically addressed energy in SIDS was the South Pacific Regional Environment Program (Stuart, 2006). This was developed in the early 1990s and "suggested the following energy policy strategies for the Pacific Island region":

- implement further energy conservation programs (especially for outer islands);
- use stored solar power combined with diesel to reduce peak demand;
- increase fossil fuel prices and remove energy subsidies in phases and
- conduct greater research and development on alternative energy (Stuart, 2006, p. 143).

While these strategies have environmental benefits and have the potential to contribute to a more reliable energy system, they are limited and not as comprehensive as those stated in the BPoA.

One section of the BPoA specifically addresses Energy Resources. Table 1, below contains the action and policy measures as stated in section VII. Energy Resources of the Barbados Program of Action.

A. National action, policies and measures
(i) Implement appropriate public education and awareness programmes, including consumer incentives to promote energy conservation. (ii) Promote the efficient use of energy and the development of environmentally sound sources of energy and energy-efficient technologies, paying special attention to the possibilities of using, where appropriate, economic instruments and incentive structures and the increasing economic possibilities of renewable sources of energy. (iii) Establish and/or strengthen, where appropriate, research capabilities in the development and promotion of new and renewable sources of energy, including wind, solar, geothermal, hydroelectric, wave and biomass energy, and ocean thermal energy conversion. (iv) Strengthen research capabilities and develop technologies to encourage the efficient utilization of non-renewable sources of energy.
B. Regional action
(i) Establish or strengthen research and policy capabilities in the development of new and renewable sources of energy, including wind, solar, geothermal, hydroelectric, wave and biomass energy. (ii) Assist, where appropriate, in the formulation of energy policies, standards and guidelines for the energy sector that are applicable to small island developing States, and enhance national capacity to effectively plan, manage and monitor their energy sectors. (iii) Gather and disseminate information, and promote regional cooperation and technical exchanges among small island developing States on energy-sector issues, including new and renewable sources of energy.
C. International action
(i) Support the research, development and utilization of renewable sources of energy and related technologies and improve the efficiency of existing technologies and end-use equipment based on conventional energy sources. (ii) Formulate and ratify international agreements on energy-sector issues in relation to sustainable development in such areas as carbon emissions and the transportation of petroleum (for example, the use of double-hulled tankers). (iii) Develop effective mechanisms for the transfer of energy technology and establish databases to disseminate information on experience in the use of new and renewable sources of energy as well as on the efficient use of non-renewable energy sources. (iv) Encourage international institutions and agencies, including public

international financial institutions, to incorporate environmental efficiency and conservation principles into energy-sector-related projects, training and technical assistance, and, where appropriate, to provide concessionary financing facilities for energy-sector reforms.

(v) Develop effective and efficient ways of utilizing, disposing of, recycling and reducing the by-products and waste of energy production.

Source: United Nations Division for Sustainable Development, 1994

There have been further developments of organizations and policies which "…will accelerate trade and energy cooperation. These include CARICOM—the Caribbean Common Market, Mercusur— the Southern Common Market, The San Jose Accord, and the Association of Caribbean States" (Haraksingh, 2001, p. 648). While these are specific to Latin American countries and the Caribbean, in January 2005, the Mauritius Declaration and the Mauritius Strategy were developed out of the UN Conference on Small Islands. Together, the Declaration and Strategy are a "pro-active program of action" (Stuart, 2006, p. 146) aimed at achieving sustainable development in SIDS. As part of this program, small islands are encouraged to develop energy policies holistically using broad-based considerations (e.g. considerations for community, economic, environment, etc.).

In addition to aiding sustainable energy development, these policies and programs have two other benefits. First, they help to reduce the energy wastage that results from ignorance and malpractice (Haraksingh, 2001) by spreading awareness on energy issues. Second, they act as tools to "…ensure true costs, including externalities such as environmental effects, are estimated in order to correctly develop energy policies" (Haraksingh, 2001, p. 653). This way, not only are energy-users affected by energy policy, but decision-makers are encouraged to create sustainable policies with achievable goals.

Unfortunately, despite the number of programs and policies developed to assist in the sustainable development of energy systems in SIDS, their benefits do not always materialize. International cooperation is a long process, making the policies slow to develop. Also, low income communities continue to have priorities that relate directly to livelihoods in the form of working and living conditions (Douglass, 2006). These priorities have influenced the types of energy systems found in SIDS today and have limited the amount of sustainable energy system development.

2.1.3. Current Energy Situation in SIDS

While many programs have been developed to assist sustainable energy development in small island states in the Caribbean, there is still a heavy dependence on imported fossil fuels which has negative implications. Trinidad and Tobago remain the primary producers of oil in the Caribbean although Barbados produces a small amount of offshore oil as well (Haraksingh, 2001). Thus, for most SIDS, energy is largely derived from fossil fuels that are imported. There are several negative implications here. First, there are no bulk electricity markets or competition to reduce prices, second (and resultantly) energy is monopolized, and finally, where there is privatization, there is usually foreign investment (Stuart, 2006) which inhibits local financing and economic growth.

Although small islands tend to rely heavily on petroleum-based fuels, they "…have ample but unutilized renewable energy resource potentials that can contribute to sustainability" (Stuart, 2006, p. 139), and there are additional characteristics of SIDS that support this. First, there are economic considerations. In general, islands with a higher cost of conventional fossil fuel-derived electricity bodes well for the development of alternatives. In this case, the price of more sustainable alternatives will not seem high (Stuart, 2006). In addition, Haraksingh (2001, 649) states that "with limited financial resources, it is encouraging to note that many studies have reported significant decline in the unit cost of renewable energy technologies within recent times", which could greatly influence the future development of sustainable energies. There is also a cost savings when producing energy locally as "transmission and distribution may contribute as much as 30% to the cost of delivered electricity in a large continental system" (Stuart, 2006, p. 140). Therefore considerable costs and also the amount of land used for transmission and distribution can be saved with small distributed energy systems. Not only can the cost of energy be lowered, but business and employment opportunities can become available through the development of renewable energy in SIDS (Stuart, 2006; Haraksingh, 2001). As such, governments are beginning to recognize alternative energies' potential to improve socio-economic conditions (Stuart, 2006; Haraksingh, 2001). However, it should be noted that long term investment is often needed in the development of renewable energy and so SIDS typically look to large rich countries for research and development assistance, and often work in conjunction with them (Stuart, 2006).

There are also geographic considerations for renewable energy development. The limited land area of SIDS may actually work in their favour in terms of the logistics of electricity generation and delivery. Stuart (2006) explains:

> In small islands, electricity may be produced in stand-alone generation plants, which supply power directly to the local distribution network or to a single industrial facility. These so-called distributed generation systems, which include engines, small turbines, fuel cells and photovoltaic systems, can contribute to sustainability since they can produce electrical power not only from fossil fuels but from other sources such as household waste, biomass or photovoltaic cells (p. 140).

This favors a decentralized electrical system where the generation 'plant' or source is connected to a local or community energy system. The benefits of decentralization include adaptation to meet local needs, local economic development, (Kauneckis & Andersson, 2009), participation and education of community members, and improved energy security.

Furthermore, there are social considerations for alternative energies. For example, to increase the adoption of alternative energy systems, Stuart (2006) suggests that buy-in programs for the community will make these systems more appealing and, hence, more successful with community support. More holistically, alternative energy systems have the potential for more intrinsic value as they offer a sustainable relationship between community and environment. Here, Vallega (2007) emphasizes that the integrity of island culture be maintained and incorporated into sustainable energy systems.

No matter their size or location, it is important that energy systems are designed appropriately for SIDS (Stuart, 2006). This is to say that an energy system or combination of energy systems that works in one SIDS may not be the best option for another. For example, "in Reunion (France), 2 million tons of sugarcane are produced a year, providing 640 000 tons of bagasse or the equivalent of 120 000 tons of heavy fuel" (Stuart, 2006, p.140). During the sugar season, the bagasse is fuel for co-generation plants while waste heat, an output of the system, can be used for district heating: this could be an alternative energy option for other SIDS with sugar production. Arguably, solar water heaters are the best-developed form of alternative energy in the Caribbean (Haraksingh, 2001). Although they have not been developed to their full potential, they have been applied to the tourism sector (Haraksingh, 2001). In fact, the use of solar energy has been applied historically as solar crop drying is the oldest of renewable energy technologies used in the Caribbean (Haraksingh, 2001). Therefore, adopting sustainable, alternative energy systems is not a foreign concept to SIDS.

2.2. <u>Biodiesel</u>

Biodiesel falls under the general category of 'biofuels' which have caused some controversy in regards to two issues: global food resources and resource-heavy production methods.

Biofuels, such as ethanol used for transport, are commonly produced from agriculture crops. In 2008, 2.3% of the global cropland was being used for fuel crops which were grown mainly in the United States, Canada, the European Union, and Latin America.[2] Though this amount of land may seem small, it represents a 34% increase in the global amount of land used for fuel crops from the previous year. In a global environment where petroleum fuel prices are rising and energy demand is increasing, farmers are beginning to switch from food crops to increasingly lucrative fuel-crops. This is problematic "in a world where 25,000 people die of hunger every

[2] A note in the UNEP study regarding land use statistics states "some of the land requirement data… may represent rather conservative estimates" (UNEP, 2009, p. 63).

day" (Bourne, 2007, p. 53). While Estill (2005) argues that global hunger is a distribution problem rather than a supply problem, diverting land from food crops to fuel crops could "reduce food security and drive up food prices" globally (Bourne, 2007, p. 63) resulting in an overall negative impact.

The second controversial issue surrounding biofuels for transport and energy takes note of resources required for processing and production. One such resource is water. In 2007, irrigation water used for biofuels production was six times than that used for global drinking water (UNEP, 2009). However, this is still modest in comparison to food production as only 1.7% of total irrigation water is used for biofuels (UNEP, 2009).

Another resource used in biofuels production, ironically, is fossil-fuel energy. Every biofuel has a different energy balance (i.e. fossil fuel energy used to make the fuel compared with the energy in the biofuel). Furthermore, the energy balance of a specific biofuel varies depending on the methods and inputs used. For example, ethanol made from corn has an energy balance of 1.3:1 (1.3 units of corn ethanol energy produced for each unit of fossil-fuel energy used) (Bourne, 2007). Meanwhile, ethanol made from sugarcane has an energy balance of 8:1 (Bourne, 2007). The greater the ratio, the more efficient the biofuel production process. In the example above, sugarcane produces more biofuel energy per unit of fossil fuel energy used in the production process. Controversy arises when the ratio is low since valuable fossil fuels could be used more efficiently than in the production of a particular biofuel with a poor energy balance ratio.

While these two arguments (i.e. global food supply and resource inputs) against biofuels are the most common, other critiques of include loss of biodiversity through large fuel-producing monocrops (UNEP, 2009) and increased fuel and energy consumption of 'sustainable' fuels (Kemp, 2006). In response to the latter argument, it should be noted that energy conservations programs are needed globally regardless of the energy source(s) being used.

In light of these critiques, biofuels offer alternatives to petroleum-based energy as they are renewable, available locally, and have often proven to reduce emissions and enhance engine performance (Al-Widyan, Tashtoush and Abu-Qudais, 2002b). Surprisingly, their use is not new. In fact, Rudolf Diesel's patented engine in 1892 (Kemp, 2006) was designed to run on peanut oil (Boyd et al., 2004; Bourne, 2007). Crude vegetable oil can be used in diesel engines for a short time. However, due to the fuel's high viscosity and low volatility, a number of problems can arise such as "serious carbon deposits, injector fouling, clogging of fuel lines, [and] starting difficulties in low temperatures" (Al-Widyan et al., 2002b, p. 92). There have been many grassroots initiatives to develop engine modification systems to allow the use of straight vegetable oil (SVO) in diesel engines. These SVO systems basically consist of a separate fuel tank and a method for heating the fuel (in order to lower viscosity). These systems are popular in the grassroots community as they use filtered waste vegetable oil (WVO) and, therefore, aid with waste management while providing cheap, if not free, fuel. Though these SVO systems have many merits, they are not recommended for a community energy system since there is a lot of troubleshooting involved, and should only be explored by those who have the time and patience to work with such a system (Estill, 2005). Instead, biodiesel-based systems, in which the fuel is produced from SVO or a number of other sources, are recommended since the fuel closely mimics the properties of standard diesel fuel and the system can be operated by anyone familiar with diesel engines.

Biodiesel "is a safe, non-toxic, biodegradable, and renewable fuel that can be easily used in unmodified diesel engines" (Boyd et al., 2004, p. 19). It can be obtained inexpensively and "from a renewable, domestic resource, thereby relieving the reliance on petroleum fuel imports" (Zhang et al., 2003a, p.1). The following sections will describe the inputs and production of biodiesel as well as the fuel's uses, benefits, and drawbacks.

2.2.1. Feedstocks and Inputs

There are three main 'ingredients' to make biodiesel. The first is plant or animal-based oil or fat. "The use of waste cooking oil instead of virgin oil to produce biodiesel is an effective way to reduce the raw material cost because it is estimated to be about half the price of virgin oil. In addition, using waste cooking oil could also help to solve the problem of waste oil disposal" (Zhang et al., 2003a, p.2). While WVO is the most readily available feedstock for biodiesel in developing countries (Al Widyan & Sl-Shyoukh, 2002a), there are studies using waste animal fat (Tashtoush, Al-Widyan, & Al-Jarrah, 2004), fly larvae (Estill, 2005), Algae (Bourne, 2007), and even human liposuction remains (Estill, 2005; Steenblik, 2006) to make the fuel.

An alcohol and a catalyst are the other two 'ingredients' required. "Vegetable oils contain up to three fatty acids linked to a glycerin molecule with ester linkages and is called triglycerides" (Demirbas, 2002, p. 2352-2353). The alcohol, with the aid of the catalyst, breaks down this chain resulting in glycerine and an alkyl ester, such as methyl ester or ethyl ester, known commonly as biodiesel. Ethanol is a more sustainable option for the alcohol used as it can be produced from renewable agricultural sources (Al-Widyan & Sl-Shyoukh, 2002a). However, it "inherently has more water content than methanol and must be purified prior to use" (Boyd et al., 2004, p. 70). Methanol can be produced renewably from biomass decomposition (Boyd et al., 2004; Chhetri & Islam, 2008), however, even with tax incentives, this renewable method of obtaining methanol cannot financially compete with natural gas-derived methanol (Boyd et al., 2004). In order to lower toxicity of biodiesel, methanol can be recovered in the biodiesel production process. This recovered methanol can be reused and, therefore, helps reduce the amount of new methanol required.

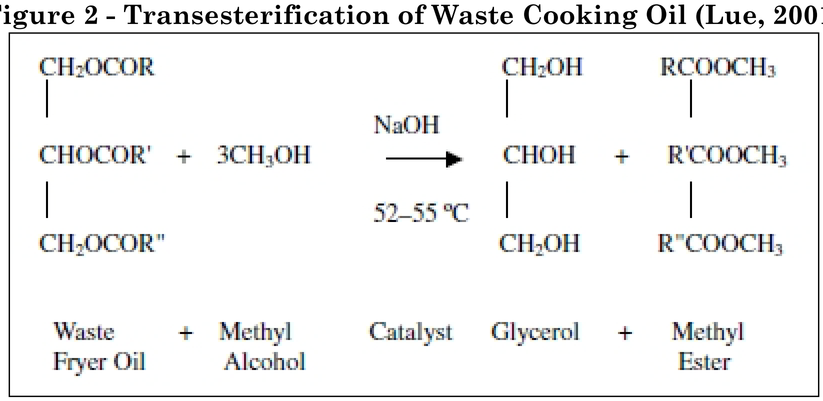
There are some discrepancies regarding what type of catalyst should be used. For example, Al-Widyan and Sl-Shyoukh (2002a) state that "…while basic catalysts may be used with many neat (unused) VOs, basic catalysts could not be utilized with used VOs, which contained 10–15% free acids" (p. 254). In this case, it was found that sulfuric acid, H2SO4, was a superior catalyst when compared to hydrochloric acid, HCl (Al-Widyan & Sl-Shyoukh, 2002a). Zhang et al. (2003a) compared the use of alkali-based catalysts to acid-based catalysts, finding that using alkali-based catalysts was a complex process requiring the most equipment, while acid-based catalysts required less equipment but more methanol and, hence, larger equipment to complete the process. Most of the literature favoured an alkali-based catalyst such as sodium hydroxide (NaOH) or potassium hydroxide (KOH) (Demirbas, 2002; Chhetri & Islam, 2008; Boyd et al., 2004), mainly because of their faster reaction times (Zhang et al., 2003b).

There are differences of opinion about which of the two alkaline catalysts are best. KOH is more expensive than NaOH but produces a liquid or 'softer' glycerol at the end of biodiesel production (Boyd et al., 2004; Kemp, 2006). This can make the glycerol easier to handle, however, Kemp (2006) suggests this is irrelevant if a proper glycerol processor is used as part of a biodiesel production system. Furthermore, Boyd et al. (2004) state that KOH should be used since the by-product can be used as a fertilizer. However, Kemp (2006) states that this process is rarely undertaken as "…quantities generated are small and there is a possibility that toxic methanol contamination will leach into the ground water" (p. 443).[3]

2.2.2. Production Process

Biodiesel is simply a plant or animal based oil without glycerine molecules. It is created through a chemical process known as transesterification, shown below in Figure 2.

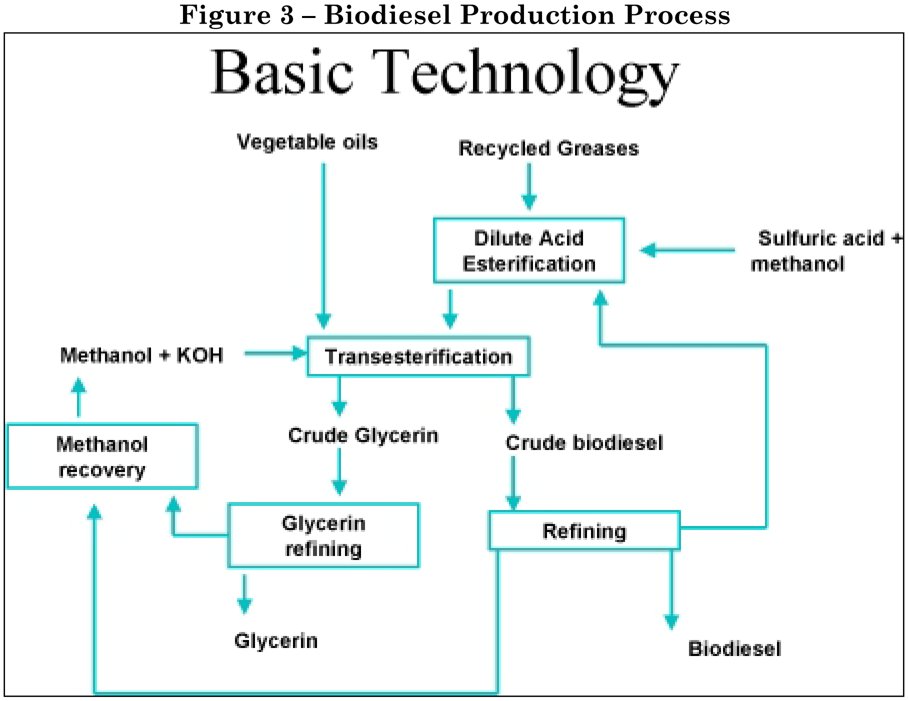
Figure 2 - Transesterification of Waste Cooking Oil (Lue, 2001)



[3] It should be noted that Demirbas (2002) created biodiesel without a catalyst. However, this required much more methanol and the outcomes were not clear. Therefore, this is not a recommended method.

The goal of transesterification is to lower viscosity of the vegetable oil to allow the fuel to flow through a diesel engine's fuel system. This is done by mixing the vegetable oil, a fatty acid chain linked with a glycerin molecule, with an alcohol in the presence of a catalyst. During the transesterification process, the glycerin molecule is released, resulting in fatty acid methyl esters (i.e. crude biodiesel) which are less dense and rest at the top of the mixture, and unrefined glycerin which settles below the biodiesel (Al-Widyan et al., 2002a/b; Zhang et al., 2003a; Tashtoush et al., 2004; Gomez et al., 2000, Kemp, 2006). Before transesterification, WVOs are usually filtered to remove any food remains. The crude biodiesel is then washed or refined with water to recover any remaining alcohol or catalyst, a process which continues until the washing water is neutral (Al-Widyan & Sl-Shyoukh, 2002a). During this 'washing', methanol can be recovered in order to be used again in the transesterification process. The biodiesel production process (U.S. Department of Energy, 2006) is shown in Figure 3, below.

Figure 3 – Biodiesel Production Process



Biodiesel can be produced on a very small scale using a household kitchen blender to mix the vegetable oil, catalyst, and alcohol. Individual refining processes vary, from leaving the mixture for a few days to allow the biodiesel to separate from the glycerin then filtering the biodiesel before using it as fuel, to washing the biodiesel by mixing it with water and allowing the mixture to separate. This latter process is often repeated several times. Variations of these basic homemade systems are how many biodiesel initiatives began (Estill, 2005).

Large or commercial-scale biodiesel can be made using either a batch or continuous process. The batch system is simpler and recommended for small-scale production (i.e. less than 4million litres per year) (Kemp, 2006). These systems are less automated and it can take up to 5 days to complete a 'batch' of biodiesel (Boyd et al., 2004). In the continuous systems, vegetable oil and reactants are continuously added, eliminating the need to charge and discharge the system. These systems are "best suited to more centralized, large capacity facilities, producing well over 10 million litres per year where the economies of scale begin to take effect" (Boyd et al., 2004, p. 76).

The energy balance of biodiesel depends on the inputs necessary for production. For exmaple Bourne (2007) claims that biodiesel has an energy balance of 2.5:1, Earley and McKeown (2009) report that biodiesel made from waste vegetable oil has an energy balance of 5-6:1, and Estill (2005) calculated his biodiesel operation, producing 200 gallons per month from waste vegetable oil, to have an energy balance of 4.14:1. Therefore, the efficiency of biodiesel production depends heavily on the ingredients used and the method by which it is made.

2.2.3. Benefits and Drawbacks

2.2.3.1. Technical

As mentioned above, biodiesel is biodegradable, non-toxic, can be used in unmodified diesel engines, and can be blended with petroleum-based diesel fuel (VanDyne, 1996). Many tests have been done to evaluate the performance of 100% biodiesel as well as blends of biodiesel and petroleum diesel. Al-Widyan et al.

(2002b) used a single-cylinder diesel engine [4] and tested the performance of the engine running on blends of "100% ester (100O), 75:25 (25D), 50:50 (50D), 25:75 (75D), and 100% diesel fuel (100D)" (Al-Widyan et al., 2002b, p. 93).[5] The study found that biodiesel blends and even 100% biodiesel provided the best engine performance. In a different study, Cetinkaya and Karaosmanoglu (2005) also used a single cylinder engine.[6] This study found that 100% biodiesel and blended 20% biodiesel (80% petroleum diesel) performed nearly the same as 100% petroleum diesel fuel with only a reduction of about 1% in power generation. This change in performance was so low that it was considered negligible (Cetinkaya & Karaosmanoglu, 2005). Both these studies suggest that biodiesel can be a viable substitute for petroleum-based diesel fuel.

It should be noted that, even when stored properly, biodiesel quality decreases slightly over time. However, changes are only significant past twelve months of storage (Bouaid, Martinez, & Aracil, 2007).

2.2.3.2. Emissions

Some authors, such as Cetinkaya and Karaosmanoglu (2005), Al-Widyan et al. (2002b), and Lue, Yeh, and Wu (2001), have suggested that biodiesel use results in a reduction in engine emissions. Then again, various emissions are dependent on the type of engine that is used to perform the emissions studies. As Kemp (2006) simply states: "different engine technologies have different emission profiles" (p. 70). Emissions results also depend on the type of emission test used (Gomez et al., 2000). According to Gomez et al. (2000), "these parameters often have an effect on the emissions data larger than the composition and properties of the fuel under

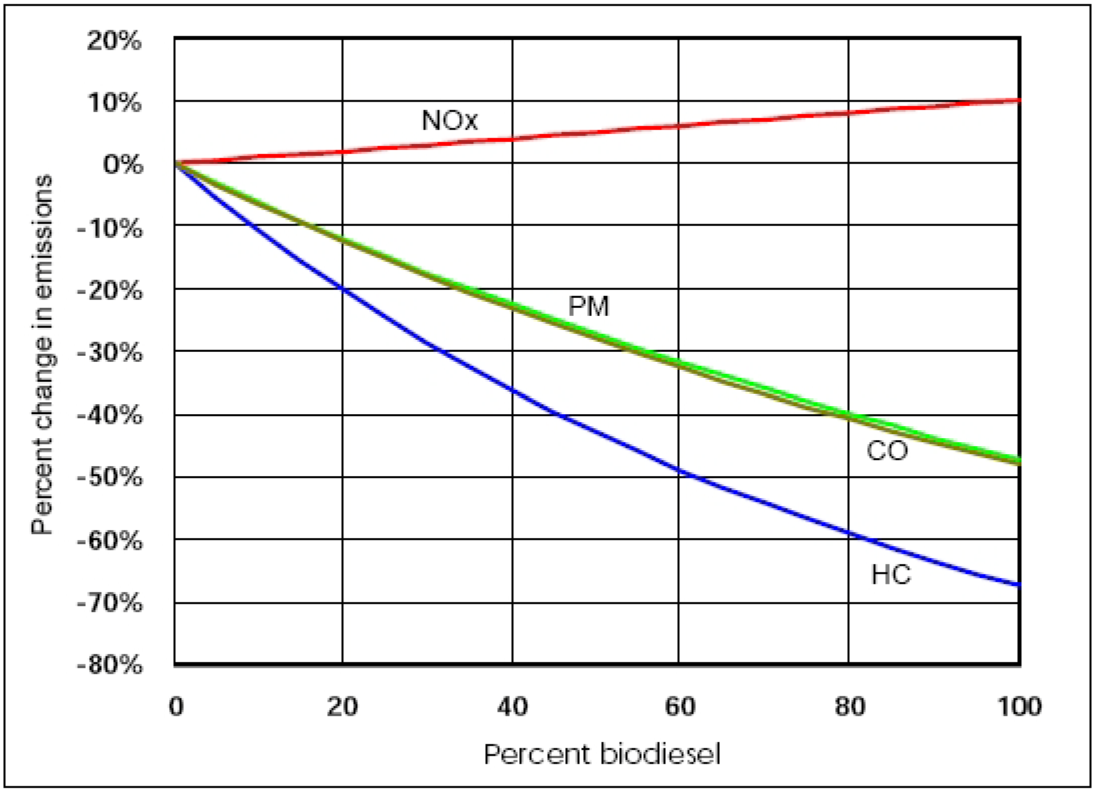
[4] Specifically, this study used a "British-made standard TEQUIPMENT TD 43 test rig consisting of a direct-injection (DI), naturally aspirated, water-cooled, single-cylinder variable compression engine coupled to an electric dynamometer" (Al Widyan, 2002b, p. 93).

[5] Here, 100% ester is pure biodiesel.

[6] Specifically, the study used "a product of Anadolu Motor, 3 LD 510 coded diesel engine. The test engine was a 90-mm stroke, 1-cylinder diesel engine with 510-cm3 displacement and had a power capacity of 9 kW and maximum rotation speed of 3000 rpm" (Cetinkaya et al., 2005, p. 649).

test” (p. 13-14). Therefore, the emissions results varied across studies. The general trend found in the literature on emissions is summarized in Figure 4, below.

Figure 4 - Average emission impacts of biodiesel for heavy-duty highway engines (U.S. EPA, 2002)



The literature consistently reports that biodiesel eliminated or produced negligible sulfuric oxide (SOx) emissions in comparison to petroleum-based biodiesel. This is due to the absence or insignificant sulfur content in vegetable oil and, hence, biodiesel (Cetinkaya & Karaosmanoglu, 2005; Gomez et al., 2000; Lue et al., 2001; U.S. EPA, 2009). It is for this reason that specific SOx emissions results are not stated in the studies nor are they included in Figure 4, above.

The studies confirmed overall reductions in the emissions of particulate matter (PM), smoke caused by unburned hydrocarbons (HC), carbon monoxide (CO), and carbon dioxide (CO_2), while suggesting that nitrogen oxides (NO_x) emissions increased slightly (Al-Widyan et al., 2002b; Boyd et al., 2004; Cetinkaya &

Karaosmanoglu, 2005; Gomez et al., 2000; Lue et al., 2001; U.S. EPA, 2009). It is suggested that increases in NO_x emissions from biodiesel is related to the fuel injection timing (Cetinkaya & Karaosmanoglu, 2005) and biodiesel's high oxygen content due to the fatty acid triglycerides in vegetable oil (Tashtoush et al., 2004). This is an active and much needed area of research (Gomez et al., 2000).

2.2.3.3. Economic

The raw, yet renewable, forms of oil account for approximately 70-95% of biodiesel production costs (Zhang et al., 2003b). Therefore, most authors recommend using WVO as this is the most cost-effective method of to produce biodiesel (Al-Widyan et al., 2002b; Kemp, 2006; Zhang et al., 2003b).

2.3. Integration of Biodiesel Energy Systems with Sustainable Development in SIDS

A biodiesel-based energy system provides a theoretical solution to many of the development challenges faced by SIDS. If implemented properly, the system can maximize benefits while minimizing drawbacks while addressing air quality, waste management, cost of energy, local energy production, and local economic development.

Biodiesel is non-toxic and burns cleaner, producing less emissions. This is especially significant in developing countries where programs to decrease smog and pollution do not exist. Here, a biodiesel energy system can help improve community health. Indeed, the National Biodiesel Board (2002) produced a press release on biodiesel reducing the risk of cancer.[7] This is just one way in which the human health benefits of biodiesel use instead of petroleum-based diesel use is suspected.

Also important to environment and human health is proper WVO disposal. A biodiesel energy system can affect this waste management system both positively and negatively. The disposal of WVO can be costly for businesses such as

[7] Unfortunately, no peer-reviewed articles were found to support this and the press release did not include any citations.

restaurants and hotels. Here, biodiesel provides an opportunity for 'free' disposal (Kemp, 2006), which helps reduce overhead costs. However, this may simultaneously eliminate the need for a WVO disposal service, hence negatively affecting existing businesses. The relevance of this latter impact is greatly dependant on the traditional method of WVO disposal.

The cost of biodiesel is dependent on a number of factors including feedstock type, for example WVO versus virgin vegetable oil, and production scale. "Previous work on the community-based biodiesel production concept suggests that in some situations biodiesel may be competitive with petro-diesel on a price basis" (VanDyne, 1996, p. 3). This would mean that there would not be a significant change in cost of fuel from regular diesel to biodiesel. However, Zhang et al. (2003b) disagree stating that biodiesel "costs approximately one and a half times that of petroleum-based diesel depending on feedstock oils" (p. 229), making biodiesel significantly more expensive.

Whether the cost of biodiesel is more or less, the fact remains that a biodiesel-based energy system has the potential to contribute to community energy production. In fact, "It is possible for small island developing states (SIDS) to employ a range of modular distributed generation equipment to produce sustainable systems to their advantage" (Stuart, 2006, p. 141). Since biodiesel can be locally produced, such a system could aid in energy security and reliability, as well as local infrastructure and economic development.

There are many economic impacts to a biodiesel energy system and VanDyne (1996) explains the macroeconomic effects of such a system using a case study in Missouri, U.S.A.[8] From this case study, it was found that "overall employment from the operational side of a biodiesel plant will be positive, although net job creation is not expected to increase substantially" (VanDyne, 1996, p. 4) as new jobs relating to the operation of the biodiesel plants were offset by jobs lost in other production

[8] This study assumed that biodiesel was produced from existing grain farms in community-based plants: 1 plant to produce 500,000 gallons, 13 plants to produce 6.24 million gallons, and 32 plants to produce 15.6 million gallons (VanDyne, 1996).

areas (e.g. grain production and petroleum diesel systems). However, temporary jobs would be created during the construction of the biodiesel plants.

Van Dyne (1996) also explained that an increased tax base could result from the development of a biodiesel production plant through property tax as well as employee income tax. This could have potential benefits for SIDS's government operating budgets as some aspects of community-biodiesel could be taxed. This would, theoretically, provide governments with the financial capacity to develop community programs and initiatives.

However, the potential for the benefits mentioned above can only be realized through careful planning and development of a community biodiesel energy system.

2.4. Political Ecology

The study of political ecology influences this thesis as it is more than simply a study of the human-environment relationship; it is a study of how economic, political, and social structures affect the natural environment (Robbins, 2004). Political ecology helps enhance our understanding of complex systems and has become a useful in articulating the context in which sustainable practices are to be developed. More specifically, sustainable development problems are largely attributed to political and economic systems and political ecology attempts to answer the questions 'how?' and 'why?' These are important questions to be answered and a defined context with which to study them is needed. Therefore, political ecology can be understood as "less a coherent theory than a fluid and ambivalent space that lies among political economy, cultural theory, history, and biology" (Armitage, 2008).

Though political ecology may lack efficiency as a study tool with its ambiguous definition of ecology and the natural environment, the field is very adaptable as it provides a range of factors (e.g. cultural, political, social, economic, moral, etc.) to be studied. As this allows the study to break down issues, it is able to address questions of causation. Here, political ecology is able to analyze scale, structures, and interactions and uses these variables to create chains of explanation. Neumann

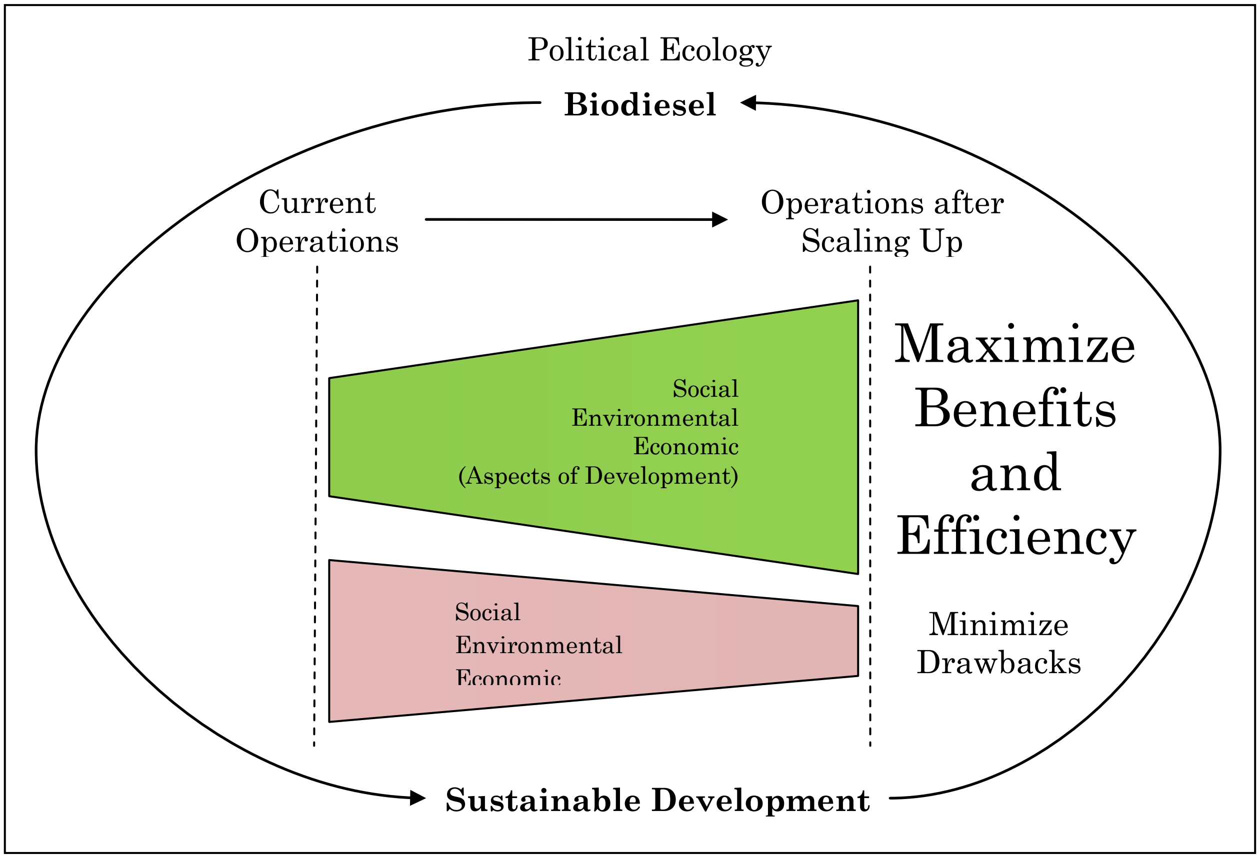
(2005) further supports the idea of chains of explanation as a function of political ecology by demonstrating how small events can result in large-scale change of systems (social, environmental, etc.) over time.

Political ecology, at times, seems to focus primarily on system theories and models that summarize global environmental issues and, while it is useful to understand these theories and models for future decision-making, political ecology is home to more readily observable, 'real-world' studies. Indeed, this project focuses on the use of a community-based biodiesel energy system in SIDS. Political ecology can be used to assist in understanding who the key decision-makers are. As described by Adger, Benjaminsen, Brown, and Svarstad (2001), this subscribes to the populist discourse which includes community-based approaches and the decentralization of development and management. Political ecology theories can also help to determine who will use the resource and where the resources will come from. Furthermore, the theories can also be useful in addressing issues of scale. For example, 'should the vegetable oil be used only by the community in the immediate area of where it is sourced?' and 'what implications does transport of the fuel have on the natural environment?' are possible questions regarding spatial scales. Also, the idea of chains of explanation will help to answer questions such as 'how much energy from biodiesel can be provided for the local community?' and 'what environmental ramifications will result from a biodiesel energy system?' Together, the various aspects of political ecology will help to create the questions that shape this project and provide a variety of lenses through which findings can be analyzed.

2.5. Conceptual Framework

The broad conceptual framework for this project has been developed in consideration of development challenges facing SIDS, the goals of sustainable development, the application of biodiesel as an alternative form of energy, and the relationships between systems used in political ecology. The conceptual framework is shown in Figure 5, below.

Figure 5 - Conceptual Framework



The idea of sustainable development and the application of biodiesel work together in a way that will maximize external (e.g. social, environmental, and economic) benefits while minimizing external drawbacks. The relationships between various systems (e.g. environmental, social, etc.) are complex and are analyzed using political ecology.

In consideration of practical operations, the external effects of a biodiesel-based energy system are linked to the system's internal operations. Therefore, in order for external benefits to be maximized, internal operations must become more efficient and obstacles to operations must be minimized.

2.6. Evaluation Framework

The following section, Critical Success Factors for a Biodiesel Operation, describes the necessary elements for a single biodiesel operation as well as common problematic areas. This section introduces the first evaluation framework for the case study as a biodiesel operation must be efficient and successful before it can be scaled up in such a way that its benefits are maximized. The next section, Scaling-up Small Development Systems, will introduce the second evaluation framework and will identify the necessary steps to scale up a biodiesel operation. Both evaluation frameworks will be used to analyze the findings of the field research by identifying where and how scaling-up can take place.

2.6.1. Critical Success Factors for a Biodiesel Operation

Broadly, the way an enterprise or project is developed and operated will affect whether or not that enterprise or project is able to achieve its goals. In the case of biodiesel, Boyd et al. (2004) provide "four critical strategic factors that will impact the success or failure of a potential biodiesel project…:

1. The ability to balance feedstock supplies, processing technology and market demand/penetration for products produced within an integrated system that that is both reliable and efficient;
2. The ability to form key and stable strategic alliances with feedstock sources/suppliers, distributors, end users and other stakeholders;
3. The ability to anticipate and to deal effectively with competitive pressures;
4. The ability to accomplish the above while providing a risk/return profile that will allow the project to be financed and to maintain financial health." (p. 116).

It should be noted that the first item on this list is especially important when making considerations to 'scale-up' and this will be described further in the following section. However, in summary, production must be efficient, input (e.g. feedstocks) and output (e.g. endusers) must be constant, and the operation must remain competitive and financially feasible. This list will provide a baseline to help analyze biodiesel systems development and demonstrate how a community biodiesel energy system can address some of the development challenges facing SIDS.

The four critical success factors in the list above call for particular technical and social circumstances. To help identify technical circumstances, McDonald (1999) provides the following table of problems encountered by entrepreneurs in small island states in the beginning stages of enterprise development, such as a biodiesel system.

Table 1 – Common Problems in Enterprise Development in SIDS (McDonald, 1999, p. 167)

Problems	Frequency among Entrepreneur
Raw Material	54%
Machinery and Equipment	52%
Finance	51%
Labour	33%
Licence/Approval	20%
Technical Know-how	19%
Packaging	4%

Raw material, machinery and equipment, and finance are frequently problematic. Therefore, special attention is needed in these areas to help avoid obstacles and delays to biodiesel system development.

While technical success factors are important, they must exist within the proper social settings in order to materialize. When describing capacity building, appropriate energy policies, and energy restructuring, Stuart (2006) says "careful assessment of the outcomes of reform must be carried out. In other words, the reform needs to be carefully driven to achieve approval and support by the community" (Stuart, 2006, p. 145). This means that the development of biodiesel energy systems must be done in a way that will enable them to be approved and supported by communities in SIDS. Even more so than just approval and support, participation by the community helps develop projects that cater to the community's needs. According to Wright (2002),

> some energy projects to introduce new, fuel-efficient techniques or renewable technologies, particularly in developing countries, have failed partly because the projects and technologies have been designed by engineers without input from end users. End users… should participate in the design of energy projects and the adaptation of technologies to suit local needs and preferences (p. 380-381).

Of course, community involvement should continue beyond the development stage. Participation can include maintenance activities or simply be feedback on the operation.

These critical success factors will not only help to analyze existing biodiesel energy systems, but will identify key areas on which to focus when starting out a new biodiesel facility in SIDS. This will ensure an established and functional system with potential to be scaled-up.

2.6.2. <u>Scaling-up small development systems</u>

The notion of 'scaling-up' has recently become an important aspect of development research as it provides a specific and practical context within which research results can be implemented (NRSP, 2005) and is appropriate for a biodiesel energy system. "Scale up usually refers to taking a tested concept, pilot project, initiative, enterprise and expanding it, in terms of people served, revenues generated, or other targets" (Creech, 2008, p. 5). One study used the terms 'horizontal' and 'vertical' to describe methods of scaling-up in Natural Resources Management (NRSP, 2005). Horizontal scaling up can be thought of as obtaining more clients or participants geographically for the current system. It can be accomplished through making an existing operation larger thereby increasing output from one central location or by increasing the number of units in a decentralized format so that overall production increases as a sum of various production facilities. Horizontal scaling-up can be done with biodiesel by either buying a larger processing unit to yield a larger batch of biodiesel at once or by adding several smaller units. On the other hand, "vertical scaling-up is institutional in nature and involves other sectors and stakeholder groups in the process of expansion – from the level of grassroots organisations to policymakers, donors, development institutions and international investors" (NRSP, 2005). This type of scaling up is political and bureaucratic in nature. This relates to a biodiesel energy system in how the operation is run (e.g. stakeholders involved) and what opportunities and limitations exist given the energy and development policies of a given SIDS.

As one of major components of this research is to determine how to effectively scale up a biodiesel-based energy system, it is important to refer to the literature for examples of other projects that have been 'scaled-up'. An International Institute for Sustainable Development report lists eight steps for scaling up initiatives:

Table 2 - Scaling Up Initiatives (Creech, 2008, p. 9)

1. Establish that the technical intervention, methodology or approach that is being considered for scaling up leads to desired results through carefully evaluated and documented research.
2. Assess possibilities for scaling up (need, available resources, political will, potential partners, etc. and potential barriers to scaling up (opponents and their arguments, policies, etc.).
3. Build consensus for scaling up among decision makers, implementers and leaders of those who participate in the programme/use the intervention through meetings, presentations, field visits, etc. with key individuals and groups.
4. Ensure that policies are supportive and that resources will be available.
5. Develop plans/proposals with decision-makers and implementers on the organizational structure and relationships of the scale-up, activities, management, monitoring and evaluation, training and technical assistance, etc. Programme designs or interventions should be simplified as much as possible and should be accessible in "user friendly" language.
6. Be prepared to solicit many donors and negotiate many hours in order to put all pieces into place. The amount of funding needed for large scale programs is often not available through only one donor. Negotiate contracts, budgets, work plans.
7. Prepare training and technical assistance teams and materials to work at regional or other level depending on organizational structure. Be flexible and adapt to meet local conditions whenever possible without losing essential elements of quality.
8. Programme implementers meet regularly on local, regional and national levels to monitor progress, detect problems, develop innovative solutions/approaches, strengthen skills and build team. Ensure that representatives from those who are participating in the programme (community men and women, etc.) participate in monitoring and evaluation at a minimum at the local level.

This list is the second evaluation framework and will help determine what must be done to scale-up a community biodiesel energy system and how this can be accomplished given the political, social, and environmental circumstances surrounding the system.

This evaluation framework contains elements of both horizontal and vertical scaling up. As mentioned above, horizontal scaling-up can be accomplished by making an existing unit larger or by increasing the number of units. While both will inevitably increase overall production, making an existing unit larger may be problematic in SIDS where importing larger equipment is costly and land area is at a premium. Therefore, increasing the number of units may be a more realistic and beneficial method of horizontal scaling-up. Indeed, Kauneckis and Andersson (2009) provide a list of the benefits which include more appropriate service, or energy, delivery as it is easier to accommodate preferences at the local level, improved accountability as operations are closer to the end user, and improved financial management as individual operations remain small in scale, all of which are said to help increase participation. The only drawbacks to decentralization described by Kauneckis and Andersson (2009) were related to local governments and included "the increased potential for elite capture, conflict over competition for new political resources opened at the local level, and exclusion of local minority populations" (p.24). While these concerns are related to vertical scaling-up and could impeded overall scaling-up activities, they are more frequent in less developed countries and, therefore, are not believed to be of significance to SIDS in the Caribbean.

2.6.3. Evaluation Framework Table

Table 4, below, incorporates the criteria of the two evaluation frameworks with the challenges facing development in SIDS.

Table 3 – Evaluation Framework

Evaluation Framework	**Challenges to Development Facing SIDS**												
Critical Success Factors	Small Populatio	Uneven Developm	Size	Imports	Resource Scarcity	Locationa l	Small Infrastru	Tourism	Low Exports	Governan ce	Poor	Fair	Good
1. Balance supplies, technology, and demand?				•	•		•						
2. Alliances with sources, end users, and other?		•		•		•	•						
3. Anticipate and deal with competitive pressures?		•		•	•		•						
4. Financial health?	•			•	•	•	•			•			
Scaling-up Initiatives													
1. Research the technical approach for scaling up?		•		•	•								
2. Assess possibilities for scaling up and potential barriers?		•				•	•			•			
3. Build consensus for scaling up?	•	•			•					•			
4. Ensure that policies are supportive and that resources will be available?	•			•	•	•	•			•			
5. Accessible and efficient programme designs for scale up?	•	•				•	•			•			
6. Donors? Funding?		•				•				•			
7. Prepare training and technical assistance? Flexible and adaptable to local conditions?	•				•	•	•			•			
8. Monitor progress, detect problems, develop solutions? Ensure that community participates?	•					•	•			•			

This shows how a community biodiesel operation has the potential to addresses these challenges. Take, for example, the first Critical Success Factor: a biodiesel operation's ability to successfully balance supplies, technology, and demand can reduce the amount of petroleum-based diesel imports, contribute to local resources (i.e. fuel), and add to the island's infrastructure. These relationships are discussed in more detail in Chapter 5.

Chapter 3. Methods and Case Study Context

3.1. Research Design

In order to achieve the objectives of this project, a research design, "…in a manner that aims to combine relevance to the research purpose with economy in procedure," (Palys, 1997, p. 76) is needed and, for this project, the research design involves the use of a case study. Case studies help us to "understand complex social phenomena" (Yin, 1988, p.14) and "allow[s] an investigation to retain the holistic and meaningful characteristics of real-life events" (Yin, 1988, p.14). The holistic 'picture' of the event will include all the phenomena – social, environmental, economic, etc. – that is analyzed in political ecology. Furthermore, "case studies are the preferred strategy when "how" or why" questions are being posed, when the investigator has little control over events, and when the focus is on a contemporary phenomenon within some real-life context" (Yin, 2003, p. 1).

Yin (1988) explains there are four tests to judging the quality of research designs and the most relevant test of these four is that of 'external validity.' This test is used to determine whether the study's findings are applicable to the other areas or cases (Yin, 1988, p.43). The external validity test appropriate to this project as the case study will be used to create recommendations for other small developing states. However, critics tend to state that a single case study cannot appropriately be generalized. Here it must be noted that studies are not statistically generalized but analytically generalized. In other words, "the theory…that lead to a case study in the first place is the same theory that will help identify the other cases to which the results are generalizable" (Yin, 1988, p.44). This supports the idea that a biodiesel-based energy system that works in Barbados could work in other SIDS having similar conditions.

Case study research and the use of qualitative data go hand in hand. Indeed, qualitative data, in the form of words or pictures, is collected in field research and "is usually use[d] for exploratory and descriptive studies" (Neuman, 1997, p.33). Palys (1997) describes the process of qualitative research:

> The qualitative approach typically involves beginning with individual case studies in context, trying to understand each situation on its own terms, and leaving open, for the moment, the question of whether generalizable theoretical concepts can ever eventually be drawn together in anything resembling a grand theory (p. 19).

In this way, theories can be developed *after* the qualitative research is conducted, not before. This being said, the project was approached with objectives and some anticipated findings.

While in the field, my objectives were to:

- Describe a biodiesel energy system from source-to-sink
- Describe the intention of the biodiesel enterprise and assess the operations effectiveness and efficiency
- Discover whether the initial intention of the biodiesel enterprise could work at a larger scale or whether or not benefits would arise from moving to a larger scale.

Anticipated findings related mostly to funding (as being a major obstacle to scaling-up) and government regulations (as being a bureaucratic limitation to scaling-up). However, these objectives could not be met in full due to the study's research limitations which are described in Chapter 5's discussion.

3.2. Data Collection

An initial literature review using journal articles, books, and websites was conducted in order to gain a better understanding of SIDS, their energy systems and development policies, biodiesel, and options for integrating biodiesel and sustainable development. This review helped identify gaps in the literature and aided the development of a model for scaling-up a community-based biofuel energy system.

In the field, there were three methods of data collection: interviews, direct observation, and participant observation. Themes in the literature were used to form interview topics and questions. Interviews were either semi-structured (n=5) or structured (n=12), the latter following a specific set of questions. The open-ended interviews were conducted with those who had a more participatory role in the biodiesel system as these informants were more likely to have formed opinions about the system and could, therefore, offer specific feedback. Focused interviews were conducted with informants who had limited interaction with the system. Data gathered this way were used to understand basic operation procedures.

The founder and manager of the biodiesel operation in Barbados was the primary source of in-field information which was gathered through on-going, informal interviews. Four more open ended interviews were conducted with various informants. These interviews were with informants who demonstrated a stronger interest in the biodiesel system and who could afford the time to participate in an open-ended interview. Five focused interviews were conducted with managers or employees responsible for setting aside waste cooking oil at five separate locations of the fast food chain, Cheffette. Finally, seven focused interviews were conducted with community biodiesel users. This accounted for approximately 30% of the clientele.[9,10] A summary of the interviews conducted is in Table 4 below.

[9] The biodiesel operation served 24 clients at the time of the field research. However, not all of these clients used the biodiesel on a regular basis. The seven informants were those who were available for an interview.

[10] Interviewees are referred to as INT #1-17, see Appendix B.

Table 4 - Case Study Interviews

Informant	No.	Type of Interview	Purpose / Information obtained
Mr. Handel Callender	1	Semi-structured / Direct observation	Thorough understanding of operations.
Biodiesel Employee	1	Semi-structured	Operations.
Private Restaurant Owner	1	Semi-structured	Motivations for participation.
Community Ambassador	1	Semi-structured	Motivations for participation. Community applications.
Managing Director – Solid Waste Solutions and Services	1	Semi-structured	Operations Motivations for participation. Scaling-up participation.
Restaurant Employees	5	Focused	Participant knowledge / interest in system
Biodiesel Users	7	Focused	Community knowledge. Motivations for participation.

Direct observation was also used to understand the operation. This included field visits to the case study "sites": the biodiesel processing facility and the various restaurants from which waste vegetable oil was collected. These instances of direct observation often lead to participant observation, allowing for first-hand experience with the biodiesel system. Waste vegetable oil collection was the primary activity in which participant-observation occurred. However, assistance with daily operations and tasks was also done.

Field work was conducted during two visits to Barbados. The first visit lasted one week in early September 2008 and acted as the exploratory phase. This phase "…helps researchers begin to understand the points of view of actors in the setting, identify worthy research questions, articulate and operationalize variables of interest, and allow theory to emerge" (Palys, 1997, 79). Specifically, the objectives of this initial trip were to gain a basic understanding of the biodiesel system and to make contacts with informants.

The second trip, lasting two weeks from the end of March to the beginning of April 2009, allowed for detailed direct and participatory observations and "... *strategic* sampling of insightful informants…" (Palys, 1997, 79). It was also used to identify methods to increase efficient operations and areas in which scaling-up could occur. Specific research objectives from this trip included: 1) describe biodiesel production and system from source to sink, 2) describe the intention of the enterprise and assess the efficiency of operations as per the evaluation framework, and 3) discover whether intention of enterprise could work at larger scale as per the evaluation framework. Also, a larger, more holistic objective of this research trip was to determine the significance of biodiesel in SIDS in order to help fill the research gap.

This project received clearance from the University of Waterloo's Office of Research Ethics. Though many participants indicated they had no objections to their names being included in the study, they will remain anonymous. However, the founder and manager of the biodiesel operation, Mr. Handel Callender, was aware of the University of Waterloo Research Ethics granted for this thesis but did not wish to be anonymous. Due to his large role in the biodiesel project, his name is used in this thesis. The interview themes and research questions can be found in Appendix A.

3.3. Data Analysis

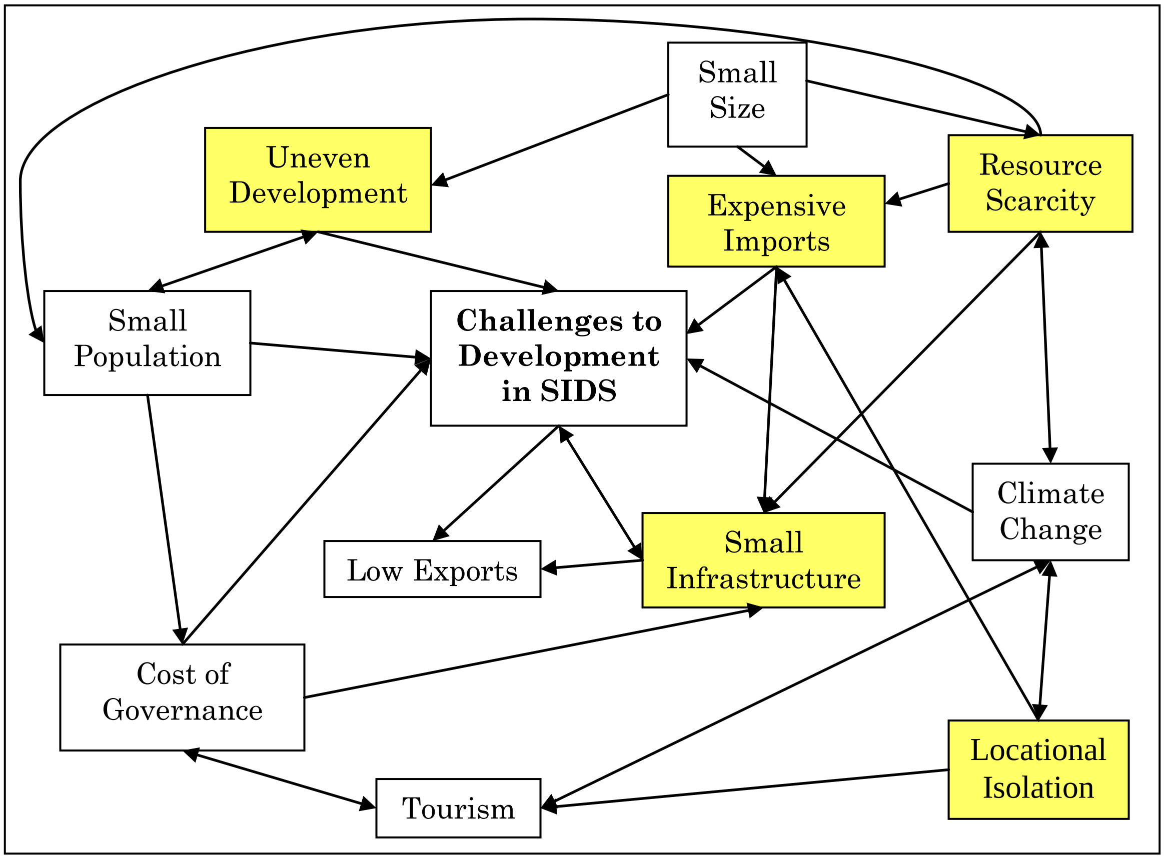
In qualitative research, processes and phenomena are analyzed and viewed in "…how they "unfold" and "evolve," and this view is reflected again in the belief that sensitive inductive research should similarly "unfold" and "evolve" as more and more is understood about phenomenon or research site under consideration" (Palys, 1997, p. 297). In this way, the analyses of findings were ongoing, allowing for recommendations and conclusions to come about naturally.

The Evaluation Framework, Table 3 found in Chapter 2, which demonstrates components of the evaluation framework that relate to the challenges to development facing SIDS, is used to analyze the field research findings. Although these various challenges to development relate to the biodiesel energy system, they are not necessarily improved by the system.

A qualitative scale was chosen for the evaluation framework as many criteria are complex. Using a quantitative scale with a numerical rating simply would not be accurate since some aspects of the each criterion are more positive or negative than others. Therefore, ratings fall under one of three categories: “poor,” “fair,” and “good.” A rating of “poor” indicates that the biodiesel operation could not function as a result of the criterion. Criteria rated as “fair” indicate that the biodiesel operation could function, albeit with some challenges, and was not meeting its potential to address certain challenges to development. Finally, the best ranking of “good” means the biodiesel operation is in good order and is able to aid some of the challenges to development. This qualitative scale is designed to foster discussion of the biodiesel system’s operations with particular attention to areas of improvement.

Figure 6, below, highlights specific challenges facing SIDS that can benefit from a biodiesel energy system.

Figure 6 – Challenges to Development in SIDS



Sources: Douglas, 2006; Koonjul, 2004; Read, 2002; Vallega, 2007

These are general relationships between a biodiesel energy system and a given SIDS. However, it should be noted that each SIDS is slightly different and ongoing research is required to continually adapt such an energy system so that it can meet the needs of an individual island.

3.4. Case Study Introduction

3.4.1. Caribbean Small Island Developing States

This study focuses on SIDS in the Caribbean for several reasons. First and as discussed in Chapter 2, small island developing states present a unique study area considering the array of development challenges they face. The SIDS of the Caribbean are no different and face the same challenges. Second, as shown in Figure 7 below, the islands in this region are close together and have very similar biophysical, economic, social, and political environments (Haraksingh, 2001; UNDSD, 1994; Wright, 2002).

Figure 7 - Map of Caribbean

Source: CIA World Factbook, 2009.

Therefore the recommendations made in this study may apply, more broadly, to many other Caribbean islands without much adaptation or change for each specific country. Third, the Caribbean was chosen because its climate is thought to be favourable towards biodiesel engine operation. Diesel engines require heat and pressure to work and colder climates can make starting difficult. Furthermore, though the biodiesel process removes glycerin from the fatty acid chains, making the fuel less viscous, the fuel can aggravate the already-difficult cold weather starts of diesel engines. Fourth, the Caribbean was chosen as the case study area due to proximity to the researcher's home, easing time and cost of travel to the study site. Fifth, and perhaps most importantly, Barbados was chosen for specific study as there was a small scale biodiesel energy system in operation there, and a desire to scale up the system: the island thus served as an excellent case to study and analyze, particularly with regards to the issue of opportunities to scale-up biodiesel production to the national level.

The context of this Barbados case study is described in the following sections beginning with general information about Barbados, then the country's sustainable development practices, followed by a summary of the energy systems in Barbados, and ending with a description of the specific case study.

3.4.2. Barbados Context

Barbados is the easternmost island in the Caribbean, just northeast of Venezuela, and has a land area of 431km^2 and population of 284,589 (July 2009 est.) (CIA, 2009). The island was colonized by England in 1627 and gained independence in 1966, yet remains part of the Commonwealth realm (CIA, 2009). The country is made up of eleven parishes and has one city, its capital, Bridgetown, which is home to the parliamentary democracy. Figure 8, below, is a map of Barbados and includes the various parishes.

Figure 8 - Map of Barbados

Source: ReliefWeb, 2009.

The Barbadian economy remained heavily based in sugar and rum until the 1990s when "tourism and manufacturing surpassed the sugar industry in economic importance" (CIA, 2009). Now the GDP is composed of 6% agriculture, 16% industry, and 78% services (2000 est.) (CIA, 2009). The most common agriculture products are sugarcane, vegetables, and cotton while industry is based on natural resources of oil, fish, and natural gas. Although some products are produced locally, in 2006, exports (including manufactured goods, sugar and molasses, rum, other foods and beverages, chemicals, and electrical components) were valued at $385 million while imports (including consumer goods, machinery, foodstuffs, construction materials, chemicals, fuel, and electrical components) were valued at $1.586 billion (CIA, 2009). This imbalance helps explain the country's concentration in services, its largest portion of GDP. Literacy rates of 99.7% have been important in the development of the service sector: "offshore finance and information services are important foreign exchange earners and thrive from having the same time zone as eastern US financial centers and a relatively highly educated workforce" (CIA, 2009). In light of these economic circumstances, current government priorities include reducing unemployment, encouraging direct foreign investment, and privatizing state-owned enterprises (CIA, 2009).

Despite these challenges, Barbados is the highest ranking Caribbean island on the Human Development Index (HDI) list, ranking 37th in the world (UNDP, 2008). The HDI is a composite measure of three aspects of human development:

> living a long and healthy life (measured by life expectancy), being educated (measured by adult literacy and enrolment at the primary, secondary and tertiary level) and having a decent standard of living (measured by purchasing power parity, PPP, income) (UNDP, 2008).

This high HDI ranking is maintained with sustainable social and environmental development policies.

3.4.2.1. Sustainable Development

The "Government of Barbados established a National Commission on Sustainable Development [NCSD] with a specific mandate to make the country a model of sustainable development incorporating government departments, interest groups and the general public in its policy development processes" (Haraksingh, 2001, p. 649-650). The NCSD, along with the Ministry of Housing and Lands, finalized the Barbados Sustainable Development Policy in 2002 (UNESC, N.D.). This policy is based on the principles and goals set by the multiple conferences held by the United Nations on sustainable development. This was then incorporated into the National Strategic Plan which, as a result, uses sustainable development principles to improve physical infrastructure as well as preserve natural resources. Indeed, Goal Four of the National Strategic Plan "advances the building of a green economy" (Government of Barbados, 2007, p.2). The government of Barbados plans to achieve this goal by advancing social and economic development while protecting the physical environment. The government recognizes here that it is necessary to find the balance between development and the natural environment.

Furthermore, "sustainable development principles have also been integrated into Barbados' Physical Development Plan, which ensures that land usage would be managed in such a way that land and natural resources are protected and conserved" (UNESC, N.D.). A copy Barbados' Physical Development Plan could not be obtained during field research; however the online table of contents confirmed the inclusion of environmental concerns in all aspects of development.

3.4.2.2. Energy

Barbados is one of the few islands in the Caribbean that produces its own fossil fuels, albeit in limited amounts (Stuart, 2006; Haraksingh, 2001). In 2007, oil production was estimated to be around 1,000bbl per day (CIA, 2009). "As Barbados has no refining capacity, its oil is refined elsewhere and then returned for domestic consumption" (EIA, 2008). In 2006, oil consumption was estimated to be about 8,500bbl per day. An energy profile for the country is shown in Table 5 below.

Table 5 - Energy Profile for Barbados (CIA, 2009)

Item	Amount
Electricity - production	1.003 billion kWh (2007 est.)
Electricity - consumption	939.9 million kWh (2007 est.)
Electricity - exports	0 kWh (2007 est.)
Electricity - imports	0 kWh (2007 est.)
Oil - production	1,111 bbl/day (2007 est.)
Oil - consumption	8,674 bbl/day (2006 est.)
Oil – exports	1,750 bbl/day (2005)
Oil - imports	10,710 bbl/day (2005)
Oil - proved reserves	2.2 million bbl (1 January 2008 est.)
Natural gas - production	29.17 million cu m (2006 est.)
Natural gas - consumption	29.17 million cu m (2006 est.)
Natural gas - exports	0 cu m (2007 est.)
Natural gas - imports	0 cu m (2007 est.)
Natural gas - proved reserves	141.6 million cu m (1 January 2008 est.)

This table demonstrates the country's ability to produce energy specifically in the form of electricity. It also shows how much more oil is being used (oil consumption) than is being produced. Biodiesel can, therefore, be a valuable, locally-produced alternative to oil.

Energy alternatives are being used in Barbados. Indeed, "in the early 70s the Government of Barbados recognised the benefits of employing SHWS [solar hot water systems] throughout the country and therefore adopted the policy of offering tax incentives for these systems" (Haraksingh, 2001, p. 650). In 2007, bagasse from sugar cane and solar water heaters contributed about 15% of the island's energy supply and the Barbados government "has committed has committed to having renewable energy account for 30 percent of the island's primary electricity by 2012" (UNESC, 2007).

The relative success of the Barbados solar hot water heater incentives program and the goals of the Barbadian government suggest that other alternative energy forms such as biodiesel might also be successful given an appropriate economic climate and community support. The next chapter introduces the case study and describes the biodiesel system in Barbados.

Chapter 4. Case Study Findings

4.1. Introduction

The biodiesel operation in Barbados, used as the case study for this thesis, started as a research project. Mr. Handel Callender (hereafter referred to as "Handel" or cited as "INT 1"), a Barbados resident, had an interest in appropriate technologies and learned about the applications of biodiesel while visiting the Dominican Republic. Upon returning to Barbados, he was encouraged to explore biodiesel as a business opportunity. After some success making biodiesel in a household blender, he applied for and received research and development grants, specifically from the Central Bank of Barbados and National Council for Science and Technology. Under the company name Native Sun NRG, Handel began to make biodiesel on a small scale using a processor built with the help of some intern students from McGill University (see Photo 1) and received funding from the United Nations Development Program (UNDP) which helped the operation to continue.

Photo 1 - Native Sun NRG Biodiesel Processor

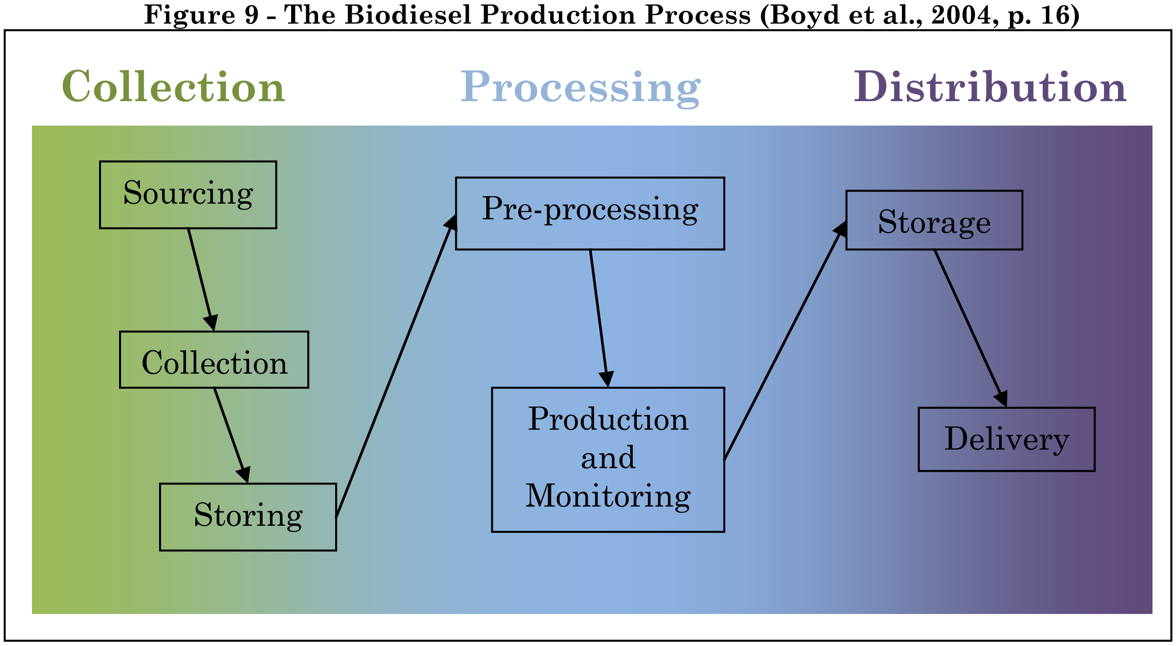
This novel idea brought about media exposure and local residents took interest. Price was also a factor as the biodiesel Handel made was always less expensive than regular diesel.

Between the first and second field trips to Barbados, Native Sun NRG was put on hold and a new company was formed through a partnership with an American-based venture capitalist company. This was done in order to help fund the purchase of materials and larger processing equipment. Handel continues to act as managing director of this biodiesel operation.

4.2. Small-scale community-based System

The biodiesel system, used as a case study in this thesis, will be described using the model, Figure 9, below, found in Boyd et al. (2004) as this covers all of the aspects of a biodiesel system under the three general activities of collection, processing, and distribution.

Figure 9 - The Biodiesel Production Process (Boyd et al., 2004, p. 16)



4.2.1. Sourcing

The biodiesel operation in Barbados uses waste vegetable oil as its feedstock. In this way, the operation avoids one of the critiques of biofuels: growing fuel-crops. In fact, waste vegetable oil is problematic in Barbados and many people simply don't know what to do with it. In terms of household waste vegetable oil, some people keep it stored in their backyards while others dump it onto the ground. One company, Roberts Manufacturing, offered a disposal service for the waste oil and used it to spray on dog food; however, they would only take limited amounts (INT 1). One restaurant employee stated that the waste vegetable oil was disposed into the sewage system (INT 6). When asked about the amount of waste vegetable oil generated from each restaurant, employees were unsure but gave approximate values which varied from 70gal per month (INT 7) to 57gal per week (INT 8).[11]

As the need for waste vegetable oil disposal grew, the company Solid Waste Solutions and Services, a private business responsible for managing wastes, extended their services to include waste cooking oil collection to the domestic, commercial, and self-employed sectors (INT 5). There is a charge of $1/gal for the collection of non-usable or contaminated (by water or chemicals) waste oil to cover the processing costs while the collection of usable or uncontaminated oil is free. Since Solid Waste Solutions and Services has been collecting used oil for 9 years, most people know what is required and, with the economic incentive, ensure their waste oil is usable. The managing director of Solid Waste Solutions and Services indicated that, specifically, those in charge of management [of commercial and self-employed businesses] do not want to have to pay for waste oil disposal and, therefore, comply with the usable waste oil requirements (INT 5). Although no interviews could be conducted with members of the Barbados government to learn more about waste vegetable oil, the managing director (INT 5) described the government's role in waste vegetable oil disposal (see Box 1).

[11] Two employees (INT 7, 8) could not estimate the amount of oil used, but stated the amount of chicken that was cooked in the oil before it was disposed (8,000 pieces of chicken and 2500 pieces of chicken respectively).

Box 1: Barbados Government Regulations for Waste Vegetable Oil

The Barbados Government has designated land areas for waste disposal around the island. Within these areas, there are smaller, specific disposal areas for different types of waste (e.g. waste water, chemicals, etc.).

One of these areas is designated for processing contaminated used cooking oil as the only regulation pertaining to waste oil disposal is that the oil must be uncontaminated. If waste oil has been contaminated with, for example water, the contaminated oil is put into a container and is left to sit long enough to allow the water and oil to separate. The waste oil is then removed and used again and the water is disposed in a separate, designated location.

The land used for waste disposal is believed to be owned by the government but this has not been confirmed.

4.2.2. Collection

The biodiesel company collects waste vegetable oil from restaurants and hotels providing an alternative waste disposal service. This service is free and is economically beneficial to the restaurants and hotels as many employees stated that they used to pay a fee for waste oil disposal (INT 4, 6, 7, 9). Chefette, a national fast food chain, is the largest source of waste vegetable oil for biodiesel and oil is collected from seven of the 13 chain locations. The oil is collected once every week or two weeks depending on how much oil is generated from a specific location. One informant indicated that it takes a month to fill a barrel (30gal) of waste cooking oil (INT 6).

The waste cooking oil is transferred to drums on the back of a truck (see Photo 2) using a pump or funnel system. One reoccurring problem in this stage was that a mechanism in the pump kept breaking causing a slowdown in the amount of waste vegetable oil that could be collected. During one trip, the team resorted to using a fabricated funnel (made by cutting off the bottom of a jug and using it upside down) to pour the waste oil from the storage containers from the restaurants into the drums on the back of the truck (Field notes, 2009).

In the collection phase, fuel consumption of the truck and amount of waste vegetable oil collected was recorded and monitored.

Photo 2 - Waste Oil Collection

Handel usually records the fuel consumption of the truck and the amount of waste vegetable oil collected. However, this data was not available due to some operational difficulties, described in the following sections. Handel has also tried calculating the exact CO_2 emissions of the collection process but the technology to do so is unavailable.[12]

Not all waste oil is collected by Handel and his team and some of the waste oil is delivered to the biodiesel processing facility. Indeed, "a vegetable oil recycling project was started with a local secondary school, the UNDP's small grants program, and surrounding community, to create awareness about renewable energies, recycling (WVO), and small scale responsible business practices" (INT 1). For this, school children were encouraged to collect waste vegetable oil from their

[12] With the data of the fuel consumption of the truck, the approximate CO_2 emissions could be calculated using the calculator provided by the National Biodiesel Board at www.biodiesel.org.

homes which would then be brought to the processing facility. Also, one informant, an Ambassador at the Parish level, was introduced to Handel's biodiesel initiative during an annual meeting where the theme was 'Physical Environment.' This person then contacted Handel to find out how to get involved. She realized that cooking oil was being used at her workplace and began collecting the used oil. She taught others about the project and had seven other coworkers get involved as well. This informant continues to participate by donating and delivering used oil (INT 3).

4.2.3. Storing

After collection, the waste vegetable oil is brought back to the processing facility, located behind the Future Centre, a local environmental education centre in Edgehill, St Thomas. This location in relation to the rest of Barbados, is shown by a red dot in Figure 10. Here, the waste oil is stored next to the processing facility in small vegetable oil containers (see Photo 3) or in a large holding tank.

Figure 10 - Location of Biodiesel Operation in Barbados

Photo 3 - Waste Vegetable Oil Storage

The waste vegetable oil can be stored in direct sunlight as this helps separate moisture trapped in the oil. While overexposure to solar energy is possible, it is more important to keep the oil well-sealed as overexposure to oxygen will break down the triglyceride molecule (INT 1).

4.2.4. Pre-processing

There are two separate pre-processing procedures: 1) mixing the catalyst and alcohol, and; 2) filtering the vegetable oil. Sodium hydroxide is the catalyst used in Barbados and methanol is used for the alcohol. These two ingredients are imported by the Barbadian company Agrochem (INT 1) from the United States. While the sodium hydroxide is inexpensive, methanol accounts for approximately 47% of production cost (INT 1). Handel would prefer to use ethanol but this alcohol must first be dehydrated, adding another step to the process. Furthermore, obtaining ethanol is difficult as it is already used for rum production in Barbados. The methanol used in Barbados is made in Trinidad, however, due to a shortage of small drums, Trinidad ships its methanol in very large containers to Florida where it is 'repackaged' into smaller, more manageable drums that can be shipped back to Barbados, adding cost at each step (INT 1). Before mixing the oil, catalyst, and methanol in the biodiesel processor, waste vegetable oil is filtered to remove large solids and impurities.

4.2.5. Production and Monitoring

As shown below (see Photo 4), a batch system processor purchased from a supplier in the United States is used to produce the biodiesel.

Photo 4 - Biodiesel Processor

Though there was no methanol available to make biodiesel while in the field, Handel described the biodiesel production process. The smaller container on the right is where the sodium hydroxide and methanol (i.e. 'methoxide') catalyst are mixed. The ratio of vegetable oil to methoxide is 5:1 (e.g. for every 100 gallons of vegetable oil, there must be 20 gallons of methoxide). This catalyzing mixture is then added to the larger container where the vegetable oil is added. Five pumps are used to cycle the vegetable oil and methoxide mix through the pipes and back through the large container. This takes approximately five hours and ensures that the mixture is sufficiently homogenized. The yield is 80-85% biodiesel, with the rest being glycerin. Once the mixture has finished cycling through the system, it must be left for 12-24 hours in order to allow the glycerin, containing methoxide, to settle at the bottom. In order to keep the operation less complicated, methanol is not recovered from the glycerin.

Once this glycerin is removed, the unrefined biodiesel is mixed with water several times in order to 'wash' the biodiesel of impurities, namely trace amounts of glycerin and methoxide. This process takes about three days with one wash per day. Though this process is long, it is important since these impurities can damage an engine if left in the biodiesel (INT 1, Kemp, 2006). Once the washing is complete, the biodiesel is removed and the wash water is disposed into the sewage system. This disposal method is not believed to pose any environmental concerns as glycerin is a natural soap and any methanol found in the water would be in trace amounts (INT 1). The new unit produces approximately 360 gallons of refined biodiesel at a time which is a significant increase over the 200 gallons at a time with the Native Sun NRG processor (INT 2).

According to one biodiesel employee, the only problem with biodiesel production is that "it's messy" (INT 2). Working with the oil as well as keeping himself and the surroundings clean is difficult (INT 2).

In the production phase, Handel and his team monitor the use of electricity and water, both of which come from the existing infrastructure on site. Most of the electricity used in the biodiesel process is for running the processor (INT 1). Though they are important, especially given the circumstances of SIDS, the electricity and water usage and costs of the biodiesel operation in Barbados are negligible in comparison to the cost of methanol (INT 1). This is significant given one of the critiques of biofuels: resource use in production. Since electricity and water usage is minimal, the biodiesel operation in Barbados avoids this critique. However, the petroleum-based methanol (INT 1) input reduces the efficiency of the biodiesel made in Barbados. The energy balance of the biodiesel operation in Barbados could not be calculated since 'input' data was not available in full. Calculating the energy balance from complete data would have resulted in an inaccurate ratio.

Two other types of monitoring relate to the biodiesel operation. The team had hoped to monitor the CO_2 emissions of the production process with the help of visiting students from McGill University, but scheduling and operational differences kept this idea from materializing. Also, it is too expensive to follow American Standards for Testing and Materials (ASTM) and, since there are no federal regulations on biodiesel production, only in-house testing was conducted to assess the quality of the biodiesel produced (INT 1).

4.2.6. Storage

The refined biodiesel is pumped through a fuel filter and stored in a tank. The longest amount time biodiesel was stored was 3 weeks indicating that storage length and decreased biodiesel quality are not a concern. In fact, some biodiesel users (INT 12, 13, 16, 17) as well as Handel himself (INT 1) reported that supply is problematic and often there is not enough biodiesel.

4.2.7. Delivery

Most biodiesel users drive to the Future Centre and pick up the biodiesel themselves (INT 2) and fill up the tank when they do (INT 14, 16, 17). Two clients (INT 11, 17) indicated that they have their own drums to fill and one employee stated that some clients drop off their drums to be filled (INT 2).

Although it was always a goal to make biodiesel available at a cost cheaper or on par with commercially available petroleum-based diesel (INT 1), the cost of methanol makes the biodiesel slightly more expensive (INT 2, 11, 13) though most clients do not mind paying more as they recognize the benefits of biodiesel (INT 14, 16, 17). Some customers chose to blend the biodiesel with regular diesel as a way of offsetting the cost (INT 15).

4.2.8. Biodiesel and Bi-products Use

Biodiesel use in Barbados is increasing as public education and word of mouth continue. As of April 2009, there were about 35 clients with new people coming every week (INT 2). Handel informs his clients of the origin and purpose of the diesel engine. This is to make his clients aware so that instead of thinking of a foreign substance being put into the engine, they realize that vegetable oil is what the engine was designed to run on (INT 1).

The fuel has multiple uses and benefits. Most of the biodiesel clients use the fuel for their personal vehicles (INT 1, 11, 12, 13, 14, 16, 17) although a few use it in their business vehicles (INT 1, 12, 17), in which case the fuel efficiency is found to be the same (INT 2, 16) and one client uses it in a home electricity generator (INT 1). The clients listed numerous benefits to using biodiesel including better engine performance (INT 2, 11, 12, 13, 15, 16), reduced smoke (INT 2, 13, 16), and better smell (INT 11, 16). The clients also acknowledged that biodiesel was better for the environment (INT 3, 11, 12, 14, 16, 17), especially in comparison to the poor quality of regular diesel in Barbados (INT 17). Biodiesel is a great way to recycle waste (INT 11).

It was interesting to learn that many of the clients are environmentally-conscious (see Box 2). One supported the idea of biodiesel since is it made from a waste product and stated we "...do not have to destroy natural environment…" to make fuel (INT 11). Another client stated that he "firmly" believes we have peaked in oil and believes the demand for oil will continue (INT 16). Also, one biodiesel client uses the fuel for his tractor on his organic farm (INT 12).

Box 2: Living Sustainably in Barbados

The diesel truck used for waste vegetable oil collection was borrowed from Handel's first customers – a couple who had settled in Barbados. Their home, in the interior of the island, was self-sustained and featured a recycled-water system, on-site sewage, and solar panels, wind turbine, and diesel generator for electricity. The couple ran both their truck and generator on biodiesel from Handel's operation whenever possible.

The biodiesel-powered truck was also used to deliver candles that the couple made to high-end hotels around the island, adding one more way that biodiesel contributed to sustainability on the island.

Clients also listed some of the problems or challenges they encountered with biodiesel. The most commonly reported problem was the location of the biodiesel plant and availability of biodiesel (INT 12, 13, 15, 16, 17). One client found that there was a harsh start to his engine with the use of biodiesel (INT 11) while another client thought that the loss of power he was experiencing was due to the biodiesel but later found out it was a problem in the fuel filter caused by poor quality petroleum-based diesel from Venezuela (INT 14). This ended up being further reason to use biodiesel instead.

The glycerin byproduct of biodiesel production also has a use that is being explored in Barbados. Indeed, while collecting waste oil in the field, we used the glycerin as a soap to clean off any oil that got on our hands. Also, one participant in the biodiesel system is investigating the use of glycerin as a hand cleaner at her place of work by looking into the cost savings and possible human health concerns.

4.2.9. <u>Biodiesel in Society</u>

Across the interviews, the level of familiarity with biodiesel ranged and, not surprisingly, coincided with the amount of participation the interviewee had with the system. Four out of the five Chefette employees who only interacted with the system by setting aside the waste vegetable oil for collection said they were not familiar with biodiesel (INT 6, 7, 8, 10). The fifth employee, in this case, had heard about biodiesel through his Church where Parish Ambassadors lead an information session on recycling in the community (INT 9). On the other hand, from those using biodiesel, two clients stated that they knew about biodiesel before meeting Handel (IN 14, 16), others learned about biodiesel from Handel, himself (INT 11, 12, 13), and some found out about biodiesel and Handel by word of mouth (INT 15, 16, 17). Biodiesel awareness is also spread in the community while the team is out collecting waste vegetable oil as this is when onlookers inquire about the activities and biodiesel operation (INT 2).

Although one restaurant manager didn't think his staff would be interested in learning more about biodiesel or seeing how it was made (INT 4, See Box 3), this was not the trend found through the other interviews. Indeed, both Chefette employees who were asked stated that they were interested in learning more about biodiesel (INT 7, 8) and one even showed an interest in visiting the biodiesel plant and suggested that there should be regular visitation times for restaurant staff and the community (INT 7). In terms of the biodiesel users, six out of the seven (INT 11, 12, 13, 14, 15, 16) clients interviewed said they had seen biodiesel made and one client (INT 17) had visited the Future Centre but did not state whether or not he had seen the biodiesel being produced. Interestingly, a manager at Solid Waste Solutions and Services stated "I would like to acquire knowledge [to make biodiesel] and be able to do it" (INT 5). He also indicated that he would like to learn how to make biodiesel as he is interested in all areas of recycling but would not like to take it on as a business initiative. Instead, he would like to have strong ties with business that make biodiesel while staying in the business of waste oil collection and distribution.

Box 3: Open Interview about Biodiesel

One restaurant owner (INT 4) indicated that he was not interested in going to a workshop on biodiesel as he did not have the time to do so nor was there any "financial reward" for him to do so. Then, over the course of this open interview, I became the interviewee as the owner began to ask me questions about biodiesel such as 'What is the biodiesel used for?', 'Can you use it the same way you use regular diesel?', and 'Do you have to use petroleum products to make biodiesel?'.

After learning a little more about biodiesel, the owner acknowledged that he would like information about biodiesel and other environmental initiatives to be more "accessible". He was still not interested in making it himself, but stated that if there was any way he could help: "I'll happily do it" (INT 4). This informant went on to tell me that the Barbados Hotel and Tourism association, of which he's a member, has an environmental program in place and that he's interested in the environment and happy to see that it is becoming more of a trend to act more sustainably.

At the end of our conversation, he provided a holistic point of view on participating in the biodiesel system by saying "The whole rest of us … are not particularly interested from the commercial side but from the wholesome side…I play a part because, at the end of the day, we all know that the world is suffering at the moment from all the pollution" (INT 4).

Another informant indicated that she believes that the benefits of biodiesel are seen at the community level through a better quality environment (INT 3). Furthermore, she explained how it didn't "take" anything (financially) to get involved (INT 3).

4.3. Potential for Scaling up

Besides understanding the current biodiesel system in Barbados, another objective of this thesis is to understand the potential to scale-up the system in order to maximize benefits and address development challenges in SIDS. The following sections describe consideration for scaling-up that were found during the field research.

4.3.1. <u>Technical and Financial</u>

The only technical aspects to scaling up involve the need for a larger processor (or multiple processors) and more 'ingredients'. Making a processor does not have to be very costly: all that is needed is a container for mixing and a heating element for the methanol recovery (INT 2). These can be made from scrap metal and cans (INT 2).

Waste vegetable oil is abundant and more biodiesel could be made if the team could get more methanol (INT 1, 2). This ingredient is very expensive and poses the greatest obstacle to scaling up (see Box 4). In fact, Handel put Native Sun NRG on hold in order to operate at a larger scale which was funded by the American venture capitalist company. This helped finance the acquisition of better processing equipment as well as methanol (INT 1), a reality explained by one informant who believed that private investment is needed in order to start environmental business initiatives (INT 5).

Box 4: A Note on Methanol

Though methanol is not the focus of this thesis, this aspect of the biodiesel system did have some significant impacts as it halted production.

There are two problematic issues with the use of methanol in Barbados. First: the lack of availability due to cost. Methanol was the most expensive aspect of the biodiesel operation since it needed to be imported from the United States. The second problem is that methanol is derived from natural gas (Boyd et al., 2004). This is the most economical way of making the substance, but it also presents a bit of conundrum when a fossil-fuel derived substance is to be used in a renewable energy system meant to alleviate some of the dependencies of developing countries on imported petroleum-based fuels.

As noted in the literature review, there are several options for making this aspect of biodiesel production more sustainable. Ethanol can be used as a substitute for methanol and can be made from renewable agriculture activities (Al-Widyan & Sl-Shyoukh, 2002a). However, the use of ethanol in biodiesel production complicates the procedure slightly as it must be purified before it can be used (Boyd et al., 2004).

Though it might be more expensive, methanol can be obtained through the decomposition of biomass – a sustainable process (Boyd et al., 2004; Chhetri & Islam, 2008). However, this is believed to be a very complicated and expensive process (INT 1). Also, methanol should be recovered during the biodiesel production process in order to reduce the amount of new methanol required.

4.3.2. Government and Policy

One informant explained that, while the Barbados government is not needed to get recycling initiatives started, it is needed to see if the recycling of certain materials is "working and working properly" (INT 5). Here, the informant was referring to the ongoing monitoring which could influence the scaling up of a biodiesel system as government regulations would have to be made regarding biodiesel waste products and where production could occur. Land is needed for a larger-scale operation or multiple operations and the allocation of land can only be done through the government especially in regards to forms of recycling programs (INT 5). While a more accessible location would benefit the biodiesel system (INT 12, 13, 15, 16, 17), this new location would have to be government-approved (INT 5) and could prove to be more costly (INT 2).

An aspect of scaling up that had already been explored by Handel was getting waste oil from cruise ships. The problem with this is that waste oil that comes to the island is considered international waste and would have to be processed within a certain distance from the waterfront before being "imported" into Barbados as biodiesel (INT 1). Since the processing facilities could not be moved and there was no real shortage of vegetable oil, this option was not investigated any further.

4.3.3. Social

Certainly the most interesting findings came through direct interviews and field observations relating to the social aspects of scaling up a biodiesel energy system. One research objective was to find out about how much initiative was being taken in the community in regards to biodiesel in order to assess whether or not there could be enough involvement in scaling-up activities.

Through interviewing staff at local restaurants, it was found that there is not much awareness of biodiesel. This was surprising as the staff was aware that the vegetable oil was being collected, but there was little initiative to find out why or what was being done with the oil. However, there was interest from management to have an information bulletin about biodiesel for staff to read (INT 7, 8, 9). Indeed, one restaurant manager indicated that it would be beneficial for Chefette to advertise that the company recycles and participates in environmental endeavors in order to demonstrate 'high quality' (INT 8). Oddly though, just a few days after this interview, I noticed a poster near where the food is ordered for customers to see in several Chefette locations that advertised how Chefette recycles. Waste vegetable oil for biodiesel was mentioned on the poster along with the American venture capitalist company's trademark and name.

Another group from which to assess the potential for participation in scaling-up activities were the biodiesel users. When asked if they would be interested in making biodiesel, four out of the seven clients said they were not interested in making biodiesel and this was mostly due to lack of time (INT 11, 12, 16, 17). The other three clients said they were interested in making biodiesel, but only for personal use (INT 13, 14, 15). It should be noted here that one of the biodiesel employees was made to understand that one or two other people are making biodiesel in Barbados on a small scale (INT 2).

One particular field observation was made that could have implications to scaling up from a social standpoint. Vegetables are imported in Barbados and, hence, are very expensive. Meanwhile, many Barbadians own houses with small yards but many of these are not used for gardens. After asking about this, it was explained to me that many Barbadians would rather go to work, get paid, and pay for their food rather grow food themselves (INT 1). There seems to be a tradition of 'not doing more' and perhaps being risk averse. There is also a sense of competitiveness, described by one informant in Box 5, which can be applied best in a career where there are opportunities to 'move up the corporate ladder'.

Box 5: Competitive Culture

As described by one biodiesel employee, having biodiesel too much in the public eye could be negative. This informant stated that if people with waste oil start to see biodiesel being made and sold, they would begin to charge for the waste oil. There is a feeling of "if they can't benefit from it, you shouldn't benefit from it" (INT 2). From his experience, there are people who have waste vegetable oil that could be collected for biodiesel production but they would rather dump it. "I witness people just go and dump the oil instead of giving you it…they just dump it in the ground, throw it in the bushes, throw it in the gully, dump it inside the drainage. They just don't care, because they don't want you to make money out of it" (INT 2).

4.4. Summary of Findings

The current biodiesel operation in Barbados is already a scaled up version of the original project from which it came. From beginning as an experiment using a blender in Handel's home to a homemade batch processor to a corporate biodiesel business with multiple employees, the system has slowly grown and been able to benefit more and more waste vegetable oil generators and biodiesel energy users. The most limiting factor along the way was always financial (INT 1). Whether it was repairing old equipment, getting larger processing units, paying staff, or obtaining more methanol, financing the project was a constant stress.

However, having enough money would not take care of all the obstacles faced. As seen through the informants' responses to a higher level of participation, it is clear that there is not much interest, for example, in making biodiesel.

Though, with enough funding the biodiesel system could simply hire more people to run the operation at a larger scale, the integrity of the project might be lost. The biodiesel system initiated by Handel was meant to have intrinsic community value: acting as an opportunity for community environmental education while contributing to sustainable energy development in Barbados.

The field research findings demonstrate that biodiesel in Barbados can avoid many of the critiques that biofuels normally face. First, the fuel is made from a waste and not from virgin crops. Also, few resources are used throughout the operation's activities. Though methanol is derived from petroleum-based sources, there are other options for this ingredient that could help the overall efficiency and sustainability of the operation.

Chapter 5. Discussion and Implications

In this chapter, the field research findings are combined with the Evaluation Framework in order to understand the interactions between the biodiesel system and challenges facing SIDS. The findings are further analyzed to discover the successes and challenges of the existing system. Also, the implications for scaling-up are discussed.

5.1. Evaluation Framework Assessment for Biodiesel in Barbados

Table 6 shows, again, how a biodiesel system addresses challenges facing SIDS and, now, also shows an evaluation of the Critical Success Factors from Boyd et al. (2004) and Scaling-up Initiatives from Creech (2008). Each item is discussed following the table.

Table 6 – Evaluation Framework

Evaluation Framework	**Challenges to Development Facing SIDS**												
Critical Success Factors	Small Populatio	Uneven Developm	Size	Imports	Resource Scarcity	Locationa l	Small Infrastru	Tourism	Low Exports	Governan ce	Poor	Fair	Good
1. Balance supplies, technology, and demand?				•	•	•	•				✓		
2. Alliances with sources, end users, and other?	•					•	•			•			✓
3. Anticipate and deal with competitive pressures?		•		•			•						✓
4. Financial health?				•	•	•	•			•		✓	
Scaling-up Initiatives													
1. Research the technical approach for scaling up?		•		•	•							✓	
2. Assess possibilities for scaling up and potential barriers?		•				•	•			•			✓
3. Build consensus for scaling up?	•	•			•					•		✓	
4. Ensure that policies are supportive and that resources will be available?	•			•	•	•	•			•	✓		
5. Accessible and efficient programme designs for scale up?	•	•				•	•			•		✓	
6. Donors? Funding?		•				•				•			✓
7. Prepare training and technical assistance? Flexible and adaptable to local conditions?	•				•	•	•			•			
8. Monitor progress, detect problems, develop solutions? Ensure that community participates?	•					•	•			•			

5.1.1. <u>Critical Success Factors</u>

The following four critical success factors were applied to the observations of and information about the biodiesel operation in Barbados and were rated accordingly. How these factors related to the challenges facing SIDS is also discussed for the case in Barbados.

1. <u>"The ability to balance feedstock supplies, processing technology and market demand/penetration for products produced within an integrated system that that is both reliable and efficient" (Boyd et al., 2004, p.116).</u>

   A biodiesel system, supplying a locally-produced, renewable fuel, has the potential to reduce the amount of petroleum-based diesel imports, contribute to local resources (i.e. fuel), and add to the island's infrastructure. However, the research revealed that these benefits were not realized consistently in the Barbados system. First, methanol must be imported which adds yet another item to the long list of SIDS imported goods. Furthermore, methanol is expensive and not readily available, leading to periodic stalling of biodiesel production. Second, there were several mechanical problems with the pump used for waste vegetable oil as well as the processor pumps. This was a frustrating set-back yet, interestingly, these problems fell under the top two categories of common problems in enterprise development in SIDS: raw material, and machinery and equipment (McDonald, 1999). These two problems contributed to the inconsistency of biodiesel production creating an imbalance in supply and demand. Field observations of this supported statements from the biodiesel users. The biodiesel system did not balance supplies, technology, and demand consistently nor efficiently in a way that addressed the challenges faced by SIDS and, as a result, this criterion is rated as 'poor'.

2. <u>"The ability to form key and stable strategic alliances with feedstock sources/suppliers, distributors, end users and other stakeholders" (Boyd et al., 2004, p.116).</u>

   This aspect of a biodiesel operation demonstrates its symbiotic relationship with the small population characteristic of SIDS. As noted through some of the interviews, word of mouth spreads quickly on small islands allowing for alliances to form quickly through community participation and interaction. While this helps the biodiesel system by uncovering new sources of waste vegetable oil and increasing the number of biodiesel users, the small population benefits, in turn, with growing levels of interaction that reduce locational isolation. Also, a biodiesel system can be an inexpensive contribution to infrastructure as making the processors is not costly (INT 2) which lowers the per capita costs of building conventional energy infrastructure.

The increasing amount of participation from those setting aside waste vegetable oil and using biodiesel led to this criterion being rated 'good.' Although there may be a competitive culture in Barbados (as described in Box 3), this was not observed during the field research. In fact, most of the biodiesel users were enthusiastic to talk about their experience with the fuel and, though some of the employees were not familiar with biodiesel, they were interested in learning more about it.

3. "The ability to anticipate and to deal effectively with competitive pressures" (Boyd et al., 2004, p.116).

As one informant indicated, there may have been a few others making biodiesel in Barbados (INT 2) but none that would cause an issue of 'competition.' This is perhaps a benefit of operating on such a small island as there is limited infrastructure.

However, competition with regular diesel fuel did exist. Due to the cost of methanol, the biodiesel operation could not always compete economically with the price of regular petroleum diesel. Even so, many of biodiesel users stated they didn't mind paying more for biodiesel. This was because the benefits of biodiesel were worth the extra cost, making the fuel competitive with petroleum based diesel in terms of quality.

Another area of competition was anticipated to exist with other waste vegetable oil collectors. However, field observations demonstrated that there was no shortage or difficulty in obtaining sources of waste vegetable oil.

Since there was no real competition with another biodiesel producer, the operation continued to have faithful clients, and waste vegetable oil sourcing was not a problem, this aspect of the operation was rated as 'good.'

4. <u>"The ability to accomplish the above while providing a risk/return profile that will allow the project to be financed and to maintain financial health" (Boyd et al., 2004, p.116).</u>

This criterion was given a rating of 'fair' in the evaluation framework for the sole reason that funding was always an issue. During the first trip to Barbados, Handel was contemplating selling his operation to the American venture capitalist company in order to fund the purchase of new equipment. This was not an ideal scenario as Handel would no longer be the sole proprietor of the operation and having employees was not necessarily one of the initiative's goals (INT 1). However, by the second trip, the decision to sell had been made: ever since that decision, the operation has been producing more biodiesel using a larger processor purchased by the American venture capitalist company. The larger processor did help to meet more of the needs from biodiesel users. However, it was clear during my time in Barbados that funding from the American company was not constant, and caused some stress linked to employee pay, periodic inability to obtain more methanol, and to finance operational activities.

The overall performance of the biodiesel operation in Barbados was not observed to be very successful. It is possible that this may have been due to the timing of the field visits as the general consensus of the operation from the biodiesel users was very positive and the operation appeared to have a lot of potential for benefits at the community level.

5.1.2. <u>Scaling-up Initiatives</u>

Many obstacles facing the biodiesel operation in Barbados were observed at the community scale, and these impeded the amount of information and research that could be done regarding opportunities to scale up. However, some of the observations and information gathered while performing the field research did relate to the evaluation framework for scaling-up. These are discussed under the criteria below.

1. <u>"Establish that the technical intervention, methodology or approach that is being considered for scaling up leads to desired results through carefully evaluated and documented research" (Creech, 2008, p. 9).</u>

   The biodiesel operation in Barbados was already a scaled-up model from which it started. However, this criterion was given a rating of 'fair' as scaling up to the national level had been discussed but no real documented research had been done. The company was still focusing on making operations at the community-scale consistent.

2. <u>"Assess possibilities for scaling up (need, available resources, political will, potential partners, etc. and potential barriers to scaling up (opponents and their arguments, policies, etc.)" (Creech, 2008, p. 9).</u>

   Although the formal research into scaling-up had not been done, Handel had inquired about other sources of waste vegetable oil and had been considering other areas where biodiesel could be made. For example, obtaining waste oil from cruise ships was considered (described in section 4.3.2). Upon further investigation though, Handel found that the biodiesel would have to be made on the coast which made this option unfeasible.

   Locational isolation and uneven development are two challenges to development that should be addressed when assessing the possibilities of scaling-up the biodiesel operation. As one informant indicated, the government does play a role in determining where recycling activities can occur (INT 5) and, therefore, could act as either an aid or barrier in terms of where scaling-up occurs. Unfortunately, no concrete information could be obtained regarding the political role in this regard.

   Of course, where possibilities exist for scaling-up technically, the possibilities to increase infrastructure also exist. In this way, scaling up can help address the issue of limited infrastructure in SIDS. The only observable barrier to scaling-up was the fact that the current operation at the community level was already having difficulty operating and, therefore, could not begin to address methods for scaling-up.

Despite the lack of formal research, the constant dialogue for how to improve and scale-up the operation in Barbados is the reason for the rating of 'good' for this criterion.

3. "Build consensus for scaling up among decision makers, implementers and leaders of those who participate in the programme/use the intervention through meetings, presentations, field visits, etc. with key individuals and groups" (Creech, 2008, p. 9).

Even after selling the biodiesel operation to the American company, Handel remained the primary decision maker in terms of operations. However, in order to scale-up the operation to the national level, input from the American company's key decision makers would be needed if the operation were to scale up under the American company's name.

In terms of consensus from the biodiesel users, it is expected that there would be much support for scaling-up activities since the demand for biodiesel was higher than the supply that could be made at the community level.

Once again, the political/government aspect of consensus for scaling-up could not be explored during the field research.

As there is no concrete evidence for the support for scaling-up, this criterion was rated as 'fair'.

4. "Ensure that policies are supportive and that resources will be available" (Creech, 2008, p. 9).

This criterion was rated as 'poor' simply due to the fact that methanol was a difficult and expensive resource to obtain and was already restricting operations at the community level. Furthermore, based on the information gathered on the operation in Barbados, this resource does not help improve the issue of 'expensive imports' but rather contributes to this difficult challenge faced by SIDS.

On the other hand, waste vegetable oil was abundant and provided a resource that could help improve the issue of resource scarcity in SIDS for its potential to be turned into fuel.

As described in the literature review, the government of Barbados' National Strategic Plan was based on sustainable development policies that resulted from multiple conferences held by the United Nations. The government also set a goal of having 30% renewable energy sources in the energy mix by 2012 (UNESC, 2007). These policies and goals may have been the reasons for which Handel was able to obtain funding for his Native Sun NRG biodiesel operation through the Central Bank of Barbados and the National Council for Science and Technology. However, a confirmation of this could not be obtained during the field research.

5. "Develop plans/proposals with decision-makers and implementers on the organizational structure and relationships of the scale-up, activities, management, monitoring and evaluation, training and technical assistance, etc. Programme designs or interventions should be simplified as much as possible and should be accessible in "user friendly" language" (Creech, 2008, p. 9).

Although the biodiesel operation was not far enough along for plans and proposals for scaling-up to be developed, this criterion is rated as 'fair' since Handel had trained employees on how to use the larger equipment and his use of 'user friendly language' enabled more community members to become involved in the system.

6. "Be prepared to solicit many donors and negotiate many hours in order to put all pieces into place. The amount of funding needed for large scale programs is often not available through only one donor. Negotiate contracts, budgets, work plans" (Creech, 2008, p. 9).

This aspect of scaling up was rated 'fair.' Handel was successful at applying for and receiving funding for the biodiesel operation from development organizations. However, the contract with the American company was not very successful with all the trouble it presented in terms of receiving on-time payments to cover employee pay and the purchase of materials (notably methanol).

7. “Prepare training and technical assistance teams and materials to work at regional or other level depending on organizational structure. Be flexible and adapt to meet local conditions whenever possible without losing essential elements of quality” (Creech, 2008, p. 9).
8. “Programme implementers meet regularly on local, regional and national levels to monitor progress, detect problems, develop innovative solutions/approaches, strengthen skills and build team. Ensure that representatives from those who are participating in the programme (community men and women, etc.) participate in monitoring and evaluation at a minimum at the local level” (Creech, 2008, p. 9).

Again, due to the obstacles faced by the operation at the community level, these last two practical aspects of scaling-up were not observed nor discussed. As such, these criteria were not given a rating.

5.1.3. Commentary

A deficiency in the evaluation framework was found after the analysis of the field research findings. The field research revealed much of the social environments that surrounded the biodiesel operation in Barbados including the ‘eco-conscious’ nature of biodiesel users, the high level of interest in the alternative fuel, and even the competitive culture (described in Box 5). These social environments influenced the success of the biodiesel operation by limiting participation in some ways and encouraging participation in other ways. However, neither the critical success factors provided by Boyd et al. (2004) nor the scaling-up initiatives from Creech (2008) address the necessary social environment. Boyd et al. (2004) note the importance of “key and stable strategic alliances” (p. 116) while Creech (2008) calls for the building of consensus, but neither comment on the social environment beyond that which is directly involved in the system.

5.2. Bridging Literature and Practice

The literature review began with an introduction to SIDS, describing the special challenges they face to development. Two major interacting challenges are resource scarcity and expensive imports: resources are scarce due to the island’s small size which means goods need to be imported which is expensive due to the island’s small population which make less expensive 'bulk' orders unnecessary (Koonjul, 2004, Stuart, 2006). The biodiesel system in Barbados addresses these as it acts as a new resource, created by a waste already generated on the island.[13]

The scarce resource addressed by the biodiesel system is fuel suitable for use in internal combustion engines and diesel generators. This translates, if only a little bit at a time, into less petroleum that is required to be imported into the country. The significance here is the increase in self-sufficiency that Barbados experiences as global petroleum prices rise; as Stuart (2006) points out, SIDS will be less likely to complete on a global scale for this increasingly rare and expensive resource.

Biodiesel also addresses the energy challenge presented by Stuart (2006) of the storage of electricity. Biodiesel can be stored for some time (see Bouaid et al., 2007) and, as observed in Barbados, is very useful in diesel electricity generators as well as automotive engines.

One interesting link between the literature and what was observed in Barbados was the 'Virgin Islands Paradox' (see Stuart 2006). Indeed, in Barbados, the demand for biodiesel grew beyond the means of the installed system. This resulted in the need for more financing to purchase larger equipment to meet the demand. In this regard, the biodiesel system was not able to contribute to financial growth in the community. However, the materials and equipment contribute to the community's fixed assets.

'Financing' is another aspect of the literature found to be in sync with the observations of the biodiesel system in Barbados. Stuart (2006) explained how financiers prefer to fund short-term energy reform projects and this is true of the case in Barbados where the project was initially funded by the UNDP (INT 1). This fact could have significant implications for other SIDS wishing to use a biodiesel system and how they go about getting the funding to do so.

Short-term energy reform projects are typically small and do not require much infrastructure. This links to another item discussed in the literature review: the

[13] It is recognized that methanol is an expensive, imported ingredient used in the biodiesel production process. However, this ingredient could be substituted with ethanol, which can be produced locally. This is explained in further detail in Chapter 6.

extreme vulnerability of SIDS's infrastructure to the effects of climate change. The biodiesel operation in Barbados was relatively simple system in comparison to traditional energy systems that involve pipelines and transmission towers. It's 'infrastructure' can be rebuilt quickly or evacuated to safety which has great significance to Barbados and other SIDS since these areas are prone to natural disasters that destroy infrastructure (Barnett, 2002). Furthermore, the system does not require any specialized training, a human-resource related development challenge for SIDS (Haraksingh, 2001).

Although the biodiesel operation in Barbados will not significantly change global greenhouse gas emissions, the reduction of local diesel-based pollution may benefit the local community and possibly even the tourism industry of Barbados. The reduction of black smoke (the typical and unwelcomed end result of using regular diesel fuel) was confirmed by many biodiesel users. This is consistent with the literature reports of reduced particulate matter in emissions (Al-Widyan et al., 2002b; Boyd et al., 2004; Cetinkaya & Karaosmanoglu, 2005; Gomez et al., 2000; Lue et al., 2001; U.S. EPA, 2009). This reduction in black smoke emissions contributes to better local air quality and provides a more aesthetically pleasing vacation spot.

The literature review also addressed the issue of scaling-up and described the difference between 'horizontal' (geographical) and 'vertical' (institutional) (NRSP, 2005). The current biodiesel system in Barbados resulted from both these types of scaling-up. Horizontally, scaling up occurred by collecting waste oil from more restaurants around the island and selling biodiesel to a growing client base – affecting more areas of Barbados geographically. The system has scaled up vertically from its beginnings as a home experiment to becoming an operation funded by the Central Bank of Barbados and National Council for Science and Technology, the UNDP, and later, an international venture capitalist company – involving new stakeholders along the way. The evaluation framework addressed both of these types of scaling-up, however, only information pertaining to horizontal scaling up was obtained due to the lack of information regarding national policies and lack of interviews conducted with government officials.

A gap in the literature on scaling up was discovered after the field work was conducted. The biodiesel operation had been quite successful using the smaller processor that was made with the help of the intern students from McGill University (INT 1). Problems arose when the operation was switched over to the larger processor and funding from the American venture capitalist company for methanol to keep the operation running became problematic. Why was the operation successful at one scale and not another? Gibson, Ostrom and Ahn (2000) explain the concept of hierarchy theory and how issues of scale can be problematic: "the causes and effects of any phenomenon may occur on levels above or below the one analyzed… some processes may be isolated at one level, while other may not" (p. 225). This is to say that what works at one level of organization or scale may not work at another scale. The study of transferability from one scale to another is relatively new, yet active, area of research and could have significant value for small sustainable energy projects such as the biodiesel system in Barbados. Gibson et al. (2000) provide four steps to determine whether a concept could function on a different scale:

1. Clearly identify the scale and level of the study and their appropriateness for the phenomenon,
2. Know the important variables impacting on the phenomenon at different scales and levels,
3. Know when one is translating levels or scales and to recognize issues involved in top-down or bottom-up thinking, and
4. Sample and experiment across scales and levels (p. 225).

Steps 2 and 3 are significant reasons why transferability of the biodiesel to a slightly larger scale was problematic. Though Handel was the managing director of the 'scaled-up' biodiesel operation, it was now funded by an external company seeking profit. This resulted in top-down thinking; thinking that was financially motivated without an understanding of how the biodiesel system, with all of its technical and social interactions, worked. Understanding the balance of these interactions (notably, importing enough methanol to produce enough biodiesel for users to generate profit) is part of knowing the important variables that Gibson et al. (2000) describe. It is possible that this transfer of understanding simply did not 'scale-up' along with the rest of the operation. Indeed, I would argue that the misunderstandings lead to stress and overall lack of support for the system. However, it could also be rationalized that technical and social interactions are better understood at the smaller scale where they are less complex, allowing an operation, such as the biodiesel system to better achieve efficiency.

Although the scaling up of the biodiesel system in Barbados was not put into practice and, therefore, could not be assessed in depth, the system provided an example where some of the theory found in the literature can provide valuable guidance for alternative energy systems beneficial for SIDS.

5.3. Implications for SIDS

As described throughout this thesis, the issue of energy poses a unique development challenge for SIDS. Indeed, "small islands, as well as isolated regions, have to take a particular path to the development of their electricity power systems, bound to the limits of geography and unable to profit from economies of scale" (Duic, 2003 p.96). While Duic (2003) refers here to electrical systems, biodiesel can be used for electricity generation when used in a diesel generator as well as for a petroleum-based diesel fuel substitute in automotive engines. In either case, biodiesel produced within the SIDS helps reduce the amount of energy that needs to be imported. As with the case in Barbados, a biodiesel energy system can help SIDS overcome further development challenges such as uneven development, resource scarcity, and small infrastructure. Furthermore, "waste generation and energy production and usage provide sustainable resource management problems for all states, large and small. These problems are particularly accentuated in small islands…. (Douglas, 2006, p. 79) and a biodiesel system such as the one found in Barbados addresses both of these resource management problems.

Perhaps a more practical implication of this research for other SIDS wishing to start a biodiesel operation relates to funding. Gaining funding for a start-up biodiesel energy system will greatly increase the ability to begin a successful operation with the right equipment. Succeeding at funding competitions also helps increase awareness of a biodiesel operation, leading to community support for and involvement with the system.

However, an interesting social phenomenon that could impede community involvement in other SIDS was discovered during the field research. It was explained that farming and labour-type work is still viewed by some as something that the less fortunate and even uneducated community members do whereas office-related work is done by the 'successful' members of society (INT 1). Since a biodiesel energy system is 'messy' and labour-intensive, it could have difficulty in gaining community involvement in SIDS where this social stigma is popular. Indeed, there must be active community participation in order for a biodiesel system to 1) function, and 2) be able to aid some of the challenges to development faced by SIDS.

Drawing from the previous section, an implication for SIDS is that careful attention is needed when scaling up successful, small-scale development projects. Input materials, scenarios, and even motivations are just a few examples of the elements that can change across scales and can influence the success of a development project. Indeed, this was the case in Barbados where the supply of methanol could not be scaled-up and the motivation behind the operation changed as the operation grew.

SIDS face a variety of constraints and pressures from the larger, global socio-economic system leading to multiple implications of a biodiesel energy system. First, as small nations with little resources they are marginalized and forced to rely on larger, more powerful nations for the goods they cannot produce themselves. In this way, they have little control over the goods they import which can compromise the sustainability of the biodiesel operation. For example, it is probable that the cheapest type of vegetable oil is imported into Barbados, made from unsustainable agricultural practices. Also, the methanol used is cheapest alcohol to use for production even though it is petroleum based further compromising the biodiesel system's sustainability. Second, environmental initiatives and programs in developing countries are believed, by many political ecologists, to be "doing pernicious work or helping to secure the power of an elite community" (Robbins, 2004, p. 109). If this is true, the underlying motive for environmental initiatives will never accurately serve the needs of SIDS. Finally, these constraints add to already existing pressures in SIDS, given their few resources, to generate revenue and increase GDP so that they may play a role in the global market.

It is in this global context that the benefits of a locally developed and run biodiesel operation are determined. The implication for SIDS then is that a biodiesel energy system can address some of the challenges to development but the level of sustainability will be determined by the system's connections to the global environment.

These nations must compete larger, more powerful countries while also relying on these large Douglas (2006) states "the success of sustainable development programmes, environmental protection policies and resource management strategies requires good governance, transparency, accountability and compliance with agreements, directives and regulations" (p.79). If these aspects are present in a particular SIDS, a biodiesel energy system will have the potential to help address challenges to development at all scales.

5.4. Implications for Academia

The significant amount of research on alternative energy in SIDS that focuses technically on wind and solar energy systems presents two gaps in the literature. First, more research needed to determine the social and economic environments needed for the success of sustainable energy systems. Second, there is a need for biodiesel to be addressed in the literature as method of sustainable energy development.

The peer-reviewed literature on biodiesel is also technically thorough but more research needed surrounding the social and community interactions with biodiesel.

To date, this type of analysis is vaguely addressed in books and only widely addressed anecdotally online.

While this thesis is a contribution to the field of political ecology by introducing some of the challenges of moving across scales, there is a significant need for research on the issues of scale and, specifically, on the transferability of concepts, such as biodiesel, to different scales. Van Alphen states "although numerous frameworks and models have been introduced to cover various aspects of technology transfer, there are no corresponding theories" (p. 165). This statement is significant for two reasons. First, the various aspects van Alphen is referring to could be social, technical, political, economic, etc. While many of these play a role in a biodiesel energy system, the case study would suggest that the technical and, perhaps, operational aspects are most in need of appropriate frameworks and theories. Second, the 'corresponding theories' are necessary as these are the first step in developing effective strategies to 1) determine the feasibility of scaling-up and 2) develop a general guide for scaling-up.

The implications of this thesis for academia are relatively limited, as described in the following section.

5.4.1. <u>Research Limitations</u>

The first research limitation encountered by this project was in regards to funding. This project was completely self-funded and, as such, funding was a major limitation to the amount of field research that could be done. The limited amount of time spent in Barbados made it difficult to carry out many interviews and gain a complete understanding of an ongoing biodiesel operation. Furthermore, it is difficult to travel around the island quickly and efficiently. Therefore, even though I was in the country, many interviews had to be completed over the phone. Although this made it more convenient for some informants to participate in an interview, I sensed that it made some informants feel as though they were being given a survey and, therefore, made them reluctant to participate. Unfortunately, interview timing and scheduling did not work out with at least ten key informants, primarily government and funding agency representatives. For this reason, direct government findings were beyond the scope of this project. Any findings pertaining to federal or local regulations is second-hand information obtained through other interviews.

Another limitation to this study was the fact that biodiesel was not being produced at the time that the fieldwork was being carried out. This was due to insufficient operational funding and the mechanical problems described in Chapter 4. As such, fewer of the biodiesel system's participants were available as they were occupied with other endeavours. However, I was able to maintain electronic contact Handel which allowed me to gain a better understanding of how the biodiesel system was functioning.

A cultural limitation was articulated in one of the informal interviews. The interviewee suggested that there was a lack of initiative from local residents to provide good customer service and general help to other local residents unless there was a direct personal benefit. As an apparent visitor, I did not experience this at first hand. However, when asking a key informant on his opinion about community initiatives, he indicated that Barbadians are less apt to participate in programs unless there is a direct personal benefit (INT 2). I believe this is another reason why some informants were reluctant to participate in interviews.

Finally, in terms of this study's transferability to other cases, it can be argued that a single country case study limits generalizability. Again, as described by Yin (1988) in the section above, the description of this case study will help identify other similar cases to which this project's findings are analytically generalizable. This being said, transferability might be reduced by the fact that Barbados is one of the richest Caribbean SIDS. Although the development of the biodiesel operation described in Chapter 4 demonstrates how this initiative received external funding, it is still possible that a similar operation in a lower income country could experience more challenges, especially in the beginning stages.

Chapter 6. Recommendations and Conclusions

6.1. Recommendations

Based on the findings and analyses in this thesis, recommendations for the biodiesel operation and its potential to scale-up, biodiesel development in SIDS, and academia are made in the following sections.

6.1.1. Biodiesel in Barbados

1. Create an information pamphlet or poster specifically for staff.

During waste vegetable oil collection, it was discovered that restaurant employees were not familiar with biodiesel. An information pamphlet or poster would have two purposes: 1) educate employees how to properly set aside oil for collection and 2) increase awareness of biodiesel in the community. The latter has the potential to increase participation with increased word of mouth. The poster or pamphlet should be created by the biodiesel operation's employees and contain information on how waste vegetable oil should be set aside (type of containers and with as little debris/food particles as possible), the basic production process, and contact information for those who wish to become more involved.

2. Hold public information sessions and demonstrations.

As indicated by one informant (INT 7), public information sessions and demonstrations would increase public awareness of the biodiesel operation. These should be presented by Handel, biodiesel employees, or volunteers who understand the system and could occur once a month. The events should be advertised in the restaurants that set aside waste oil for the biodiesel operation, at local parish meetings, and by word-of-mouth. The demonstrations could be held at the Future Centre and/or at public gatherings such as the Friday night fish fry in Oistins, Barbados – a weekly exhibition of food and goods by local fishermen and artists that is attended by hundreds of locals and tourists. Along with showing how biodiesel is made, each demonstration or information session should explain how community members can participate in the system; for example, community members can collect their waste vegetable oil, help make the biodiesel, or use it in their own diesel engines or generators.

3. Research and use a different source of alcohol.

As described in Box 4, the issue of methanol is not the focus of this thesis. However, since the lack of this key ingredient in biodiesel production had significant effects, it is recommended that another source of alcohol be used. Handel has tried to obtain locally-produced ethanol for biodiesel. However, the ethanol produced in Barbados is for rum, one of the few sources of income for the country through export (INT 1). Handel was informed that the ethanol could not be diverted to another industry (INT 1). In this case, it is recommended that the amount of ethanol needed for biodiesel production be determined first followed by a cost-benefit analysis for biodiesel made with locally produced ethanol versus petroleum-based diesel imports and percentage of ethanol diverted for biodiesel use from rum production. This would help determine the impact of using some of the ethanol, normally used for rum production, for biodiesel production and whether this could benefit the country. In the meantime, it is recommended that methanol recovery during biodiesel production be done in order to reduce the need for new methanol.

4. Set up a call/answer service for biodiesel customers.

Many of the biodiesel users stated that the somewhat remote location of the operation was problematic along with the lack of availability of biodiesel. Therefore, it is recommended that the biodiesel operation set up a call/answer service that biodiesel users could call in order to find out the hours of operation and the availability of biodiesel. This would increase the efficiency of the system by allowing users to verify the availability of biodiesel before driving out to the facility.

5. Determine the energy balance of the biodiesel operation.

This should be calculated by the staff once the operation is running and consistent data for the operation's inputs are available.[14] Determining the energy balance will

[14] The online calculator www.homerenergy.com is recommended.

demonstrate how efficient the biodiesel system is and will indicate where the operation can be improved in order to maximize efficiency.

6.1.2. Scaling up to the National Level

1. Estimate total waste vegetable oil.

Before the operation in Barbados can be scaled up, the total amount of waste vegetable oil available for use as a feedstock should be determined. This can be done by the biodiesel employees or community volunteers. It is an important as it will determine whether or not scaling-up using a local resource (waste vegetable oil) is possible.

One method of calculating the amount of waste oil is to determine how much usable waste vegetable oil is left over from a given amount of virgin cooking oil. Once this ratio is calculated, trade statistics can be reviewed to determine how much vegetable oil is imported and how much, if any, vegetable oil is produced locally. This total amount of virgin vegetable oil can then be translated into the amount of waste vegetable oil available by using the ratio.

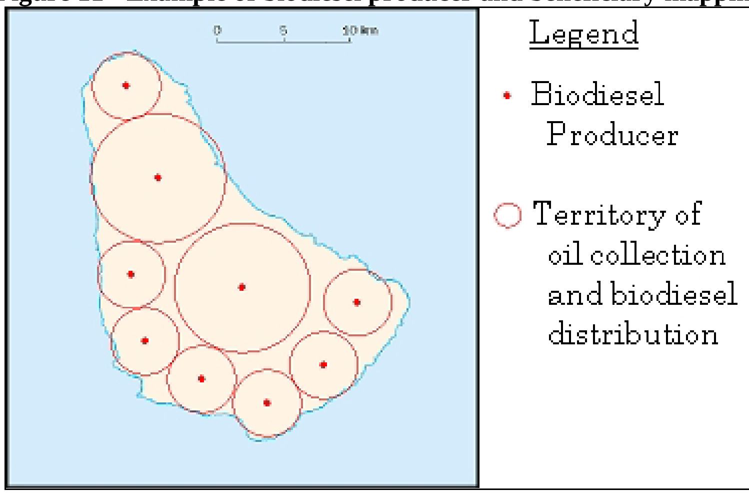
Another method to determine the amount of waste oil available for biodiesel production is to consult restaurant owners on how much virgin vegetable oil is purchased or even how much waste vegetable oil is generated.

2. Scale-up to the national level in a decentralized manner (i.e. multiple small units producing biodiesel around the island).

Based on the discussion of the biodiesel system in Barbados, decentralization is recommended as this would maintain the benefits of small biodiesel-based energy systems and would address some of the challenges faced in scaling up. First, smaller processors require less initial start-up costs as they can be made from scrap metals and larger containers, such as the original processor used by Native Sun NRG in Barbados. Next, multiple units would encourage greater community involvement as well as contribute to community energy independence. The challenge of uneven development on the island could be addressed through local economic development through biodiesel sales, although generating profit does not have to be a goal of scaling-up. Decentralization would also increase public environmental education. Also, with processors scattered around the island, there is more efficient access to feedstock (waste cooking oil) and less energy consumed driving collected oil to the nearest processing facility rather than to one central location. The only delivery to the multiple locations would be for the methanol which, if imported, could now be imported in bulk to supply all the biodiesel processing locations. This would reduce the per-unit cost of methanol. These benefits are in line with the benefits of decentralization described by Kauneckis and Andersson (2009).

One suggestion for setting up the separate biodiesel processing locations is to create a kit for biodiesel producers to purchase (this would be the initial, low start up cost if the system were to be for generating profit). Alternatively, biodiesel producers could make their own processor based on directions provided by Native Sun NRG. If the system's purpose is to generate profit, it should be determined how much a producer can expect to make per gallon of biodiesel produced. This revenue analysis could provide a financial incentive for Barbadians to become biodiesel producers. Finally, the biodiesel production locations should be allocated with a surrounding radius or area for vegetable oil collection and beneficiaries. This radius or area will be determined based on the amount of vegetable oil produced and demand for biodiesel in the given area. An example of this is shown in Figure 11, below.

Figure 11 - Example of biodiesel producer and beneficiary mapping



Of course, decentralization should be done in a way that reflects the system's purpose. If the system is meant to provide energy security more than local economic development, more portable and highly efficient processing units are required. Whereas, if the system is meant to provide local economic development, the processing units can be larger so that larger, 'bulk' batches of biodiesel can be made.

Scaling-up through decentralization in this way assumes several factors. First, it assumes an availability of waste vegetable oil for biodiesel production. This should be determined before scaling-up occurs as noted in the recommendation above. Next, it assumes community participation since personnel will be required to operate the individual processors. Finally, it assumes a growing demand for a diesel-fuel alternative.

6.1.3. <u>Biodiesel Development in SIDS</u>

The recommendations for the biodiesel operation in Barbados and for scaling-up apply also to biodiesel development projects in other SIDS. It is also recommended that SIDS beginning a biodiesel operation apply for funding as a single, small operation then proceed with scaling-up activities. As Stuart (2006) indicated, aid agencies prefer to fund smaller, energy reform projects. This will also give the biodiesel operation an opportunity to assess the effectiveness of the system and how it can address the challenges facing the individual island.

6.1.4. Academia

The recommendations for academia pertain to existing gaps in research. For example, as the research demonstrated, further research is required into the political aspects of the biodiesel system. If national policies are more restrictive than anticipated, scaling-up activities will have to adjust accordingly. Also, the literature needs to focus more on the practical aspects of a sustainable energy system. For example, how does one turn moral community support into physical participation? And for the issue of scale, what determines effective transferability of scale in small island energy systems? On a more general note, Stuart (2006) states: "the complete energy chain, from source of supply to ultimate consumption and waste, needs to be viewed with fresh eyes that are sensitive to all possibilities" (p. 146) inferring that a wider variety of aspects of energy development can be studied in depth with more researchers for this topic.

As a result of using the evaluation framework to analyze the findings, it was found that the criteria lack attention to the social environments required for a successful biodiesel operation as well as scaling-up initiatives. The social environment in Barbados was quite influential on the biodiesel operation. Therefore, it is recommended that new evaluation frameworks be developed to include this influential aspect.

6.1.5. Project Integrity

The original intention of the Native Sun NRG project was to educate the Barbadian community on sustainable practices through the use of biodiesel. The biodiesel system of Native Sun NRG was also supposed to be a business model, demonstrating how environmental responsibility could be partnered with good business practices (INT 1). Based on observations in the field and conversations with Handel, it would appear that some of the project's integrity was lost when

Native Sun NRG was put on hold and the new biodiesel company formed and 'scaled-up' since the business agreements did not materialize as planned, funding was short, and pressure to create profit was generated from the 'top-down.'

In light of this, it is recommended that all sustainable development activities develop a mandate to define their vision for benefitting the community and local environment. From there on, all aspects of development activities should reflect the mandate ensuring the projects' integrity.

6.2. <u>Conclusions</u>

The purposes of this thesis were twofold: 1) bridge the gap between the challenges to development facing SIDS and biodiesel energy systems and 2) analyze and contribute to a real-world example of the theories in the literature. Theoretically, a biodiesel based energy system has many characteristics that enable it to benefit small island developing states by producing energy locally, reducing dependency on imported fuels, and creating even development across an island.

The biodiesel system in Barbados provided a real-world case study to test these theories and demonstrated that some aspects of the challenges facing SIDS are more difficult to overcome. For example, a substitute for methanol in biodiesel product has yet to be found resulting in the fact that this ingredient will continue to be imported. Also, there are many more social aspects to the system that need to be considered in order to ensure the system has enough community support to physically run the system. While these aspects were discussed in Chapter 5, the following sections will revisit the research objects for this thesis and provide some concluding remarks.

6.2.1. <u>Revisiting Research Objectives</u>

Objective 1: Develop an evaluation framework for a community-scale biodiesel operation and scaling-up activities based on the literature.

The literature explained the various challenges to development faced by SIDS. Those that applied to a biodiesel energy system were used: small population, uneven development, size, expensive imports, resource scarcity, locational isolation, small infrastructure, tourism, low exports, and governance (Douglas, 2006; Koonjul, 2004; Read, 2002; Vallega, 2007). Two sets of criteria, critical success factors for a biodiesel system (Boyd et al., 2004) and scaling-up initiatives (Creech, 2008) were used in order to determine how a biodiesel energy system could address the development challenges faced by SIDS.

Objective 2: Document the activities of a community-scale biodiesel operation.

Through field observations and interviews with key informants all aspects, from initial development to operations to end-use and by-products, of the biodiesel system were described. This allowed for a thorough analysis of a real-world case to be compared to the literature. In this way, theoretical gaps in the literature were filled using practical information. For instance, it was found that a biodiesel energy system does address certain challenges to development faced by SIDS even though this had not been explored in the literature.

Also, the field research introduced new topics to be explored in the literature: specifically, the transferability of systems across scales (see Gibson et al., 2000). This was found to be a relatively new area of research in need of further exploration.

Objective 3: Identify the benefits and challenges of the operation as well as the opportunities to scale up the operation as per the evaluation frameworks.

The critical success factors demonstrated how the various tasks of the biodiesel system used as a case study in this thesis related to development challenges in SIDS. It was found that the biodiesel system most effectively addressed the issues of 'resource scarcity' and 'expensive imports' by creating a new energy resource locally and 'small infrastructure' by acting as a new energy-processing facility. The greatest challenge to the system was obtaining methanol, an expensive import. This was further complicated by inconsistent funding.

Since the system was having difficulty operating at the community scale, the scaling-up initiatives could only suggest how a larger scale operation might address the challenges to development faced by SIDS.

Objective 4: Provide recommendations for the biodiesel operation as well as methods for scaling up.

After using the evaluation framework to analyze the biodiesel system in Barbados, recommendations for a more effective operation, scaling-up, and biodiesel in SIDS were made. The current system in Barbados could benefit from information posters and sessions for restaurant employees as well as the general public and a call/answer service for biodiesel users to allow this group to confirm biodiesel availability before travelling out to the processing facility.

The recommendation with the greatest potential impact, however, was to find an alternate source of alcohol (either methanol or ethanol) for biodiesel production since the current source proved to be very expensive due.

The primary recommendation for scaling up is to do so in a decentralized manner. This will increase the benefits of the biodiesel system and keep set-up costs low.

While the recommendations for the biodiesel operation in Barbados and for scaling-up can apply to biodiesel in other SIDS, these island states are encouraged to start out as a single, community based operation and then scale-up as this will provide time to adjust the biodiesel operation to the individual islands' needs and increase the likelihood of funding from aid agencies who prefer to fund smaller development projects.

6.2.2. Contributing to Sustainable Development

Sustainable energy development is of great importance to the populations and environments of SIDS. Indeed, "holistic energy solutions can be a source of social and economic development, self-esteem and healthy living for residents of all ages" (Stuart, 2006, p. 146). The case study featured in this thesis has demonstrated how a biodiesel-based energy system has the potential to address some of the challenges to development facing SIDS. For example, such a system can contribute to local economic development while increasing community interaction and improving local air quality. Of course, the challenges to development in SIDS are interactive, influencing the causes and effects on one another. As a result, the benefits of a biodiesel energy system in SIDS are not limited to one area or system and, through a ripple effect, can be beneficial to many aspects of development. According to Stuart (2006), "energy solutions should extend to transportation, urbanization, built environments, consumption, health and demographics" (p. 146).

Biodiesel presents one more sustainable energy option that can be added to a mix of wind, solar, and geothermal energy sources. With this mix of sustainable energy sources, SIDS can address some of the challenges they face while acting as global leaders in sustainable development.

Epilogue

The tensions surrounding the American venture capitalist company's involvement with the biodiesel system in Barbados (along with an interest in travel) motivated Handel to consider working on biodiesel elsewhere. Several months after the second field research trip to Barbados, he left the country for a short time to help organize the initial set-up of a biodiesel operation in Dominica along with one of his employees from Barbados. Upon returning to Barbados, Handel began to look into biodiesel operations in Canada. After receiving an offer to work on biofuels with an organic farm in Hamilton, Ontario, Handel sold the smaller biodiesel processor, used under his company Native Sun NRG, to another Barbadian who had been making biodiesel in Barbados (Handel had known about this producer but the two never interacted while both were making biodiesel in the country). The new processor bought with the funds from the American venture capitalist company is still located at The Future Centre and the operation is being run by one of Handel's former employees.

Handel arrived in Canada in mid-April 2010 and is scheduled to give a presentation on biodiesel to elementary school students at the end of the month. Handel is also planning on writing a book on biodiesel development in SIDS and, during his stay in Canada, has promised to help me make my first 'blender batch' of biodiesel.

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Appendix A: Interview Themes and Sample Questions for Open-ended Interviews

Interview Themes

- Biodiesel use
- Waste vegetable oil generation
- Materials supply
- Community Involvement

Sample Interview Questions

Biodiesel Knowledge and Use

- Are you familiar with biodiesel?
- For what purpose? Automotive or Generator?
- How much to you use?
- What benefits have you noticed?
- Have there been any complications?

Waste Vegetable oil Generation

- How much waste vegetable oil do you produce?
- How do you dispose of it?
- What are the options for disposing of it?
- Would you be interested in giving it to a biodiesel producer?
- Would you be interested in selling it to a biodiesel producer?
- Are you interested in buying biodiesel back?

Materials Supply

- How do you supply materials to the biodiesel producer? Shipping? Delivery? Other?
- Is it possible to increase supply?

Community Involvement

- Do you use biodiesel or give/sell waste vegetable oil?
- What is your participation with the biodiesel system?
- What benefits are there to participating in this system?
- What challenges are there to participating in this system?

Appendix B: List of Interviewees

Key Informant #1 (INT 1): Ongoing. Mr. Handel Callender, Managing Director, *Native Sun NRG Barbados*

Key Informant #2 (INT 2): March 31, 2009 and April 10, 2009. Biodiesel operation employee.

Key Informant #3 (INT 3): April 8, 2009. Community Ambassador.

Key Informant #4 (INT 4): April 6, 2009. Private restaurant owner.

Key Informant #5 (INT 5): April 9, 2009. Managing Director, *Solid Waste Solutions and Services* employee

Key Informant #6 (INT 6): March 31, 2009. Senior staff, *Cheffette*.

Key Informant #7 (INT 7): March 31, 2009. Senior staff, *Cheffette*.

Key Informant #8 (INT 8): March 31, 2009. Senior staff, *Cheffette*.

Key Informant #9 (INT 9): March 31, 2009. Senior staff, *Cheffette*.

Key Informant #10 (INT 10): March 31, 2009. Senior staff, *Cheffette*.

Key Informant #11 (INT 11): April 6, 2009. Biodiesel user.

Key Informant #12 (INT 12): April 7, 2009. Biodiesel user.

Key Informant #13 (INT 13): April 7, 2009. Biodiesel user.

Key Informant #14 (INT 14): April 8, 2009. Biodiesel user.

Key Informant #15 (INT 15): April 9, 2009. Biodiesel user.

Key Informant #16 (INT 16): April 9, 2009. Biodiesel user.

Key Informant #17 (INT 17): April 9, 2009. Biodiesel user.