Recycling Plastic in the US Virgin Islands:

An Analysis and Proposal

A Master's Project by Elizabeth Jackson

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December 2011

~Submitted in partial fulfillment of the requirements for the Master of Environmental Management Degree in the Nicholas School of the Environment, Duke University~

Abstract: Located in the pristine Caribbean Sea, the United States Virgin Islands bring in more than two million visitors a year that exacerbate the already pressing problem of waste management for the nearly 108,000 inhabitants of St. Thomas, St. Croix, and St. John. Reduce, reuse, and recycle would presumably be the priority in any island region, yet the USVI have historically viewed recycling plastic as infeasible due to high transportation costs and distance to economies of scale with processing facilities. As a petroleum byproduct, plastic is the 2nd most valued commodity in the waste stream and makes up 14% of the US Virgin Islands MSW. With the USVI facing landfill closure within the next five years, waste management is a true concern with expanding the recycling to include plastic proving to be a viable solution.

After analyzing different scenarios and taking all of the unique characteristics of the USVI into consideration, I have proposed a business model for a closed loop plastic recycling operation in the US Virgin Islands in order to decrease transport costs and environmental impacts. A closed-loop process would prove to be a viable investment using locally sourced PET (Polyethylene Terephthalate, #1) to produce high-quality plastic flake to substitute virgin plastic in manufacturing, such as in the bottling industry, and plastic strapping which is in high demand for the packaging and shipping industry. The reprocessing plant would be strategically located in the industrial sector of St. Croix with access to a highly trafficked import, export, and trans-shipment port. The proximity to manufacturers in need of plastics would be pursued for product contracts in order to secure a profitable demand schedule. This Master's Project offers background on plastics, recycling, and the US Virgin Islands in order to understand the unique characteristics in developing this proposal. The proposal details, business model, and sensitivity analysis will be discussed before offering conclusions and steps to move the project forward.

Table of Contents:

I. Introduction to the US Virgin Islands

Location: The United States Virgin Islands are made of three main islands, St. John, St. Thomas, and St. Croix, which face unique challenges for some of the very same reasons that make them so incredibly alluring. Being a US Territory allows exemption from certain governance and federal taxes also contributing to the feeling of "escape" that brings more than two million cruise ship visitors and 600,000 tourists to the islands every year (NOAA 2011). But this brings with it a delay in implementation of common practices found in the continental United States, especially federally funded projects, as well as environmental shifts taking place across the country. The distance to economies of scale creates increased costs in materials and transport, but, once again, attributes to the appeal of "the islands getaway". Accurate monitoring and lack of transparency are a common problem in the USVI as well as a delay in enforcing standards such as EPA's Clean Air Act, Clean Water Act, and landfill regulations (EPA 2011).

US Territory Implications: The United States Virgin Islands, like Puerto Rico, are unincorporated US owned territories, meaning they operate under federal US law but do not pay federal taxes or enjoy all benefits of being part of the United States (Wikipedia, NOAA 2011). This is particularly of interest for understanding the decision-making process of the VI Waste Management Authority, the monitoring and enforcement of EPA standards, and the difficulty in adopting common practices of the incorporated United States such as recycling. The government is a closely-knit group of leaders who operate in the "I scratch your back, you scratch mine" mentality. There have been multiple efforts by NGOs such as the St. Croix Environmental Association (SEA) to bring light to environmental oversight and hazards associated with high levels of benzene, dioxins, Polycyclic Aromatic Hydrocarbons (PAH) and Volatile Organic Compounds (VOC) from various operations in the USVI. The lack of transparency towards recordkeeping, monitoring, and reporting as well as poor regulation and enforcement have been addressed to no avail for both the Water and Power Authority as well as the local Hovensa oil refinery (SEA 2009). Both landfills in the USVI, Bovoni serving St. John and St. Thomas and Anguilla on St. Croix, face closure within the next five years due to non-compliance. EPA found the landfills to have improper disposal issues, surface and subterranean fires, and leaching contaminants (EPA 2010, VIWMA 2011). One of the largest problems facing the USVI is sustainability concerning waste and costs surrounding future waste management.

The Waste Problem: More people equal more waste, and with tourism being the primary economy of the USVI, the waste management problem is exacerbated for the 112,000 inhabitants of St. Thomas, St. Croix, and St. John with only 133.73 square miles of land. The USVI receives overwhelming anthropogenic impacts from the millions of tourists and cruise ship visitors that come to explore its beautiful beaches and pristine waters (NOAA, Wikipedia 2011). If you look at islands as a unique operating system, which have a continuous in-flow of packaged, shipped-in, and disposable goods (i.e. water, food, & other consumer goods) and very little out-shipping of waste, the problem is glaring. Coupled with landfill closure, the Virgin Islands Waste Management Authority has assessed multiple scenarios for achieving waste reduction with Waste to Energy as the proposed solution. However, if this proposal is not approved, the VIWMA faces tremendous costs, estimated to be more than $300 per ton (AEG 2011). Their best alternative in this case is expanding their existing aluminum recycling operation to include glass, paper, and plastic as well as island-wide composting in order to reduce the amount of waste needing to be shipped off island.

A “Waste Characterization Study” was published in December 2009 by a waste management consulting company, Gershman, Brickner, and Bratton (GBB), providing data on the breakdown of the Municipal Solid Waste (MSW) in the US Virgin Islands. This data is being used by VIWMA and other interested entities for waste management analysis, WTE potential, and alternative solutions. The study breaks down the Municipal Solid Waste (MSW) of the US Virgin Islands into multiple categories with an uncategorized of 30,000 tons per year (GBB 2009). In the table below, plastics are divided into recyclables and non-recyclables based on the type given in the study. “Recyclables” refer to #1 and #2 plastics, which are commonly acquired for their reprocessing potential as discussed later. This study was primarily done to conveniently display the potential for each type of MSW towards quota needs in contractual agreements between VIWMA for energy outputs in the Waste to Energy proposal. For this project, the “recyclable plastics are of most importance and reveal feedstock potential of nearly 5,000 tons per year (GBB 2009).

USVI MSW Breakdown		
MSW	***Tons/Year***	***%***
Paper	43,932	30.266
Plastic		
Recyclables	4,705	3.241
Non-Recyclables	14,441	9.949
Glass	7,699	5.304
Metals		
Recyclables	5,879	4.050
Organics	48,327	33.294
Special Wastes	20,168	13.894
Total	145,151	100.000

Figure 1*: Table showing MSW breakdown in USVI (GBB 2009).*

Recycling in the USVI: The environmental health of each island consistently points toward waste and pollution problems throughout the Virgin Islands. Local concerns surrounding the proposed Waste to Energy operations are focused on costs, environmental impacts, and the presumed negligence of recycling (Davis et al. 2011). You would assume that Reduce, Reuse, and Recycle are a priority in any island region, yet expanding the recycling program has historically been viewed as infeasible due to high transportation costs and distance to economies of scale with processing facilities that would benefit from purchasing the USVI's plastic. Moreover, the WTE proposal adds a new facet to decision-makers in regards to needing the recyclable materials for the waste quotas rather than incentivizing them to recycle MSW recyclables.

There is currently no plastic or paper recycling programs in the USVI. St. Thomas and St. Croix have grassroots efforts under the Recycling Association of the Virgin Islands with St. John operating under its environmental organization called the St. John Community Foundation (SJCF, RAVI 2011). The Recycling Association of the Virgin Islands (RAVI) was established back in 2007 with support from Virgin Islands Waste Management Authority, USDA, and EPA.

The statement below from the project manager, Colleen Sullivan, for the Recycling Association of the Virgin Islands St. Croix sums up the primary problem facing grassroots efforts:

> "RAVI does not have any funding. I have been doing all volunteer work now for 2.5 years. It has been a struggle. We are making progress but there is not any funding. The $70,000 in grants that I wrote had no admin capability so all my work was free."

RAVI ST. Croix has been successful at collecting aluminum cans with a recycling facility completed summer 2011. St. John is currently showing success with aluminum collection as well, using a holding pond for its collection facility. Sites throughout the two islands allow people to drop off cans at no charge. Volunteers from both organizations collect the cans and bring to a central location. At this point, a volunteer trucking company delivers the cans to a metal firm, Sanitary Trash Removal, on St. Thomas for purchase. There are occasional financial gains for the two organizations from the metal firm but the money is primarily used to pay the volunteer transporters.

Aluminum has proven successful due to a more attractive price for reprocessed aluminum, average of $.90 per pound compared to $.50 per pound (MRA 2011). This price advantage motivated metal separation by waste management for monetary gain as well as a conveniently located metal collection operation on St. Thomas who sells the aluminum to a buyer located in either Puerto Rico or the continental United States. Some of the problems with expanding the recycling program were highlighted in my interview with the St. John Community Foundation including a lack of funding, current operations are comprised of a volunteer workforce, there is a lack of contracts with carriers for transport, and doubts about consistent revenue streams.

These implications resonate when considering recycling plastic. The less valuable plastic waste disables the duplication of the aluminum recycling operation. The nearest reprocessing facility would not benefit from purchasing the USVI's plastic when considering transport costs for comparable weights of plastic. On average, plastic makes up only about 10% by weight in waste generation but contributes to over 40% in volume, further highlighting the significance of plastic's smaller value but requiring more shipping space (EPA 2011). However, even in the continental US where recycling is incentivized, a disappointing 85% of all plastics in the Municipal Solid Waste stream still ended up landfilled (Pyper 2011). Although expanding to include recycling plastic has been considered in the USVI, the transportation costs and feasibility have inhibited forward movement or endorsement from the VI Waste Management Authority.

WTE and Recycling Plastic: The approval of the Waste to Energy (WTE) facility in the USVI will play a major role in the future of a plastic-recycling program offering multiple scenarios for the future of plastic in the USVI: 1) Collect the higher valued plastics (PET and HDPE), sell off-island, and use the remaining plastic in the WTE process; 2) Use all plastics in the WTE process for its high energy content and efficiency in the logistical process with other MSW collection; 3) Recycle the plastic at a reprocessing plant in the US Virgin Islands, use the remaining waste in the WTE process.

The American Chemistry Council and Columbia University have done extensive research alleging Waste to Energy as promotional for recycling as well as crucial for the future energy mix of the United States (NREL, Killinger 2011). Europe has over 400 WTE plants and a totally different view of WTE operating in the neighborhood of its recipients. For example, the WTE plant in Horsholm, Denmark decreases heating costs by 80% in winter and electricity costs by 20% (Killinger 2011). With only 86 Waste to Energy facilities in the United States and no new plants since 1995, the US has been slow to adopt this technology facing staunch opposition for dirty plant operations and NIMBY issues (EPA 2011). Speculation and increased fears surrounding landfill costs and capacity constraints propelled the small boom in WTE facilities in the US in the late 80's, early 90's; therefore, the majority of existing plants in US are antiquated and technology is outdated. Technology has progressed dramatically and dioxins and CO2 abatement are minimal for recently built plants in Denmark and Germany.

Places that have WTE have actually shown to increase recycling rates by 5% in the United States therefore dismantled accusations that WTE recovery would deter from recycling efforts. Recycling is prevalent in the US for a small portion of plastics with the remainder being landfilled. It is estimated that 28.8M tons of non-recyclables are landfilled each year, which is the energy equivalent of 139M barrels of oil or 36.7 tons of coal (ACC 2011, CU-MIT 2005). This energy recovery value has vital implications for a unique environment such as the US Virgin Islands, with high fuel prices and primarily diesel generators for power. There are multiple technologies that have been used around the world successfully reducing emissions by approximately 90% from WTE operations 15 years ago (Killinger 2011).

VI Waste Management Authority's proposed Waste to Energy (WTE) plant aims to alleviate the waste problem and offer an alternative energy supply for the islands. It is supposed that the VIWMA needs the plastic to meet waste quotas under contractual agreements. However, this proposal only plans to use the PET, which makes up about 3% of the waste stream (GBB 2009). The bottom line for the sake of this proposal is that recycling and WTE do not have to be in competition with one another. This proposal should be considered even if the WTE facility is approved. VIWMA provides the funding for the aluminum-recycling program through community grants and logistical support. Therefore, recycling plastic would have to be viewed as non-competitive and seen as an attractive investment opportunity in order to get funding by the Virgin Islands Waste Management Authority.

II. The Importance of Plastic

***Source and Value*:** Plastic is made from hydrocarbon cracking where bonds in ethane and propane are broken at high temperatures to create alkenes/olefins (chemical molecules containing at least one carbon-carbon double bond). Plastics are divided into two categories, thermoplastics and thermosets. Thermoplastics can be heated at high temperatures and reformed without undergoing chemical changes whereas thermosets, such as rubber and resins, can only be formed once. As a petroleum byproduct, plastic has been undervalued for its high-energy content, and, just as with oil, natural gas, and coal, reprocessing technologies aim to recover this valuable energy (Wikipedia, Davis et al. 2011). One pound of mixed plastic produces 15,500 Btu when incinerated and PET (primarily used for plastic bottles) has an energy value of 10,900 Btu/pound whereas Wyoming Coal has an energy value of 9,600 Btu/pound (Themelis et al. 2011). There are multiple technologies emerging such as converting plastic directly to oil, providing one liter of oil for every kg of plastic, and Waste to Energy plants which heat plastics at different temperatures providing derived fuels. Solid recovery fuels from plastics are substituted for dirty conventional fuels and used in industrial boilers or cement plants. More commonly, reprocessing plastics is a promising way to ensure diversion from a premature end of life, wasting the energy available (4R Sustainability 2011). Different types of reprocessing facilities provide different qualities and types of reprocessed plastic products. This is due to the different make up of different plastics and requirements set forth for the various plastic uses. For example, FDA has stringent standards for food-grade packaging making a specialized reprocessing facility such as PET only more attractive, while the textile industry can use a lower grade reprocessed flake from PET and HDPE/LDPE (Sinha 2008, SPI 2005).

Plastic Types: As seen in the table below, there are seven types of plastics (#1-#7), and the primary plastic of interest for this project is Polyethylene Terephthalate or PET (pronounced Pete) (GBB 2011). Plastic #1, PET, is most commonly known for its use in water bottles but is also used as microwavable packaging, synthetic fibers, and textiles. The estimated annual production of each plastic type in the USVI is shown in the far right of the table below, revealing over 2,000 tons per year of PET in the USVI's Municipal Solid Waste mix (GBB 2009).

Plastic Types and the USVI				
#	**Abbreviation**	**Name**	**Use**	**USVI MSW (tons/yr)**
1	PET/PETE	Polyethylene Terephthalate	drink bottles, microwavable packaging, polyesters: fibers, textiles	2,298
2	HDPE	High Density Polyethylene	milk jugs, detergent bottles, trash cans, water pipes, toys	2,407
3	PVC	Polyvinylchloride	plumbing pipes, shower curtains, windows, vinyl flooring	
4	LDPE	Low Density Polyethylene	plastic bags, plastic film, outdoor furniture, floor tiles, siding	5,200
5	PP	Polypropylene	bottle caps, drinking straws, appliances, yogurt containers, car parts	
6	PS	Polystyrene (often foamed)	yogurt containers, disposable razors, foam packaging/to-go containers, cutlery/cups, cds/cassettes	1,438
7	PA, PC, ABS, PU	Polyamides, Polycarbonate, Acrylonitrile Butadiene Styrene, Polyurethane	nylons, eyeglasses, car parts, cell phones, electronic parts, cushioning foams, thermal insulation foams, printer rollers,	
Uncategorized Plastic Waste from study		Non-recyclables from #3, 5, & 7		7,803

***Figure 2**: Table showing plastic types, primary uses, and the estimated generation of each in the USVI (GBB 2009, Wikipedia 2011).*

Plastic and Toxins: Most plastics are thermoplastics and have additives or plasticizers such as phthalates and adipates to make them less brittle for common uses. Immense research suggests toxins from these additives are linked to human and environmental health problems; six different types of phthalates have actually been banned by the European Union. While the United States limits some forms of phthalates, most companies have independently chosen not to use them in toy production (FDA 2011). Bisphenol-A (commonly referred to as BPA) and phthalates are endocrine disruptors and have both been connected to autism, ADD, heart disease, and cancer (Kim et al. 2009, Newschaffer et al. 2007,). Additionally, large corporations such as Target, Wal-Mart, and Microsoft pledged efforts to eliminate PVC in their product choices, with Honda, Nissan, and Toyota banning the use of PVC in their car interiors altogether (Wikipedia 2011). The burning of plastics is particularly concerning because of the link to dioxin production and dioxin-like PCB (polychlorinated biphenyls) production and their associated toxicity (Teller 1985).

Plastic litter can lead to strangulation, choking, & toxicity in marine species that would affect the food chain. Therefore, the primary environmental problem with plastic is 2-fold: plastic itself can be hazardous and plastic contains toxins. Plastic debris contributes to the transfer of invasive species, strangulation of marine species, and is slow to degrade, breaking down into small particles over time that are ingested and often lead to starvation. As the plastic breaks down, the additives/plasticizers, such as Phthalates, which make them less brittle for use in food packaging, release toxic dioxins, heavy metals, and other byproducts that threaten the health of the exposed species and environment. (Derraik 2002, NOAA 2011). This is not just a problem for the health of the Caribbean Sea, but also for the health of the islands and its inhabitants.

Plastic in the Caribbean: Plastic is used excessively in the islands due to everything being shipped in and the weakness of paper in the heat/humidity. According to a study done for the Virgin Islands Waste Management Authority, approximately 24,500 tons of plastic and paper are produced a year (GBB 2009). Driving around the islands, I found plastic litter everywhere from grocery bags, plastic bottles, plastic-ware, and to-go cups to plastic packaging and fishing/boating supplies (see figure below). Plastic degrades very slowly, over time breaking down into smaller plastic particles and often just washing up on shore or collecting in the

Mangrove roots creating unhealthy ecosystems. Research continues to highlight the devastating effects these and other plastic waste have on marine life. These problems are exacerbated by the complexities of insular communities and the need for action and consensus on solutions that satisfy the economy and environmental concerns.

Figure 3: *Plastics found in the mangroves on St. John, USVI (personal photos).*

Increasing scientific interest around plastics and micro-plastics throughout the seas endorse the urgency of eliminating plastic waste in the Virgin Islands. Data gathered from over 35 years revealed plastics as the most frequently reported marine debris in the Caribbean (Ivar do Sul & Costa 2007). Plastic debris can be contributed from land-based sources such as human litter, runoff, and dumps or ocean-based sources such as cruise ships, fishing vessels, and merchant vessels. Approximately 80% of marine plastic debris comes from land-based sources with the remaining 20% from the shipping industry. Plastic degrades very slowly, breaking down over time into smaller plastic particles that are prevalent in Caribbean waters, and as discussed above, the existence of plastic marine debris with their associated toxins are threatening the health of the islands, surrounding waters, and their delicate ecosystems (Poussart 2008).

The Business of Plastic: Over 40% of plastic produced is disposed of after one year with potential chances for life-cycle increase through recycling, reprocessing, incineration, and conversion (ACC 2011). Research by the Council for Solid Waste Solutions indicates that PET's scrap value is only second to aluminum among container materials. The Center for Plastics Recycling Research projects that the market for reclaimed PET will grow between 11 and 17% annually (CPRP 2011).

The current total market demand for RPET (reprocessed PET plastic) is at 1.2 billion pounds per year and only 800 million pounds per year are processed in the US and Canada (Fox Petroleum 2011). According to a European study done on plastics, the total global production of plastics grew from 1.5 million tons to 245 million tons in the last 60 years (EPR 2010). North America and Western Europe generate 100 kilogram per capita currently with growth expected to reach 140 kilogram per capita by 2015 (Fox Petroleum 2011). The US EPA reported an increase from 1-12% in landfilled plastics since the 60's and only 7% of the MSW is recycled (EPA 2011). These numbers coupled with multiple companies, including Fox Petroleum, looking to acquire more plastics to meet this demand in the US and Canada seem to reflect the potential for an attractive investment opportunity in the Caribbean. A Fox Petroleum subsidiary currently earns revenues of more than $5 million per year processing about 30 million pounds of post-industrial and post-consumer plastics per year (Fox Petroleum 2011).

Among the over 14 Billion pounds of PET used in the US, four billion pounds was for textiles and 3 billion was for packaging. Over the last 20 years, the amount of reclaimed PET has grown to over 700 million pounds. This is in part due to large corporate shifts encouraging market demand through sustainable initiatives. For example, Coca Cola plans to use 25% of recycled or renewable materials in their bottles by 2015 (Coca Cola 2011). There has also been an increase of more than 35% reclaimed PET in the textile industry for use in carpet manufacturing. This rise in demand has pushed prices for reclaimed PET to roughly 10% of the virgin price.

When looking at commodity prices for scrap aluminum according to most recent prices, it is obvious how a market exists in the USVI for recycling aluminum and not plastic. Historical aluminum prices have averaged over $.80 per pound for the last two years. Current aluminum prices are at $.98 per pound for mixed aluminum scrap according to the London Metal Exchange (LME 2011). It must be taken into consideration that all aluminum scraps can be shredded and baled for purchase and the St. Thomas Metal Company takes in all aluminum from St. John as well to contribute to a feasible scaled operation. On the contrary, stable plastic markets in the continental US exist primarily for polyethylene terephthalate (PET/#1: i.e. soda and water bottles) and high-density polyethylene (HDPE/#2: i.e. milk jugs, detergent bottles) (MRA 2011). These two preferred plastics only value on average $.50 per pound and contribute about 5,000 tons per year or 3.2% of the total annual MSW stream in the USVI (MRA 2011, GBB 2009).

The graph below displays the favorable investment in terms of scrap PET plastic at over $.40 over Mixed Film and Rigid at roughly $.12. Therefore, the primary target for a profitable business would be PET or plastic #1. Moreover, the value of reprocessed PET products such as high-quality flake and plastic strapping see prices over $.50 and $1.00 according to company annual reports (Morningstar 2011, ASBDC 2011, AERT 2011).

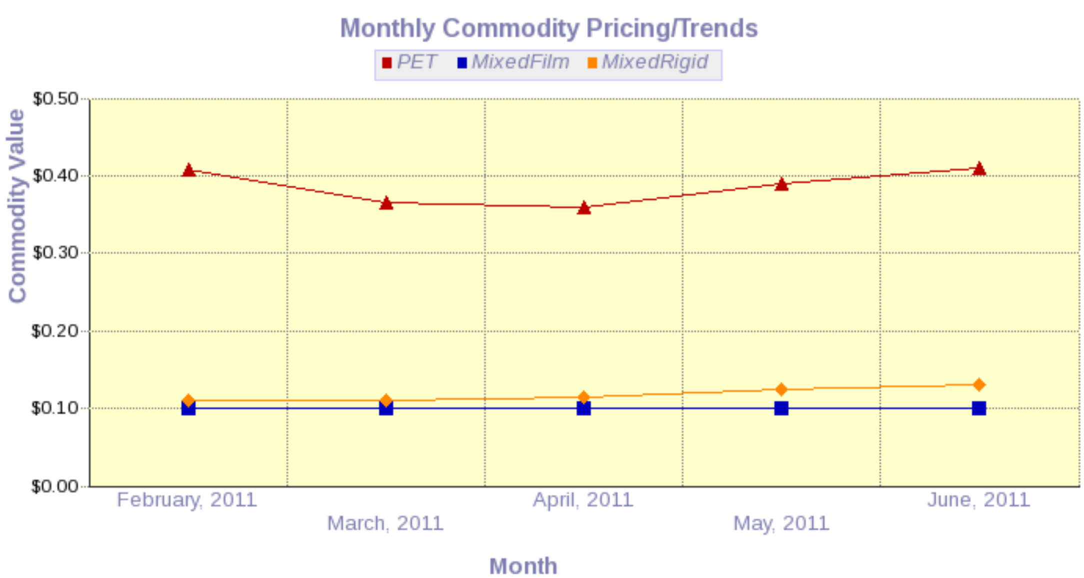

Figure 4: *"Monthly Commodity Pricing/Trends" according to Scrap Plastic Pricing 2011 (MRA 2011).*

III. The Proposal

Closed Loop Opportunity: Over the summer of 2011, I had the opportunity to meet with local organizations of the US Virgin Islands such as the St. John Community Foundation, Virgin Islands Waste Management Authority (VIWMA), St. Croix Recycling Association, and the St. Croix Environmental Association (SEA) as well as meet with waste management companies in the continental United States to assess the feasibility of a plastic-recycling operation in the USVI. An initial assessment of potential for feedstock supply, market analysis, and demand potential pointed to the potential for a closed loop operation. With further research into comparable businesses, the plan proved to be a viable business model.

To address the primary barriers of cost and transportation, the plan sources the PET feedstock from within the USVI, processes the PET at a plant on St. Croix, then offers the products for purchase to industry located in the USVI as well. Specific fuel costs associated with shipping the plastic from the primary ports on St. John and St. Thomas to St. Croix was included in the business model as well as trucking from the north end of St. Croix to the south side at the proposed location for operation.

PET Feedstock: The report done by the firm Gershman, Brickner, and Bratton estimates that plastic waste makes up about 15% or 19,000 tons per year, which translates to over $5.5 million in management costs if the proposed Waste to Energy facility is denied after landfills close. Recyclable plastics only make up approximately 3% of the MSW stream in the USVI; therefore, this supply could be extracted, non-competitively from the MSW before the Virgin Islands Waste Management Authority would deal with it. Every 1-ton of plastic recycled saves the amount of water one-person uses, on average, in two months and 2000 pounds of oil (Fox Petroleum 2011). Recycling plastic not only reduces the need for petroleum to make the virgin material, but a sustainably conscious plant could generate carbon credits.

The use of only PET in the Plastic-Recycling Operation in the USVI allows a simplified process of collection and sorting, for example “just bottles” bins located at ports and MSW dump sites. This amount comes to about 4,596,000 pounds of PET per year within the USVI (GBB 2009). This amount does not include port waste from the shipping industry and more importantly the cruise industry that brings in more than two million visitors annually (NREL 2011). There is also potential for growth when considering the natural growth rate of plastic bottle consumption up until the recession was around 10% per year (Napcor, APR, PETRA 2011). Finally, additional feedstock could be found in surrounding islands that lack recycling operations such as the British Virgin Islands.

Reprocessed Product: The product of interest for this proposal would be high quality plastic flake and plastic strapping. According to a Cambridge University study, both of these products make up about 15% of recycled PET use on average, with the textile industry being the predominant use for recycled PET (C-MIT 2005). The reprocessed strapping for industrial purposes is more durable and offered at a lower cost than the alternative metal strapping. This industrial strapping is used for securing, bundling, or attaching bales, boxes, crates, gaylords, pallets, and shipping containers (Wikipedia 2011). The high quality, reprocessed plastic flake could be used as a substitute for virgin material in manufacturing things such as plastic bottles. The production percentage of strapping and flake would be made according to the actual demand needs.

Plant Location: A regional reprocessing plant, eliminating long-distance travel costs, could lead to investment opportunities driving funding for the entire plastic recycling operation. The St. Croix industrial sector is home to Hovensa, the nation's second largest oil refinery, a Coca Cola Bottling subsidiary, the Diageo Rum Distillery, and various other industrial facilities. These companies are incentivized to locate in the USVI through the Economic Development Commission (EDC). Companies that operate under the requirements outlined by the EDC to enhance the economy of the USVI are offered major tax exemptions in order to increase their bottom line (Gantley 2011). For example, businesses are exempt from all property and excise taxes and 90% of income tax. They also benefit from getting the "made in the USA" label without export tariffs when shipping to the continental USA. This program is therefore vital to the success of any business locating in the USVI. An important consideration for constructing a plastic reprocessing center in the Caribbean when looking at high costs of utilities would be the significant use of water and power in the recycling process. Upon researching the area, I found that this region in St. Croix offered more affordable utilities because they operate their own desalination plant and coal plant for the industries. There is also a complex infrastructure for operations and communication to further decrease operation costs and capital investment needs. The next point of interest for the industrial hub is the proximity to Port St. Croix. This is a deep-water port located in a primary import, export, and trans-shipment route for the international shipping industry (Renaissance Park 2011). When considering the product of this proposal, plastic strapping for shipping and packaging, this access to target demand is key in the viability of the business. Moreover, the Diageo Distillery and Coca Cola Bottling Subsidiary would be primary targets for future contracts for reprocessed PET strapping and flake as well.

Proposal Operation: The proposal estimates 40 jobs from production personnel and administration to guards and a logistics crew. The logistics crew would be responsible for collection and transport of plastics from specific drop off sites on the three islands to the reprocessing plant. The main components for the proposal operation include trucks, dumps/bins, balers, bale-breaker, forklift, wash processor, extruder, automatic sorter, and building. Recycled plastic must undergo extensive sorting and cleaning in order to be accepted and valuable in the plastic market. There are multiple steps of sorting color, type, and foreign matter then washing to remove sand, film, metal, soil, paper, glass, stones, and labels. The plastic will go through several cycles of cutting, grinding, sifting, washing, and rinsing followed by a final mechanical sorting of flakes for quality purposes. The last step of the operation would be to sort out how distribution of the product to contracted customers would occur. Depending on the proximity of the client, the idea would be to maximize efficiency by delivering the final product to the customer on the way to collect the new feedstock on the islands. The total costs associated with the plant capital and operations are estimated to be about $3.8 million. These numbers were established from annual reports of comparable companies, scaled to approximate capacity of this proposal.

IV. Business Model

Details and Assumptions: All aspects of the business model have been outlined previously, but the details of estimates and assumptions with tables showing samples from spreadsheet calculations are given below. All numbers were based on annual reports from Horizon Packaging, ECO2 Plastics, Greenwave Recycling Systems Inc, KW Plastics, and Replay Plastics as well as research from the American Chemistry Council, Resource Recycling, and the Environmental Protection Agency.

The fuel costs were estimated using the current price for diesel in St. Croix of $4.15 per gallon. With an estimated amount of pick-up circuits per year, calculations for mpg in trucking and shipping, and calculated distances in logistics, the annual fuel costs were estimated to be about $500,000. The plant itself is estimated at 20,000 square feet of warehouse space for purchase at $1.5 million. The total cost of equipment was estimated to be $1 million and labor costs approximately $1 million. The revenue stream is based PET feedstock for the nearly 5 million pounds per year, with no growth in PET supply, from Municipal Solid Waste, and starting with predominantly flake production then ramping up the production of strapping to 98% with flake at 2% by year five. The reprocessed PET strapping price of $1.08 and reprocessed flake price of $.55 were used accordingly. The revenues were then calculated according to percent of each type of reprocessed product multiplied by the correlated price. The total costs of capital, operations, and maintenance were subtracted from the revenue stream for each year. This profit value was then adjusted according to the tax rate of 3.5%, assuming the plant would qualify under the Economic Development Commission for tax breaks. To keep things simple for assessing the primary question of making plastic feasible for USVI, I assumed the plant was 100% investor financed, with the life of the plant depreciating over a 20 years and the equipment over 5 years. Using these numbers, the plant would begin making profits in year two with profits reaching over $2.5 million by year five.

Type	***Low Value***	***High Value***	***Use***
Virgin PET ($/lb)	0.65	0.73	drink bottles, polyester fibers/textiles
rPET Flake ($/lb)	0.43	0.55	bottles, carpet, packaging
rPET Strap ($/lb)	0.9	1.08	shipping/strapping

Product Breakdown:	Year	rFlake	rStrap
% recovered	1	0.652173913	0
% recovered	2	0.217391304	0.782608696
% recovered	3---	0.02173913	0.97826087
PET recovered in USVI		rFlake	rStrap
4,596,000	1	2,997,391.30	-
(total PET feedstock lbs/yr)	2	999,130.43	3,596,869.57
	3---	99,913.04	4,496,086.96

Figure 5 & 6*: Product Price and Feedstock Amount.*

Basic Model	**Value**
REVENUES	
PET feedstock (lbs/yr)	**4596000.00**
10% growth	*459600.00*
40% growth	*1838400.00*
**option for growth*	
rPET flake price ($/lb)	
low	*$0.42*
medium	*$0.50*
high	***$0.55***
rPET strap price ($/lb)	
low	*$0.90*
medium	*$1.00*
high	***$1.08***
**option to change price*	
TOTAL REVENUE ($/yr)	**$4,914,962.40**
CAP & OM	
Fixed CAP&OM costs ($/yr in yr 5)	**$1,455,340.00**
% of each product from stock	lbs of stock
rPET Flake 0.02	*919200*
rPET Strapping .98	*4504080*
**option to change %*	
fixed fuel used (gal/yr)	124157.56
variable fuel cost ($/gal)	**$512,770.72**
low diesel	***$4.13***
medium diesel	*$4.45*
high diesel	*$4.56*
TOTAL COST ($/yr)	**$1,968,110.72**
Total Profits before Taxes	**$2,946,851.68**
3.5% Tax	***$103,139.81***
30% Tax	*$884,055.50*
Profits after Taxes	**$2,843,711.87**

***Figure** 7: Basics of Model Showing Variables.*

Sensitivity Analysis: A sensitivity analysis was done to evaluate the areas where profitability is most vulnerable. The main factors presumably would be diesel fuel prices, rPET prices, feedstock supply, and tax. Therefore, 19 different scenarios were evaluated combining the different variables shown in the table with a graph showing the results below. For example scenario 1 shows a "low P, low d, no g", meaning the parameters for that scenario included the low reprocessed PET price, the low diesel fuel price, no growth rate in feedstock, and had profits of $2.1 million before taxes.

Scenario Parameters	#	Scenario Profits	with Low Tax (3.5%)	with High Tax (30%)
low P, low d, no g	1	$2,124,167.68	$2,049,821.81	$1,486,917.37
low P, med d, no g	2	$2,084,437.26	$2,011,481.95	$1,459,106.08
low P, hi d, no g	3	$2,083,195.68	$2,010,283.83	$1,458,236.98
low P, low d, low g	4	$2,533,395.52	$2,444,726.67	$1,773,376.86
low P, low d, hi g	5	$3,761,079.04	$3,629,441.27	$2,632,755.33
med P, low d, no g	6	$2,581,929.28	$2,491,561.75	$1,807,350.49
med P, med d, no g	7	$2,542,198.86	$2,453,221.90	$1,779,539.20
med P, hi d, no g	8	$2,540,957.28	$2,452,023.78	$1,778,670.10
med P, low d, low g	9	$3,036,933.28	$2,930,640.61	$2,125,853.29
med P, low d, hi g	10	$4,401,945.28	$4,247,877.19	$3,081,361.69
hi P, low d, no g	***11***	***$2,946,851.68***	***$2,843,711.87***	***$2,062,796.17***
hi P, med d, no g	12	$2,907,121.26	$2,805,372.01	$2,034,984.88
hi P, hi d, no g	13	$2,905,879.68	$2,804,173.89	$2,034,115.78
hi P, low d, low g	14	$3,438,347.92	$3,318,005.74	$2,406,843.54
hi P, low d, hi g	15	$4,912,836.64	$4,740,887.35	$3,438,985.65
hi P, med d, low g	16	$3,398,617.50	$3,279,665.89	$2,379,032.25
hi P, hi d, low g	17	$3,397,375.92	$3,278,467.77	$2,378,163.15
hi P, med d, hi g	18	$4,873,106.22	$4,702,547.50	$3,411,174.35
hi P, hi d, hi g	19	$4,871,864.64	$4,701,349.38	$3,410,305.25

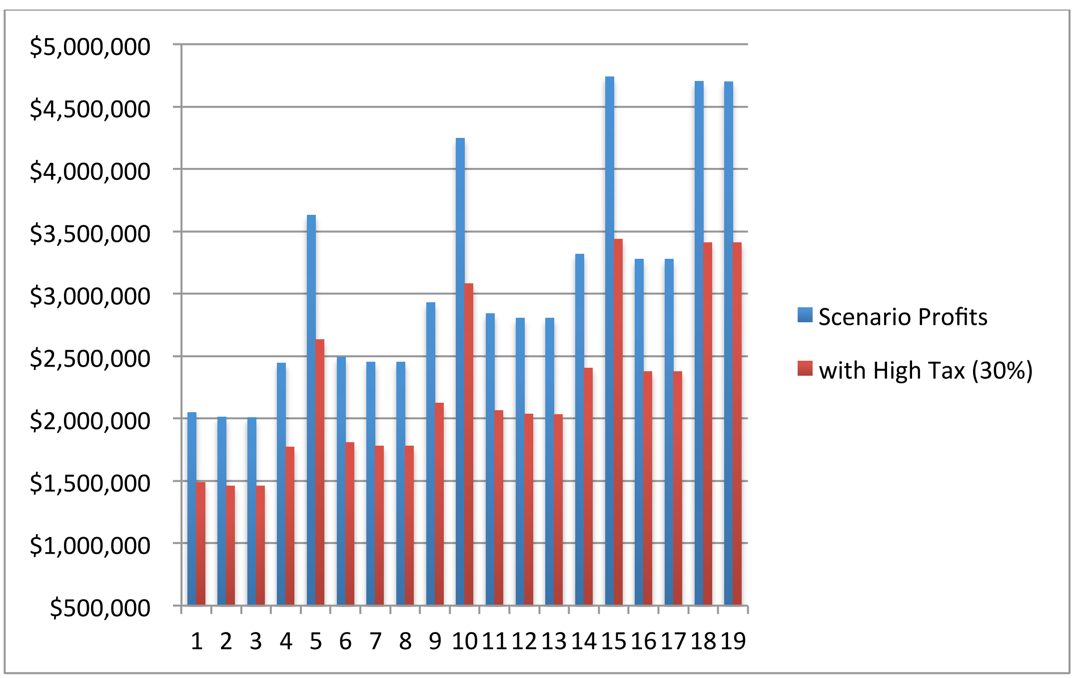

***Figure 8 & 9**: Scenario Parameters & Profits (with Low and High Tax); Graph of Scenarios with low tax in blue and high tax in red.*

In general, a trend of price increases for diesel fuel is shown by the decrease in profits between columns 1-3, 6-8, and 11-13. The range of rPET prices correlate with blocks of lower profits in column 1-5, medium profits in column 6-10, and higher values in the remaining columns. The baseline model with parameters highlighted in the table above is represented with column 11. The scenarios with high feedstock growth rates of 40% are shown in columns 5, 10, 15, 18, and 19, with the best-case scenario of high growth, high rPET price, low diesel, and low tax shown in 15. A possibly more realistic growth rate of 10% is shown in columns 4, 9, 14, 16, and 17, with column 14 representing a low growth profit for the baseline model. Even with a high diesel price and low rPET price, column 3 shows profits above $1 million with either tax rate. The columns in red display the difference with the higher tax rate of 30%, which is the typical tax found in the continental US company reports. The lowest profits in this model reach $250,000 compared to $340,000 with the lower tax rate. The best-case scenario in column 15 would still reach profits near $3.5 million, and the baseline scenario profits would decrease to around $850,000 per year with the higher tax rate. The primary take away from this analysis is the importance of feedstock growth and inclusion in the Economic Development Commission's tax exemption program.

V. Conclusions

Feasibility: Recycling plastic has the potential to become a gainful business, and with investor interest and industry coordination, a plastic reprocessing plant would prove feasible offering opportunities for a successful plastic recycling program in the US Virgin Islands. The small variations in profit based on the sensitivity analysis show that a closed loop operation proves false the former assumptions that transportation costs and commodity price inhibit feasibility of recycling plastic. The largest factors are not necessarily the more volatile diesel fuel and reprocessed PET prices, yet more certainly the tax benefits that would be a priority for any company locating in the USVI. The potential for growth shows that even a 10% increase in feedstock could increase profits by nearly 20%, with more ambitious growth goals increasing profits over 60%. This unique proposal proves the operation can be feasible. The background, costs, and market information outlined in this paper provide a starting point for a viable business plan. I hope that this research will help inform decision makers on the best solution for both USVI residents and the environment towards a sustainable future.

Key Players: With more clarity on target industry players as well as the future of MSW in the USVI, the exact financial needs for developing an investor-driven reprocessing and plastic-recycling operation could be finalized. The product and thus profit of the business would depend on the mix of production to meet demand. The essential components of the proposal are securing supply of PET feedstock as well as a profitable demand schedule. This would be done through local cooperation and participation in the collection side of the operation and developing industry contacts with local target clients. The approved tax breaks under the Economic Development Commission are vital to the success; therefore meeting designated requirements would be a priority in developing the business. The final point to note would be maintaining a working knowledge of not just the plastic market but the recycling industry in general as new developments in best available technology and best practices could prove to be more efficient, have higher production and success rates, as well as increase bottom line.

Next Steps: GHG emissions and carbon credits would need to be further evaluated in order to assess the true market potential. Diverting from landfill decreases CO2 equivalent emissions as well as saving barrels of oil from virgin production; with markets moving in this direction, future opportunities should be considered. Green industry leaders with sustainable, strategic goals would be prime targets for investor potential. Coca Cola is already working towards using recycled content in bottles/packaging and received the National Recycling Coalition's (NRC) 2008 "Recycling Works" award. This award recognized the company's goal to recycle or reuse PET plastic bottles and aluminum cans, their commitment to sustainable packaging, and their investment in recycling infrastructure (Coca Cola 2011). Further evaluation of the local construction, fishing, manufacturing, and plastic industries would help develop an actual demand schedule and profitability based on product mix (% strapping v. flake). A portfolio of potential clients and production specifics with help attract investors and bolster proposal credibility. After analyzing all of the background and surrounding circumstances of the US Virgin Islands, this closed-loop plastic recycling operation is a sustainable investment for business and the environment.

VI. Acknowledgements

This project would not have been possible without the belief and encouragement from so many at the Nicholas School, in particular to Dr. Lincoln Pratson, Dr. Dalia Patino-Echeverri, Mr. James Emery, Dr. Paul Baker, and Dr. Bruce Corliss who provided invaluable guidance that I will carry into my professional career. Thank you to everyone at the Nicholas School for the incredible interdisciplinary view of this exciting field. My hope is that this project will encourage people to think non-traditionally to integrate systems that naturally become more efficient and sustainable. Thank you to my husband, my family, and my friends for your pervasive support. Most of all, thank you to my beautiful daughter who inspires me every day to live fuller and work harder at maintaining balance in this beautiful world to help preserve it for future scientist-adventurers.

"We have not inherited this land from our parents; rather we have borrowed it from our children." ---Kenyan Proverb

Resources:

1. American Chemistry Council (ACC). 2009. *United States National Post-consumer plastics bottle recycled report. [Cited June 2011]. Available from: www.americanchemistry.com.*
2. American Chemistry Council. 2011. *Production and Sales of U.S. Plastic Resins See Rebound in 2010. [Cited October 2011]. Available from: www.americanchemistry.com.*
3. Alpine Energy Group (AEG). 2011. *The Alpine Energy Project.* [Cited October 2011]. Available from: http://aeg-usvi.com/.
4. Association of Small Business Development Centers (ASBDC). 2011. *Writing Business Plans for Recycling Enterprises: Plastics, Glass, or Rubber.[Cited August 2011].* Available from: http://www.bplans.com/.
5. 4R Sustainability, Inc. 2011. *Conversion Technology: A complement to plastic recycling.* American Chemistry Council. [Cited August 2011]. Available from: http://plastics.americanchemistry.com/Plastics-to-Oil.
6. Cambridge-MIT Institute. 2005. *The ImpEE Project: Recycling of Plastics*. University of Cambridge.
7. Center for Plastics Recycling Research. 2011. [Cited September 2011]. Available from: http://webtest.engr.scu.edu/.
8. Coca Cola. 2011. [Cited November 2011]. Available from: http://www.thecoca-colacompany.com/citizenship/packaging.html.
9. Davis, Haase, Warren. 2011. *Waste to Energy Evaluation: U.S. Virgin Islands*. National Renewable Energy Laboratory/TP-7A20-52308.
10. Derraik, Jose G.B. 2002. The Pollution of the marine environment by plastic debris: a review. Marine Pollution Bulletin/44(2002) 842-952.
11. Edgar Online, Inc. 2011. *Advanced Environmental Recycling Technologies Inc.* Form 10-K.
12. Environmental Protection Agency. 2002. *Recycling the Hard Stuff.* EPA/530-F-02-023. [Cited June 2011]. Available from: www.epa.gov.
13. Environmental Protection Agency. 2010. *Municipal Solid Waste Generations, Recycling, and Disposal in the United States: Facts and Figures for 2009.* EPA/530-F-010-012. [Cited July 2011]. Available from: www.epa.gov.
14. Environmental Protection Agency. 2011. *Hovensa LLC, Clean Air Act Settlement*. [Cited July 2011]. Available from: http://www.epa.gov/compliance/resources/cases/civil/caa/hovensa.html#violations.
15. European Plastic Recylers (EPR). 2010. *How to Increase the Mechanical Recycling of Post-Consumer Plastics.* [Cited November 2011]. Available from: http://www.plasticsrecyclers.eu/uploads/media/eupr/HowIncreaseRecycling.

16. Federal Drug Administration. 2011. *Biphenol A*. [Cited October 2011]. Available from: http://www.fda.gov/newsevents/publichealthfocus/ucm064437.htm
17. Flores, Mario C. 2008. *Plastic Materials and Environmental Externalities: Structural Causes and Corrective Policy.* Lethbridge Undergraduate Research Journal/2008(3)2.
18. Fox Petroleum. 2011. [Cited February 2011]. Available from: http://www.foxpetroleum.net/corporateresponsibility.html.
19. Gantley, Beckett G. *How long must one stay in the USVI to be considered a "resident" to qualify for the 90% residence tax credit*? St. Thomas University School of Law.
20. Gershman, Brickner & Bratton (GBB). 2009. *USVI Waste Stream Characterization Study.* Gershman, Brickner, & Bratton, Inc.
21. Integrated Waste Management Board. 2003. *Plastic White Paper: Optimizing Plastics, Use, Recycling, and Disposal in California.* California Waste Management Board.
22. Ivar do Sul J.A. & Costa M.F. 2007. *Marine Debris Review for Latin America and the Wider Caribbean Region: From the 1970's until now, and where do we go from here?* Marine Pollution Bulletin 54 (2007).
23. Kilgore, James D. 1995. *Control of dioxins, furan, and mercury emissions from municipal waste combustors.* Journal of Hazardous Materials/47 (1996) 163-194.
24. Killinger, Jennifer. 2011. *Frequently Asked Questions on Plastics and Waste to Energy (energy recovery).* American Chemistry Council. [Cited October 2011]. Available from:: www.americanchemistry.com.
25. Kim, Bung-Nyun, Soo-Churl Cho, Yeni Kim, Min-Sup Shin, Hee-Jeong Yoo, Jae-Won Kim, Young Hee Yang, Hyo-Won Kim, Soo-Young Bhang, Yun-Chul Hong. 2009. *Phthalates Exposure and Attention Deficit/Hyperactivity Disorder in School-Age Children*. Society of Biological Psychiatry/66(2009) 958-963.
26. London Metal Exchange (LME). 2011. [Cited November 2011]. Available from: http://www.lme.com/.
27. Miranda, Marie Lynn, Hale, Brack. 2005. *Paradise recovered: energy production and waste management in island environments.* Energy Policy/33(2005) 1691-1702.
28. Moore Recycling Associates (MRA), INC. *Scrap Plastic Pricing.* 2009 [cited August 2011]. Available from: http://www.plasticsmarkets.org/.
29. Moore Recycling Associates, INC. 2009. *National Report on Postconsumer Non-Bottle Rigid Plastic Recycling.* Prepared for the American Chemistry Council February 2011.
30. Morningstar. 2011. *Eco2Plastics, Inc.* [cited June 2011]. Available from: http://quicktake.morningstar.com/stocknet/secdocuments.aspx?symbol=eopiq.

31. NREL. 2011. *USVI Energy Road Map: Charting the Course to a Clean Energy Future*. Energy Development in Island Nations, National Renewable Energy Laboratory/BR-6A42-51541.
32. Napcor, APR, and PETRA. 2011. *PET Container Reycling Rates.* [Cited December 2011]. Available from: www.napcor.com, www.plasticsrecycling.org.
33. National Oceanic and Atmospheric Administration. 2011. *US Virgin Islands.* [Cited April 2011]. Available from: http://coris.noaa.gov/portals/virginislands.html.
34. Newschaffer, Craig J., Lisa A. Croen, Julie Daniels, Ellen Giarelli, Judith K. Grether, Susan E. Levy, David S. Mandell, Lisa A. Miller, Jennifer Printo-Martin, July Reaven, Ann M. Reynolds, Catherine E. Rice, Diana Schendel, Gayle C. Windham. 2007. *The Epidemiology of Autism Spectrum Disorders*. Annual Reviews Public Health/28 (2007) 235-258. [Cited October 2011]. Available from: www.annualreviews.org.
35. Poussart Anna-Karin. 2008. *A Summary of Facts and Findings on Marine and Coastal Issues in the Caribbean Region.* UNEP Caribbean Environment Programme.
36. Pyper, Julia. 2011. *Discarded plastics may provide a significant source of alternative energy—study.* ClimateWire. [Cited October 2011]. Available from: www.climatewire.com
37. Recycling Association of the Virgin Islands. 2011. *RAVI Facts.* [Cited July 2011]. Available from: http://www.usvircd.org/RAVI/.
38. Renaissance Park. 2011. [Cited August 2011]. Available from: http://www.stxrenaissance.com/.
39. Resource Recycling. 2011. *PET Price; 2011*. [Cited August 2011]. Available from: http://resource-recycling.com/search/node/2011%20PET%20price.
40. Rowat, S.C. 1999. *Incinerator toxic emissions: a brief summary of human health effects with a note on regulatory controls.* Harcout Brace & Co. Ltd. Medical Hypotheses/52(5) (1999) 389-396.
41. Scrap Aluminum Pricing. 2011. [Cited November 2011]. Available from: http://www.metalprices.com/.
42. Sinha, Rajnish. 2008. *Potential for usage of recycled PET in packaging.* Horizon Technologies.
43. St. Croix Environmental Association (SEA). 2009. *SEA Testimony before the 28th Legislature*. [Cited July 2011]. Available from: http://www.stxenvironmental.org/pdf/SEA_Oral_Testimony_on_VI_WAPA_Air_Emissions.pdf.
44. St. John Community Foundation (SJCF). 2011. [Cited June 2011]. Available from: http://www.sjcf.org/.
45. The Society of the Plastics Industry, Inc (SPI). 2005. *Improving Energy Efficiency at U.S. Plastics Manufacturing Plants.* US Department of Energy.

46. Tellus Institute with Sound Resource Management. 2011. *More Jobs, Less Pollution: growing the Recycling Economy in the U.S*. NRDC. [Cited November 2011]. Available from: http://docs.nrdc.org/globalwarming/files/glo_11111401a.pdf.
47. Teller, Aaron J. 1985. *Control of Dioxin Emissions from Incineration*. United States Patent Number 4,502,396.
48. Themelis, M.J. Castaldi, J. Bhatti, and L. Arsova. 2011. Energy and Economic Value of Non-Recycled Plastics (NRP) and Municipal Solid Wastes (MSW) that are currently landfilled in the fifty states. Columbia University.
49. Virgin Islands Waste Management Authority. 2011. *VIWMA*. [Cited August 2011]. Available from: http://www.viwma.org/Home.aspx.
50. Wikipedia. 2011. *Plastic.* [Cited April 2011]. Available from: http://en.wikipedia.org/wiki/Plastic.
51. Wikipedia. 2011. Polyvinyl Chloride. [Cited April 2011]. Available from: http://en.wikipedia.org/wiki/Polyvinyl_chloride#Health_and_safety.
52. Wikipedia. 2011. *Strapping.* [cited October 2011]. Available from: http://en.wikipedia.org/wiki/Strapping#Uses_of_strapping.
53. Wikipedia. 2011. *United States Virgin Islands.* [Cited April 2011]. Available from: http://en.wikipedia.org/wiki/United_States_Virgin_Islands.
54. Working Group on Waste Prevention and Recycling. 2005. *Improving Recycling Markets.* [Cited September 2011]. Available from: http://www.oecd.org/dataoecd/24/14/35582045.pdf.