# Industrial Symbiotic Potential of the Caguas Oeste Industrial Park, Caguas, Puerto Rico

Photo provided by PRIDCO

Prepared for

FE&S 501 Industrial Ecology
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Beth Feingold
**Comment:** I added this heading. and took the colon out of references cited.

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**Acknowledgements**

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## ABSTRACT

Caguas Oeste Industrial Park is a small industrial park is Caguas, Puerto Rico comprised of companies from the manufacturing, industrial, food and service sectors. Most of the firms within its boundaries have few employees, small volumes of materials flows, and little business or social connections to one another. In order to assess the potential for industrial symbiosis in this park, the boundaries of the park were broadened to incorporate businesses in the waste management and recycling sectors. The main opportunities that exist for industrial symbiosis in the park are the development of a material broker/recycling program with myriad components, incorporating materials such as plastics, glass, paper, wooden pallets, electrical components, and scrap metal. However, in order to implement such change, the firms must 'think outside the box' and recognize that the initial capital costs of implementation will be heavily outweighed by their environmental and economic benefits.

## INTRODUCTION

The island of Puerto Rico has seen rapid industrial development over the last century. The second half of the 20th century was marked by export-oriented manufacturing of textiles, pharmaceuticals, food and electronics. Moving into the 21st century, however, Puerto Rico's economy began catering to more high-tech business ventures, specializing in biotechnology, the medical device industry and the life sciences (Ashton 2005). These shifts are apparent throughout numerous industrial parks on the island, and have largely sparked a movement which has started to address the need for more sustainable industrial development on Puerto Rico.

### Introduction of Industrial Ecology and Industrial Symbiosis

If we accept the notion that most of the past industrial development has been based on a linear model of extraction, use, and disposal, we can begin to realize that this is not a sustainable practice, as there is a finite supply of raw materials to be extracted. One of the main goals of

industrial ecology is "to find ways to make modern industrial economies mimic ecosystems by transforming the waste of one firm into the valuable input of another" (Desrochers 2002).

Industrial ecologists have for a long time recognized the value in sustainable business practices within and between firms, as they view industrial parks as systems, much like an ecologist might view an ecosystem - where the actions of one player have direct and indirect impacts on the other players within that same system. "Industrial Ecology views industrial systems in concert with their surrounding, not in isolation from them. It brings together environmental sciences, engineering, management, and policy to study the flows of energy and materials through various systems. These flows drive our industrial systems and are key to determining their sustainability." (PRIOS 2003).

An important discipline within industrial ecology, industrial symbiosis, examines these material and energy flows throughout different scales of economies. "Industrial symbiosis engages traditionally separate industries in a collective approach to competitive advantage including physical exchange of materials, energy, water, and/or by-products. The keys to industrial symbiosis are collaboration and the synergistic possibilities offered by geographic proximity" (Chertow 2000). Myriad examples of successful industrial symbiosis exist, the most notable of which is the city of Kalundborg, Denmark. In Kalundborg, companies including a power plant, pharmaceutical plant, gypsum board facility and the City of Kalundborg share utilities and various by-products or residues from one firm that become inputs for other firms, resulting in overall reductions of water consumption, use of virgin resources and environmental impact (Chertow 2000). The goal of the present study is not necessarily to emulate the system which exists in Denmark, but build on the knowledge we have gained from the implementation of such industrial symbiotic environments to ascertain their feasibility in industrial park development on the island of Puerto Rico. As outlined by Lambert and Boons, there are three industrial symbiosis (IS) opportunities that exist within the park and two which are related to external exchange, all of which will be addressed further in this paper:

- Collective sharing of utilities,
- Collective processing of waste streams,
- Mutual exchange of materials and energy,
- Applying residual products from remote companies, and
- Delivering residual products to remote companies (Lambert and Boons 2002).

**Puerto Rico: An Island of Sustainability**

The island of Puerto Rico offers a unique opportunity for a large scale investigation of industrial symbiosis for a number of reasons. Since it is an island, its physical boundaries are clearly delineated and its net imports and exports are easily quantified. It has a large industrial sector that is continuing to evolve as new business opportunities arise. Puerto Rico is working hard at maintaining a competitive advantage in various industrial markets over its neighbors such as the Dominican Republic where the cost of labor is cheaper and environmental regulations are more lax. Innovative politicians, businessmen and academics on the island see great strength in the island's ability to forge smart growth in the industrial sector; to implement sustainable industrial development by applying the tools and concepts of industrial ecology.

As part of the multi-year study, "Puerto Rico: An Island of Sustainability" (PRIOS 2003), this year's Industrial Ecology course at the Yale School of Forestry and Environmental Studies conducted an examination of industrial symbiotic activities in Puerto Rican Industrial Parks in the San Juan vicinity. The PRIOS project analyzes "Puerto Rico through the lens of industrial ecology and identifies sustainable development opportunities that have the potential to improve the island's competitiveness and attractiveness as a business location" (PRIOS 2003). The main hypothesis of this study is that *location within an industrial ecosystem will enhance economic development while minimizing environmental damage.* This project carried out in the Caguas Oeste Industrial Park, in addition to the concurrent studies in other San Juan area industrial parks, is taking the first step of analyzing a specific industrial site to develop ideas and development strategies for firm- and park-level management that have a high feasibility and address the notion of industrial sustainability. The goals of this year's projects are to determine the potential for implementing industrial symbiosis in Puerto Rico's Industrial Parks, and to establish how this potential might be realized (F&ES 2005).

By studying trends in the current industrial parks, analysis can be performed to ascertain how *eco-industrial parks* might be implemented. An eco-industrial park is understood to be "a community of companies, located in a single region, that exchange and make use of each other's by-products or energy" (Desrochers 2001). The focus of this paper will be on the aforementioned industrial park in Caguas, and how the activities of the firms within and surrounding it may be augmented to achieve such a status.

**City of Caguas**

Caguas is a city of more than 140,000 people, and a heavy manufacturing and processing sector. It is located 21 miles south of the capitol, San Juan, and with increased sprawl on the island, it has become one of San Juan's major suburbs (See Figure 1). Its community has enjoyed one of the best economies among Puerto Rican cities since at least the 1980s. During the early part of the 20th century, Caguas hosted one of Puerto Rico's most important sugar manufacturers, which gave employment to thousands of cagüeños (Wikipedia 2005).


**Figure 1: Map of Puerto Rico**

**Caguas Oeste Industrial Park**

Caguas Oeste Industrial Park (COIP) is one of many small parks situated within the city's limits. It boasts twenty companies, mostly small businesses, within a footprint of roughly one square mile. The park is dominated by the manufacturing industry, especially medical and electronic manufacturing. Smaller sectors represented are baking, assembly, and service. The park is surrounded by a strip of restaurants (Papa John's, Subway, etc), a dry cleaner, a diaper distributor, an elementary school, empty lots/field, and a vocational school specializing in automotive repair. Figure 2 shows an aerial photograph of the park. Though no industrial

symbiosis currently exists, myriad possibilities exist when the scope of the analysis is broadened to the regional level.

**Setting the boundaries: what do we learn from broadening the box?**

The assertion has been made that "larger regional areas may be more suitable for closing material loops and creating sustainable industrial ecosystems" (Sterr and Ott 2004). We found this approach to be applicable in the analysis of COIP due to its small size. If we were to solely examine the materials flows of the companies within the boundary of our park, we would find that there isn't much in the way of industrial symbiosis that would be possible or economically viable. However, if we broaden the boundary of our study to the regional scale of the City of Caguas, we find that there may be more possibilities due to larger aggregate volumes of flows of materials. Sterr and Ott faced a similar challenge in Pfaffengrund where the industrial site "proved to be much too small for almost every kind of material cycle, and due to a lack of redundancy, the stability of output-input connections was potentially endangered by even the smallest fluctuations" (Sterr and Ott 2004). Like Pfaffengrund, COIP is embedded in a larger industrial area, which allows for larger key players with more substantial flows to take part in potential materials cycling. This could lead "to a relatively high probability of finding fitting partners for output-input relations, not only between producers and waste disposers, but even among the industrial producers (Sterr and Ott 2004). When we stepped outside of the boundaries of the park, we were able to account for a number of waste management options, and with the support of the other small industrial parks within the city, recognized that there could be high potential for cycling efforts. Sterr and Ott also purport that "the regional scale allows for a high degree of societal control over as well as personal affectedness of ecologically unfavorable behavior" (Sterr and Ott 2004). Barriers which cripple such efforts have been tied to the realization that there are diverse interests and a low-level of organization around such topics when you get to a regional scale (Sterr and Ott 2004). Because such transparency is required to successfully manage larger materials streams, the lack of willingness of companies to fully disclose information about their flows will also deter such processes from happening; a problem that becomes larger as the scale increases as social connections are weaker and personal trust is weakened between entities.

These potential ideas and barriers will be assessed throughout the balance of this document. However, it is imperative to introduce the approach and methodology implemented in the project prior to discussing the findings and analysis, as specifics such as the firm level material flows will lay the groundwork for understanding our interests for scaling up the project.

**Methodology**

Project methodology consisted of:

*1. Research on companies in the COIP:* The 20 companies listed as being situated within the park were researched online. Many of them were found to either not exist or not have published websites. The Puerto Rico Manufacturers Association (PRMA) and the Puerto Rico Industrial Development Company (PRIDCO) websites provided useful information and some missing contact information. Table 1 is a list of the companies in the COIP as well as the companies outside of the park boundaries which were interviewed.

*2. Background research on Industrial Ecology and Industrial Symbiosis:* Literature searches and a review were conducted on sustainable industrial development, eco-industrial development, and industrial symbiosis. These readings provided necessary background information, and are listed in the references at the end of this report.

*3. Contacting companies:* Each of the 20 companies was contacted via the U.S. Postal Service, fax, telephone, and email if available. Letters were sent to each company explaining the PRIOS study and asking for cooperation. Members of the Caguas Team telephoned and faxed each of the companies and discussed the study and arranged meetings to be held during the week of field work to be conducted. Many companies listed as being established in the park were not able to be reached by telephone, and were later contacted in person or realized to have been defunct.

*4. Survey development:* A survey for each company to fill out was created along with a blank flow chart in which company representatives could enter their material and energy flows. These materials were faxed to all of the companies within and outside of the park that were contacted.

*5. Interviews / data collection:* A period of one business week was spent in Puerto Rico during which time interviews were held with almost every business existing within the park in addition to a few outside that were deemed important in creating linkages.

*6. Synthesis of data:* Upon returning from the field work portion of this project, we met as a group to compile our data and examine material flows that existed on the industry level within the park and surrounding area.

**Table 1. List of Businesses in COIP and other companies interviewed**

| **Company Name** | **Company Location** | **Interviewed?** |
|---|---|---|
| Avant Technologies | COIP | Yes |
| C-Axis | COIP | Yes |
| CNC 2000 | COIP | Yes |
| Comercial El Ebanista | COIP | Yes |
| Cortelco | COIP | Yes |
| Electrical and Control Manufacturing Engineers | COIP | Yes |
| Graficos, Inc | COIP | Yes |
| Halcon Bakers | COIP | Yes |
| IFCO Recycling | Caguas | Yes |
| Laboratorio AAA Central | COIP | Yes |
| Onyx Environmental Services | Caguas | Yes |
| Quality Windows and Doors | COIP | Yes |
| Rainbow Optical | COIP | Yes |
| Somerset Pharmaceuticals | COIP | No |
| Sportzone, Inc. | COIP | Yes |
| St. Jude Medical | COIP | Yes |
| Starwire | Caguas | Yes |

| | | |
|---|---|---|
| Tres Leches | COIP | Yes |
| Veolia | COIP | Yes |
| Waste Management of Puerto Rico | Caguas | Yes |

## EXISTING MATERIAL FLOW ANALYSIS

Beth Feingold

**Comment:** Caroline needs to add a couple sentences about what an MFA is and why we did them for the companies in the park. I also took out the blurb about table 1, so write somewhere in here to see app. A for MFAs of each co.

In order to develop industrial symbioses, reduce waste and increase efficiency on a park, or broader scale, it is important to understand what materials are being used, what materials are being discarded as waste, and the efficiency of these processes. For this reason, we conducted a Material Flow Analysis (MFA) on a firm level. In our interviews, we gathered information about raw material inputs, energy and water usage, volume of product creation and non-product output. It was also important to get a sense of the company's purpose and production methods, which are described in the following section. For the volumes of each company's material flow and material footprint, see Appendix A-F. Additionally, the names for each company's contact are listed in the references portion of this paper.

Before assessing the future possibilities for industrial symbiosis in Caguas Oeste, it is crucial to understand the existing synergies between firms in the park, as well as the existing material flows through each company and sector of COIP. Besides business partnerships and current joint provision of services, we also analyzed the existing social networks for the park. The following figure displays the COIP according to its Industry type, for greater understanding of

the existing structure of the park.

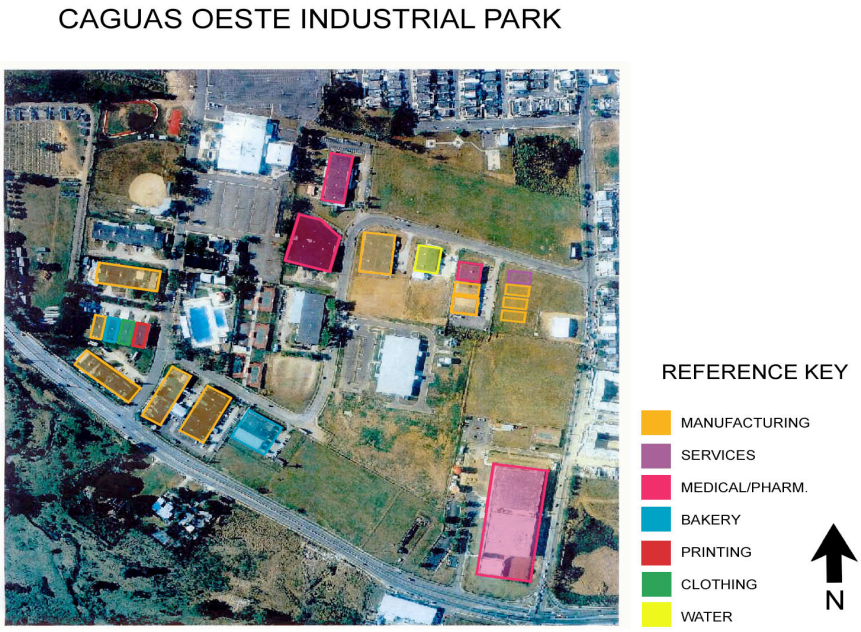



**Figure 2: Caguas Oeste Industrial Park**

This portion is organized in terms of manufacturing type and major material flow, and in alphabetical order within that. The following includes Pharmaceutical and Medical Devices, Metal and Electrical Manufacturing, Other Manufacturing and Assembly, Food Products, and Services. It should be noted that the inventory of businesses includes companies literally located within COIP and the external companies which we interviewed.

**The Current Status of Caguas Oeste: Existing Inter-Firm Synergies**

We were unable to discover any existing industrial symbioses in COIP in the traditional sense, i.e.: there are no inter-firm by-product exchanges, no installed shared infrastructure, and almost no joint provision of services. The only substantial example of shared infrastructure is that maintained by the municipality (e.g. roads, power lines, and water). Joint provision of

resources occurs in limited ways. Figure 3 outlines the major inputs and outputs of COIP.

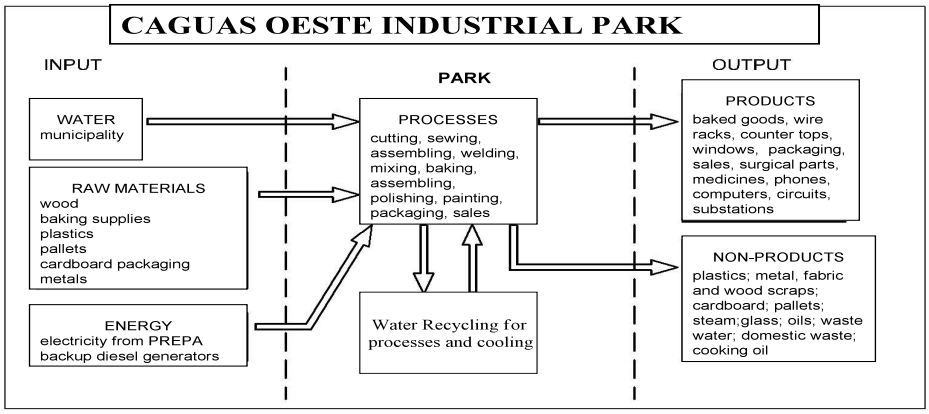



**Figure 3: Material Flow for COIP**

Joint provision of resources is limited to the small number of restaurants available for all employees, a short distance from the plant; however, this has been deemed business-as-usual. An empty lot near the Caguas Oeste Park has been converted to a variety of restaurants, including a Subway and a Pizza Hut. It is unclear if these establishments are frequented by park employees. St. Jude Medical has an on-site cafeteria facility.

Isolated instances of shared machinery were highlighted. Employees at Halcon Baker mentioned sharing a lift, lawnmowers and tractors when needed or when their machinery was broken. Though there is not a large environmental or economic benefit from this relationship, it does create social ties and trusting relationships between facilities, which are understood to be of extreme importance in the development of industrial symbiosis on a park level.

The majority of the relationships relayed to us fall under the category of inter-firm business partnerships. C-Axis located itself inside COIP because of St. Jude Medical presence inside the park. C-Axis provides St Jude with the majority of the metal rings and springs used in St. Jude's construction of complete heart valves. CNC-2000 also provides St. Jude with some similar materials, but CNC-2000 did not co-locate and is not solely dependent on St. Jude's business.

Similarly, Veolia Water did not co-locate, but has provided St. Jude with small water filtration systems in the past.

Electrical Control and Manufacturing Company constructed the power station for Somerset-Mylan pharmaceuticals, though no other cooperation between the companies has arisen from this one time deal.

## Pharmaceutical and Medical Devices

### Somerset Pharmaceuticals

Though we were unable to speak to Somerset directly, we were able to speak to Contract Operations Director of Merck Sharp Pharmaceuticals in Caguas. Merck purchases from other Caguas pharmaceutical manufacturers, including MOVA Pharmaceuticals. The MOVA plant is not inside Caguas Oeste though their production is similar to that of Somerset's, and therefore the information gleaned about them (from: Chan et al 2003; personal communication, Merck Pharmaceuticals, 2005) will be used as a proxy for the information we were unable to get from Somerset.

Like Somerset, MOVA processes solid, liquid, and sterile (injections) dosage forms of pharmaceuticals. Discharges include biomedical, industrial non-hazardous waste, and domestic waste. Hazardous waste is handled by an environmental services company, while domestic waste is removed by a general waste company (i.e., Waste Management) and then landfilled. Paper and aluminum are recycled.

MOVA has its own on-site wastewater treatment plant which then discharges water to PRASA, as well as a reverse osmosis so that water can be recycled through company processes. Electricity is provided by PREPA, though there is also a back-up diesel generator for emergencies as well as for general steam production for air conditioning and sterilization. In 2001, only about 50% of the steam was used, and if Somerset has similar waste of steam, we expect this to provide for possible symbioses.

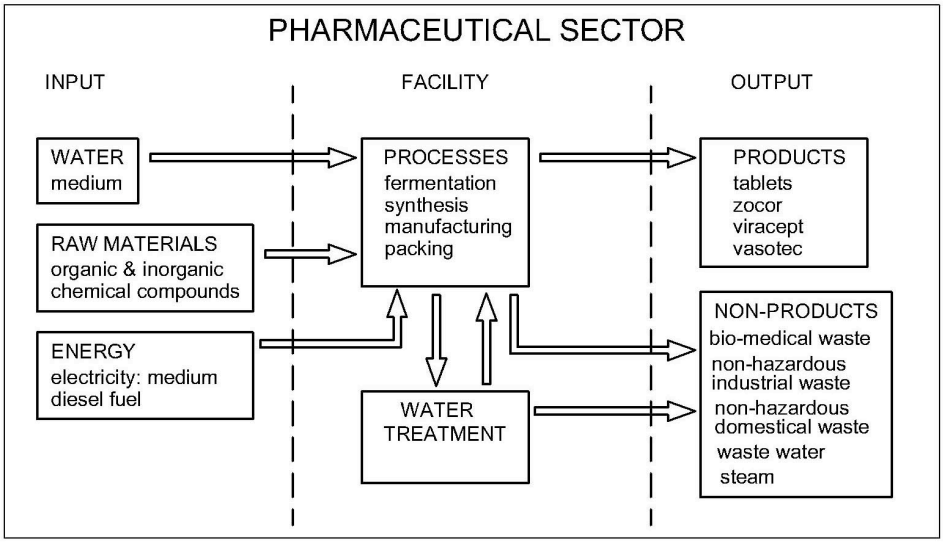



**Figure 4: Material Flow for COIP Pharmaceutical Sector**

**St. Jude Medical**

St. Jude Medical International manufactures heart valves and pacemakers. The Puerto Rican plant produces only heart valves and the St. Jude Angio-Seal™, used in angioplasty. There are plans in the preliminary stages to build an additional facility in an empty lot which would nearly double the size of St Jude, B.V. and would provide space for sterilization of the Angio-Seal™ rather than having them shipped to Minnetonka, Minnesota to be sterilized. They would also manufacture pacemakers in the new building. There is a cafeteria currently on site, run by Aramark.

Material input includes metal springs and rings, fabric, biolytic and pyrolitic carbon, plastic for injection molding, and wood pallets. 80% of inputs are from the U.S. Energy input comes from the PREPA to power all machinery and air vacuum systems. Their back-up generator runs on diesel fuel. Water is used to decompress carbon and for cleaning processes. Water comes primarily from municipal sources, but they do have groundwater extraction as a backup. 95% of their water

output is treated by the state, while material non-product outputs are taken by Waste Management. Waste plastic cannot be reused as the injection process transforms the plastic characteristics.

In terms of personal connections, the St. Jude Medical administration does communicate with the other medical device facilities on the island (a total of five). Their main competitors in the global market are Metronica, Striker, and Baxer, against which they benchmark their environmental and economic progress. The St. Jude administration was very aware of the other companies in the park and was able to list C-Axis, Veolia, Mech Tech, Mylan, and several other pharmaceuticals outside of the parks. Some of the springs and rings used by some of St. Jude's valves are manufactured by C-Axis, also located in Caguas Oeste.

St. Jude Medical expressed interest in pallet recycling, along with cardboard recycling. Additionally, with the new processes of sterilization and pacemaker manufacture, water needs will require a water treatment facility on site.

**C-Axis**

C-Axis specializes in manufacturing compressors to run manufacturing equipment. They also do contract-manufacturing for medical equipment, and they supply 90% of St. Jude Medical's heart valves. For this reason, C-Axis co-located in COIP to be near to St. Jude. C-Axis also produces heart valves, heat shrink, micro-position parts, implants, surgical parts, and fixtures for pacemakers. The main material inputs to C-Axis are steel, aluminum, cutting oil, and hydraulic oil. 95% of non-product outputs are recycled, and the other 5% of non-product output is a variety of oils which get taken away by an environmental services firm for safe disposal. Electricity is provided by PREPA, but there is also a solar-powered backup generator.

Future plans involve greater involvement with other medical companies to expand their business. Other than their business relationship with St. Jude Medical, C-Axis expressed no real social or symbiotic connection to other businesses in the park. However, in their building (owned by the municipality of Caguas, and not by PRIDCO), parking, bathroom facilities and electricity are all shared with the other businesses. C-Axis is a member of the National Manufacturing Trade Organization, PRMA, PRIDCO, and the Society of Manufacturing Engineers.

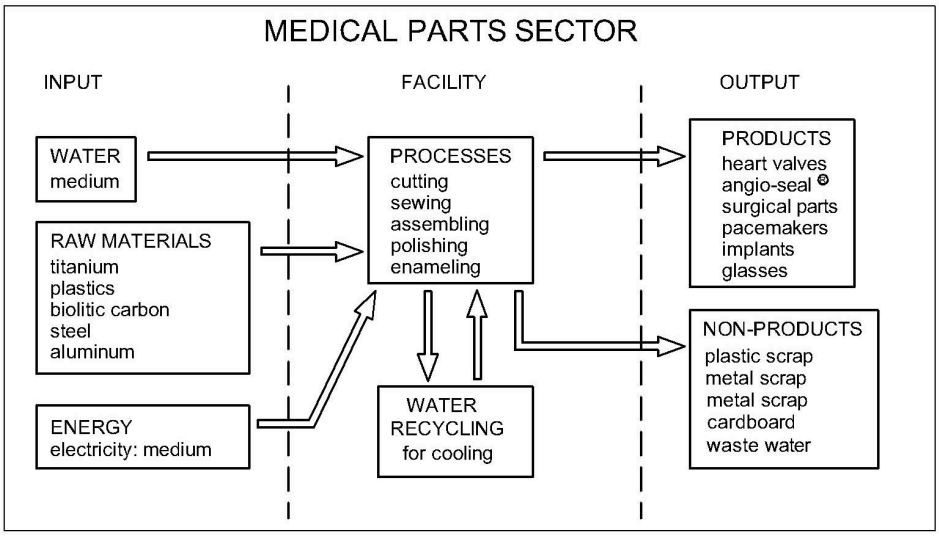



**Figure 5: Material Flow for COIP Medical Device Sector**

**Metal and Electrical Manufacturing**

**AVANT Technologies**

AVANT Technologies is a privately owned corporation headquartered in Caguas, and is one of the leading locally-owned companies which designs, manufactures, sells and services its own products. They currently offer computers under Avant PR and NewGate brand names, digital video and surveillance systems under the Video Sentinel brand name, and access control systems under the brand name "NEWTEK". The firm is a full service company that offers maintenance, service and installation and training of information technology. AVANT is the only Microsoft certified company in the Caribbean, and is also EnergyStar certified. They sell their products to government and banking institutions and not on the retail level.

Computers and video surveillance equipment are assembled at the facility, though all components are manufactured by outside companies. Custom-made metal computer frames, circuit boards, and cardboard packaging are made in Puerto Rico, while computer processors and other components are imported from the United States. The use of energy and water is minimal as no industrial processes are involved in component assembly. AVANT contracts out to an

environmental service company to remove the scrap and waste electronic equipment. They have worked with Verdico, CNC 2000, and St. Jude Medical, but did not express strong social ties to these companies.

**CNC 2000**

CNC 2000 makes high-tech precision parts and mechanisms, which change depending on market demands. Currently, their products range from precision pieces for war tanks and helicopters to metal knee joints for medical implants. Though some of these products are sold to St. Jude Medical and other companies on the island, more than 90% of their production is exported out of the island.

The materials used are metals, plastic and wood, while water is used for cleaning purposes, and mixed with oil for hydraulic processes, but is not used in production. Heat generation and use is minimal, as their main industrial processes are molding, polishing, and painting all of which require little heat. Waste is not large, but the profitable metal scraps are currently mixed with the rest of the waste removed by Waste Management. Steel scraps account for less than 1% of all processed steel, and waste rates are similar for other metals used.

**Electrical and Control Manufacturing Company**

The Electricity and Control Manufacturing Company (ECMC) specializes in the manufacture of heavy-industrial electrical transference infrastructure devices. Within the facility, stainless steel sheets are shaped and cut to form electrical circuit boxes for use as shells for substations, transformers, and circuit breakers. The primarily client is PREPA; however they work with large industries such as Somerset, also located in Caguas Oeste. ECMC constructed and installed a substation at the Somerset Caguas plant.

Aluminum and copper are used in the construction of the devices, but smaller components, such as circuits and fuses and connection boards are imported for use in the larger, industrial devices. Electrical non-product outputs are collected by an environmental services company. Water-soluble hydraulic oil is also needed as cooling fluid for the high-powered cutting and forming machines. The hydraulic oil is constantly recycled and no waste is produced, but the occasional addition of oil is required. The processes and machinery in the ECMC facility require a large energy demand; however there is minimal water use.

**Starwire Products**

Star Wire Products manufactures display racks for supermarkets, stores, and factories on the local level. There is no competition on Puerto Rico, but there are other such facilities in the Caribbean. Their sub-processes involve forming the wires, painting and forming plastics. Metals and other materials are imported from the United States, and non-product outputs are shipped to a foundry in Puerto Rico which has recently moved to the island from the mainland. Waste Management collects Star Wire's cardboard and plastic wastes. Water is used mainly for cooling, and this water is reused throughout the processes.

Star Wire is not as centrally located in the park as some of the other facilities, and there is very little interaction with other COIP facilities. However, employees tend know the families of workers at other plants, as they have been working near each other for 35 years. There are no social events between Star Wire and other facilities.

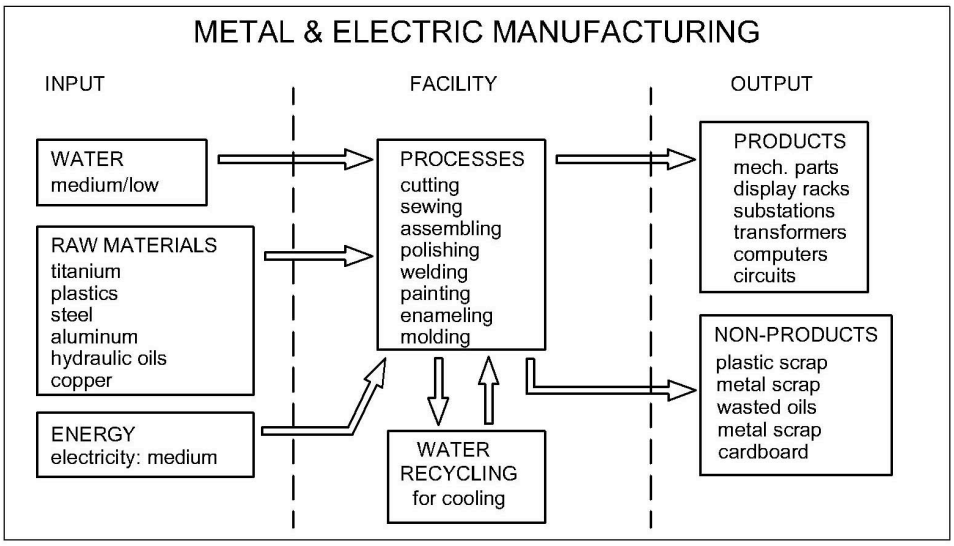



**Figure 6: Material Flow for COIP Metal & Electric Manufacturing**

## Other Manufacturing and Assembly

### Comercial El Ebanista

This firm manufactures wooden kitchen countertops, mostly for domestic use. The same company has a large facility outside of Caguas which makes the same kind of countertops, but in stone. Besides wood, solvents, glues, sealers, stains, and lacquer are also used. All waste is mixed and collected by Waste Management, so none of the scrap wood can be reused. Metal cans from synthetic products are sometimes returned to the dealership. There is no heat production involved with the processes and the use of water is only for cleaning purposes. Electricity is used for sawing, screwing and sanding; amounts are not available, but do not appear to be significant. Very little water is used, except for domestic uses.

### Cortelco

Cortelco is the second largest phone and communications equipment supplier in Puerto Rico, and has over 1500 clients. The Caguas plant is used only for equipment assembly, programming, testing and retail sale so it is not a manufacturing facility. Sales occur on-site and orders are placed through the warehouse space in the back of the facility. The front office is located on PRIDCO owned land, but the warehouse is situated on municipality land. The company's major market brand is Ayer, followed by Nortel, Mytel, Hytachi, and their own Cortelco phones.

There is minimal waste, coming mainly from packaging. Their storage area houses new equipment for processing, as well as damaged equipment returned for repair. Though some is repaired onsite, it is frequently less expensive for them to discard the damaged equipment and import new components. Their recycling service currently does not pick up waste electronics including the plastics, electronic boards, and circuits, so this is disposed with municipal waste. Cortelco produces no hazardous waste. There is minimal water and energy use as the facility is for assembly only.

### Quality Windows and Doors

Quality Windows, established only 5 years ago, is a small manufacturer of aluminum frames, doors, windows and storefronts. Quality Windows competes with standardized industrial giants like Marvin or Anderson by creating custom medium- to good-quality products. The majority of

their sales come from within Puerto Rico, and only occasionally do they sell to Santo Domingo or other Caribbean islands.

Water use is minimal, as water is used only for cleaning purposes. There is no heat involved in production other than welding; therefore we consider the electricity consumption to be low to medium. Other processes used are sawing, screwing and polishing, all of which use less water and energy than cleaning and welding processes. The major waste flow is aluminum scrap, which is sold to a local foundry for recycling. Other wastes are taken by Waste Management of Puerto Rico.

**Rainbow Optical**

Rainbow Optical manufactures lenses for glasses after being sent the frames. They produce around 800 pairs of glasses per month, after receiving large plastic lenses, dye, polish, and frames from the United States. The lenses are cut, shaped, polished, cleaned, dyed and placed in the frame. All of these processes are done on site. Each step requires a separate machine, most of which involve water, yet this water is reused to repeat the same procedure on many lenses. Similarly, very little dye, polish, and acetone are used, and none is every directly disposed.

The major non-product output is the plastic from the lenses, as about three-quarters of the initial circular lens becomes waste. Most eyeglass lenses are much smaller, once installed in the frames. This plastic waste is currently being disposed of by Waste Management Puerto Rico and is not recycled, but IFCO Recycling identified this waste as a very profitable variety of plastic.

Rainbow Optical is very centrally located in the park, and did have a strong tie to the neighboring plant of Cortelco, primarily due to proximity. Rainbow Optical's administration offered to contact Cortelco to schedule an interview. They also mentioned more personal connections through the children of employees. Finally, Rainbow Optical also mentioned the presence of a machine shop that was used by several companies in the park, but they did not provide more details regarding this joint provision of services.

**Sportzone, Inc.**

Sportzone, Inc. is an independently-owned company manufacturing and embroidering sporting uniforms, equipment and accessories. Sportzone imports all fabric, thread, trimming, zippers, buttons, hats, and plastic bags for uniform packaging and sending. Very little water or

energy is used in these processes. Waste streams include fabric, trimming, and thread scraps, all of which are taken from the plant by Waste Management of Puerto Rico.

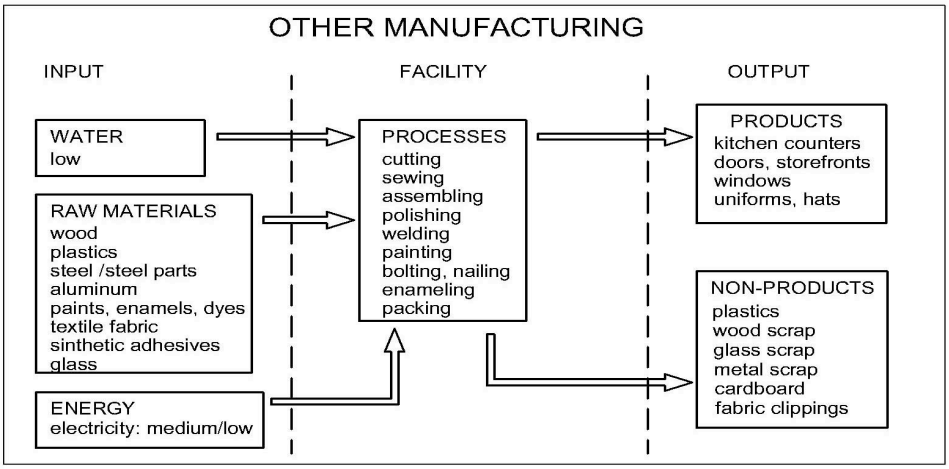



**Figure 7: Material Flow for COIP Manufacturing Sector (not including Metals and Electrical Manufacturing)**

## Food Products

### Halcon Baker, Inc.

Halcon Baker, Inc. cooks and packages food products, which are sold under a variety of labels. The *galletas,* or essentially crackers, are sold as "Poly" or "Wholesome" crackers, while the natural and artificial fruit syrups are sold with a variety of sno-cone kits, frequently under the name "La Cena". About 80% of the crackers and syrups are sold on the island, while 20% are exported to the United States, particularly to Miami. The honey, which is purchased from Santo Domingo and repackaged, as well as the brown sugar packaged by Halcon is both sold 90% on the island.

Besides the honey, all inputs including baking products and packaging materials come from the United States. All waste is mixed and picked up by Waste Management of Puerto Rico. Pallets are brought in and out, and there is no recycling program, but due to product sales, they are rarely disposed of.

**Tres Leches**

Tres Leches is a company specializing in desserts, particularly traditional desserts of Puerto Rico. Tres Leches supplies all of the cakes of some of the largest fast food franchises on the island, including Pollo Tropical, Ponderosa, Sizzler, and Ft. Roberts. At this point, Tres Leches is not exporting the cakes off of the island, but they are selling at a retail store in the Shopping Galería Paseos.

All baking supplies and packaging comes from the United States, with the exception of fresh milk which is imported from Argentina. Packaging makes up a large amount of the input and output stream, but Tres Leches does try to reuse the larger boxes in which food supplies arrive to ship their products. However, individually labeled boxes are used for the sale and shipment of most items. There is essentially no food waste, but grease is mixed with the garbage each week. The main waste problem they face is that of the wooden pallets. Waste Management refuses to dispose of them, so Tres Leches attempts to send all wooden pallets back with the deliveries, but this is not always successful.

Energy for Tres Leches comes from PREPA, yet they have a backup generator, which runs on diesel. Energy is used to power the two very large refrigerators, the small and larger oven, and two giant mixing machines. The Tres Leches area is slightly isolated from the rest of the park in a section with Quality Windows, Sportzone, and Graficos. Employees from Quality Windows are always invited to the Tres Leches employee Christmas party, and a carpool of Rainbow Optical-Tres Leches employees existed in the past. Finally, PRIDCO was mentioned as a major force in forming inter-firm relationships, due to informal conversations at PRIDCO functions.

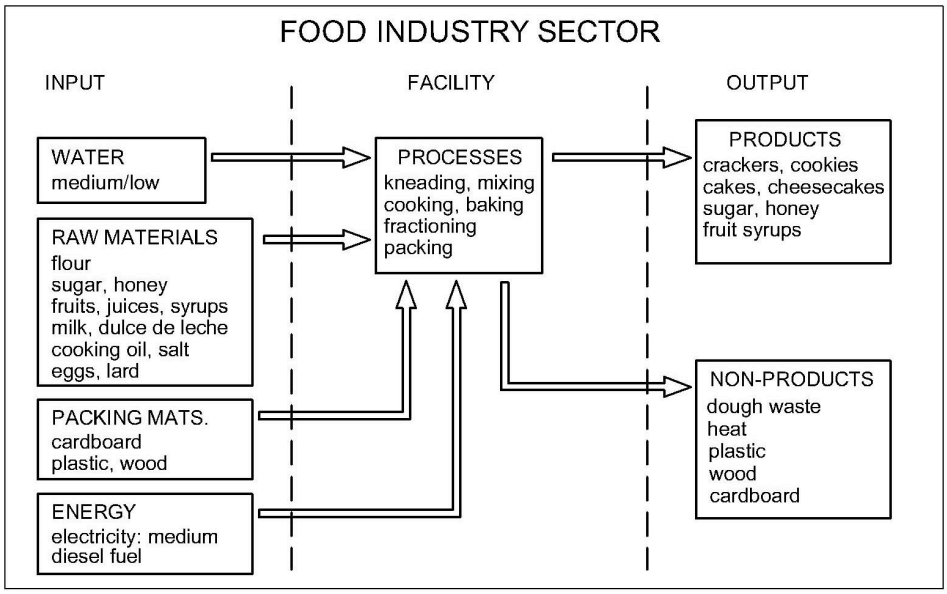



**Figure 8: Material Flow for Food Industry Sector in COIP**

**Services**

**IFCO Recycling**

IFCO Recycling is one of the largest recycling companies in Puerto Rico. It is privately owned, and there are currently three plants on the island which are located in Bayamon, Gurabo, and Caguas. They are in the process of building two more facilities, one of which will replace the aging Bayamon facility. The Caguas facility is in the process of changing as well, as they are currently in the construction stages of a new and more technological sorting method. Together, these four recycling centers will help IFCO to meet the recycling needs of the entire island. Though they are the largest recycling company on Puerto Rico, they face the competition of two other large companies, Pronatura, and Smurfy. IFCO is a member of both PRMA and PRIDCO, but they have not developed business contracts with PRIDCO as a whole. However, they do service some individual companies in PRIDCO owned parks.

IFCO Recycling mainly recycles paper products, which makes up 98% of their product flow. They also recycle small amounts of plastics, currently numbers 1-7, though they are seeking to

expand this as well, with the new facilities. While they are not a manufacturing facility, IFCO plays a large role in the potential for industrial symbiosis on Puerto Rico. They collect their "raw" materials from industry (industry's waste products), then classify them by industry specifications, and mark them for the end user. Virtually all of the paper goes to China for use in recycled products.

**Laboratorio AAA Central**

Located near the Caguas Oeste Industrial Park is the Laboratorio Central of the *Autoridad de Acueductos y Alcantarillados*. This park tests municipal waste water and drinking water. No industrial testing occurs at this facility. Material inputs are mainly chemical, all of which are disposed with wastewater treated by the city. Non-liquid wastes are removed by Waste Management. As Laboratorio AAA Central is not industrial, it was not considered as a major part of our study.

**Onyx Environmental Services**

Onyx Environmental Services has branches throughout the United States, Canada, and Puerto Rico, including a branch in Caguas. They are a part of the larger Onyx North America, which in turn is a branch of Veolia Environment. Onyx Environmental Services collects processes and resells hazardous waste and recyclables.

Solvents, acids, and motor and hydraulic oils are shipped back to the states for treatment, processing and resale or disposal. Waste from the large pharmaceutical companies on the island, particularly the large quantities of rejected medicine that does not meet all qualifications, has in the past been sold to waste-to-energy projects, including one in Cabarita, Puerto Rico. Recyclable materials that need to be disassembled prior to recycling, including light bulbs, batteries, computers, and keyboards, are all disassembled by Onyx Recycling in New Jersey and resold to manufacturers in the United States or abroad.

**Waste Management of Puerto Rico**

Though Waste Management is not located in Caguas Oeste nor is it a manufacturing facility, we chose to interview and include this company owing to its crucial role in the waste removal from Caguas Oeste and the processing and disposal of that waste. Nearly every company in

Caguas Oeste (as mentioned above) rely on Waste Management to remove nearly all on-hazardous waste streams from their facilities. Additionally, Waste Management as a whole is the largest company involved in waste disposal on the island. Their major competitors are Allied Waste and the municipal waste management agencies.

They estimate that 11,000 million tons of waste per day is generated on the island, including both municipal solid waste (MSW) and commercial waste. The Caguas facility and its employees remove approximately 1600 tons per week of MSW and 900-1000 tons per week of industrial wastes from facilities Caguas and the surrounding areas. They charge $23 / ton to landfill waste, which incorporates the cost of shipping waste off the island to be landfilled.

The conversation with Waste Management also illuminated many of the largest barriers to symbiosis on the island. When we inquired about the possibility of a waste to energy plant on the island, they explained the many previous plants that had failed in the past due to lack of economic feasibility along with overwhelming public concern regarding air pollution and the quantity of ash produced in the process. We discussed the mismatch in material flows, in that much of the same "waste" shipped off the island to be recycled or disposed of is the same materials shipped onto the island at great cost. Waste Management suggested that the state limit or tax what is coming onto the island, or import things in different formats. They did not mention the possibility of on-island reuse or recycling, and did not seem to think it was a feasible alternative.

**Existing Social Connections**

Due to the small size of the Caguas Oeste Industrial Park, social connections are not particularly strong among company owners, managers or staff. However, they are acquaintances. There are no social clubs or any other organization that would bring the workers or administration staff together. All "official" social connections and membership to groups seem to be outside the boundaries of Caguas. The following figure outlines the existing social connections.

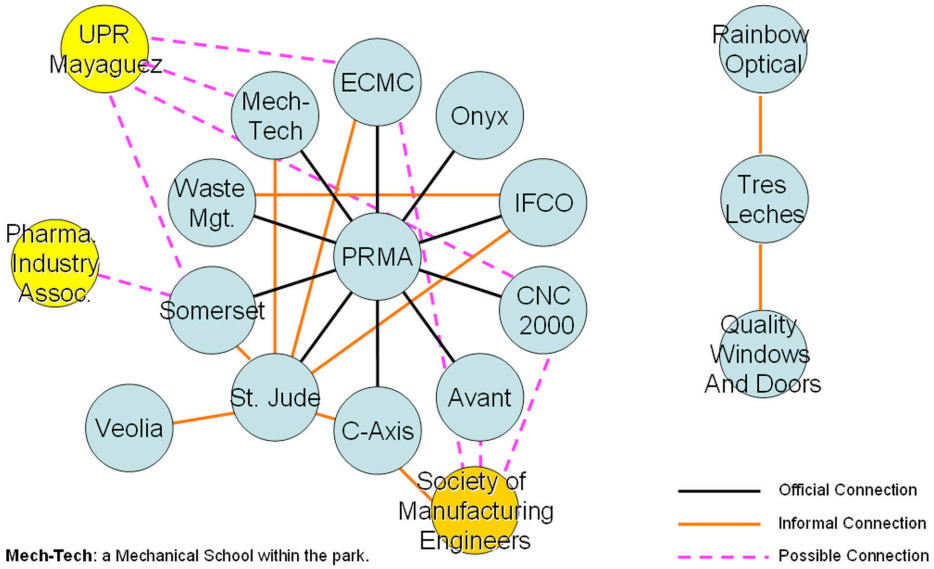



**Figure 9: Existing Social Connections**

Most companies in the park are members of PRMA. The annual gathering can be considered the only time management and staff of participating firms meet. Nevertheless, some informal relationships have developed. A sense of "helping the neighbors" exists. As mentioned above, Mr. Francisco Palomo from Halcon Bakers indicated that there is some exchange or borrowing of machines between companies, whenever an emergency occurs. For instance, he mentioned that their mowing machine was broken and that he borrowed their neighbor's. Occasionally more sophisticated machines are also borrowed for certain periods of time. This is an indication of healthy neighborhood relationships and cooperation, even if there are no formal connections.

It appears that there are closer social connections among certain firms like Quality Windows, Tres Leches and Rainbow Optical, which are not members of PRMA than among the firms that are members. Ms. Alicia de la Sota, from Tres Leches mentioned that several of their employees used to carpool together with Rainbow Optical employees and that they invite workers from

Quality Windows and Doors to the company Christmas parties. Another link in common that some companies have outside of Caguas is membership to the Society of Manufacturing Engineers, for which many of the engineers working in the park are a part of. Another source of potential links is the fact that most of the engineers and other professionals attended UPR-Mayaguez (University of Puerto Rico) as students.

## POTENTIAL SYMBIOSES FOR CAGUAS OESTE

Prior to considering traditional concepts of industrial symbiosis and what the possibilities for such ties in Caguas Oeste might be, it is important to consider the other changes that would need to occur before such symbioses could be instated. In particular, we consider the potential for greater social connections in the park and how to foster inter-firm relationships. We then consider the potential symbioses in Caguas Oeste.

### Potential Social Connections

The potential for creating new social ties among the different players in COIP may be high on one hand, due to the almost non-existent social connections, but low due of the limited size of the park.

As previously noted, many of the social connections among the companies we surveyed were happening *outside* the park, through institutions like PRMA, the Society of Manufacturing Engineers, and the University of Puerto Rico. It has been proven in many other locations that social connections drive Industrial Symbiosis (J. Christensen, personal communication, 2005). Therefore we believe it can be highly desirable and necessary to foster new social links *within* the park and with regional neighbors.

The question remains in Caguas Oeste: How can we foster such relationships? This is a fertile field for the imagination. Some ideas to encourage social connections include: a common meeting place/cafeteria, a social club or association for the industrial park tenets, and organized activities akin to block parties.

**Potential By-Product, Utility Sharing, and Joint Provision of Services Connections**

"Industrial symbiosis (IS), a sub-field of industrial ecology, is principally concerned with the cooperative management of resource flows through networks of businesses as a means of approaching ecologically sustainable industrial activity." (Chertow et. al., 2004) In an effort to frame the sustainability issues facing Caguas Industrial Park, we identified and made an effort to incorporate the following points into our model for the industrial park:

- Reduce pollution and environmental damage,
- Reduce consumption of natural resources,
- Increase opportunity for small and traditional businesses and agriculture, and
- Approach sustainable operation.

The challenges we encountered in developing ideas for industrial symbiosis and incorporating the above noted sustainability points were as follows:

- Low material waste streams limit by-product exchange potential,
- Little social activity between firms limit utility/infrastructure sharing and joint provision of services potential,
- High Tech Industries (computing, communications, precision biomedical devices) require processed and refined materials and components, limiting byproduct reuse, and
- High Tech Industries guard proprietary information for patent protection and manufacturing purposes.

The following diagram outlines the potential for symbiosis within the Caguas Industrial Park given the development of certain key anchor tenants.

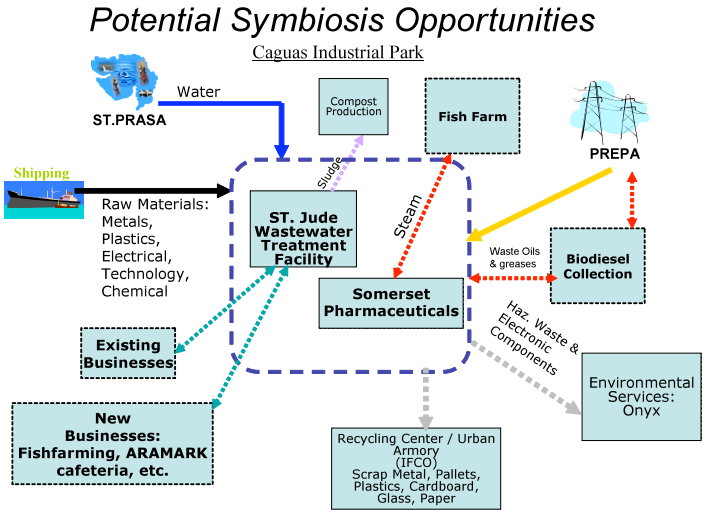



**Figure 10. Potential Industrial Symbiosis Opportunities for COIP**

These key concepts are as follows (Ashton 2005):

- by-product exchanges - the exchange of firm-specific materials between two or more parties,
- utility/infrastructure sharing - the pooled management of commonly used resources such as energy, water, and wastewater, and
- joint provision of services – meeting common needs across firms for ancillary activities such as fire suppression, transportation, food provision, and so forth.

The key concepts of Industrial Symbiosis can begin to be achieved within Caguas by incorporating one or all of the following: a materials broker/recycling center, a biodiesel collection business, a common cafeteria center within Saint Jude, a back-up electrical generation facility, a fish farm, and a compost production facility. The reality that the COIP may never achieve industrial symbiosis to the level reached by that of Kalunborg is clear. A pertinent question to ask of Caguas is, "Why not?" Barriers to I.S development for Caguas and the island of Puerto Rico, in general and for the proposed projects, will be addressed in the ensuing text.

However, building on the ecological analogy, the initiation of the businesses build around symbiotic concepts, such as a materials broker, may prove to aid in the evolution of the park to a more complex and closed material and energy system. The types of businesses located in Caguas limit the degree to which industrial symbiosis can be achieved. As such, the boundary for our study has grown beyond the property limits of the Caguas Industrial Park. The concept of by-product exchanges has been expanded to include firms not just within the park or Caguas for that matter, but Puerto Rico as a whole. However, we have conceptualized the concepts of Utility/Infrastructure sharing and Joint Provision of Services within the park. The following table outlines the potential and what we felt as priority projects for the Industrial Park.

**TABLE 2 – POTENTIAL SYMBIOTIC LINKAGES**

| Symbiotic Linkage | Firms/Industries Involved | Environ. Benefit | Feasibility | Economic Benefit | Priority |
|---|---|---|---|---|---|
| **Utility/Infrastructure Sharing** | | | | | |
| 1. Wastewater Reuse | St. Jude's & Somerset providing brown water for Ind. Park lands, and aquifer recharge. | H | M | M | * |
| 2. Wastewater Treatment | St. Jude's providing treatment for new businesses | H | L | H | |
| 3. Backup Energy | Park wide | M | L | L | * |
| **Joint Provision** | | | | | |
| 4. Common Meeting Space | St. Jude, multiple others | L | H | M | * |
| 5. Security | Caguas Oeste Industrial Park | L | L | L | |
| **By-Product Exchanges** | | | | | |
| 6. Recycling Collection Center | Pallets, scrap metal, glass, plastic, electrical components, wood pallet, etc. | H | M | H | * |
| 7. Biodiesel feedstock | Pharmaceuticals, Food Production, Waste Oils. | H | L | H | * |
| 8. Excess Steam | Generated by Somerset for fish farm | H | L | H | |

1) Wastewater Reuse

An opportunity for the park to take advantage of involves reuse of the treated wastewater from both St. Jude and Somerset, thereby incorporating the concept of cascading water use within the park. The treated wastewater could be utilized to water the park resident's lawns, trucked and utilized in local cement manufacturing, or used as potential low grade process water for new businesses that may locate in the park.

An additional consideration for St. Jude's to consider is tertiary treatment by open wetland lagoon. This treatment design involves traditional primary and secondary treatment followed by a natural bottom treatment wetland. Aquifer recharge is a major concern for Puerto Rico (Kearney, 2003). This design will allow for aquifer recharge which supports the concept of sustainability within the local environment. However, this treatment option may not be possible without the company's full compliance with sanitary waste treatment regulations, which ensure potentially hazardous containments are removed prior to the entry of the third stage of the treatment train, the treatment wetland. Wastewater treatment is regulated by the Puerto Rico Aqueduct and Sewer Authority (PRASA).

In addition to aquifer recharge, the presence of a wetland system will encourage and support local flora and fauna and also significantly add to the aesthetics of an industrial park setting. Many eco-parks around the world have wetland and park creation as a part of their design and have incorporated trials and recreational areas for the benefit of their employees. Subsequently, we felt that such a project would provide a high degree of environmental benefit, a moderate degree of feasibility and a moderate degree of economic benefit, especially if one considers the value of environmental services.

2) St. Jude's Wastewater Treatment Facility

As mentioned earlier, St. Jude Medical is planning the construction of a major addition to their facility in order to increase their capacity to sterilize Angio-Seals and manufacture of pacemakers. In addition to doubling the size of the facility, the plans include the installation of a wastewater treatment plant to deal with the large flow of wastewater imparted from these new processes. With the construction of a localized wastewater treatment facility come opportunities for new business and utility sharing. However, we felt the capital expenditures for infrastructure

design and construction of a shared system for existing park residents was inappropriate for such a small park with limited wastewater production. If larger wastewater producers were present within the park, such as a fish farm, this synergy would have a higher priority. By treating wastewater prior to its release to the municipal system, the companies may be able to arrange for lower discharge rates in addition to decreasing the potential for heavy pollutant discharges to the environment if the municipal system became overloaded. Subsequently, we felt that there would be a high degree of environmental and economic benefits; however, a low feasibility due to the design capacity of the treatment facility which is unknown at this time, in addition to high capital costs.

3) Shared Backup Power Generation

A utility sharing opportunity for Caguas to consider is a shared backup generator. The unit would preferably be powered by biodiesel fuel produced on the island in an effort to close the cycle and promote sustainability. In this way, the COIP would have the capacity to work through the semi frequent brown outs that are common on the island due to the antiquated electrical infrastructure. Incorporating a common generation facility would require limited infrastructure retrofit to the existing transmission lines in order to service the park's businesses. The facilities capacity has yet to be determined in order to fully service the park's demand. It is assumed that the power generating station would not be able to meet the full demand of the park, but would instead, be able to power lighting and computing services with some light manufacturing. The heavier loads demanded by E.C.M.C, St. Jude, and Somerset would have to be augmented by building/firm specific generators. St. Jude Medical and Somerset Pharmaceutical presently have back-up generation capabilities. The facility would however allow the park's firms to conduct business and remain in operation. A park wide back-up system would have to comply with the Puerto Rico Electric Power Authority (PREPA). Accordingly, we felt the project would have a moderate-to-low economic benefit due to increased production hours, a low feasibility because of this factor in addition to installation expenses, and a low environmental benefit.

4) St. Jude's Joint Provision / Services Center

In an effort to promote social interaction between and among the Caguas working population and management, a common meeting and food service facility has been proposed. Discussions with St. Jude's Medical have yielded the potential for creating a cafeteria, presently managed by the vendor ARAMARK, would be open to the COIP population. As seen in Kalundborg, the Environmental Club, lead by Dr. Christensen, was responsible for the brainstorming and resulting linkages of the Kalundborg system (J. Christensen, personal communication, 2005). The common meeting place or organization is essential for bringing people together and allowing for social connections to develop within and between the firms. However, a meeting place alone cannot generate potential symbiosis. Champions of environmental sustainability and industrial symbiosis must play a large role if such linkages are to develop. A discussion of social connections and barriers to industrial symbiosis follow in the ensuing text. Subsequently, we felt that such a project would have a low environmental benefit, but a high feasibility and a moderate economic benefit.

5) Shared Security:

An additional idea for joint service provision within the industrial park would incorporate a security system around the perimeter of the park. As it stands, the existing Caguas businesses must install their own fence and security systems around their property. Due to the small nature of the park and the existing security measures, we feel that installing additional measures would be an inefficient use of capital. The firms with security concerns, such as St. Jude Medical and Somerset Pharmaceutical, already have and would insist on maintaining their posted guard controlled perimeters. As a result we felt the project would have a low environmental and economic benefit in addition to a low degree of feasibility. However, this proposed model may prove to be an appealing factor for drawing in new business, and may be useful to PRIDCO's other properties. As a result we feel the project would have a low degree of environmental, economic benefits and low feasibility.

6) Waste Recycling & Trading

The most positive improvement and advancement towards I.S would be to establish a recycling center within the park. Such a venture would address the need for a new business

opportunity, by-product exchange, and joint provision of services. Sterr and Ott suggest that the development of a shared database of materials needed and products generated by each firm could be implemented and perhaps run by a third party. "A great percentage of Small to Medium Enterprises (SMEs) do not have the personnel to keep track of changing disposal opportunities and fluctuating prices on the waste market. As a result they are rather eager to reduce their individual informational costs by participating in an exchange platform that collects, systemizes, and analyzes waste disposal information from their own and neighboring companies" (Sterr and Ott 2004). This system could be a worthwhile strategy for the handful of small industrial parks in the Caguas area. A waste broker, such as Onyx and IFCO, could collect waste materials from the center, which would act as a depot. The broker would then separate and sell the valuable second hand resources to businesses either within the park or Puerto Rico, etc. Waste materials from contributing companies would be compiled together, according to material type, and therefore act to distribute materials and protect any one company's waste stream.

By locating a center within the park, PRIDCO would help to facilitate waste management, making it easier for companies to participate in waste recycling thereby minimizing landfill wastes. A problem to overcome is PRIDCO taking on the responsibility/liability of potentially hazardous materials making their way into the wastestream. Protocol for access and depositing must be developed to avoid such problems. Benefits to PRIDCO may be increased rents for waste management (although initial capital for recycling center would be low and contracts would be handled by professional waste management/brokers – which yields low overhead and a potentially good return).

Traditional recycling/material brokers such as IFCO presently have the paper line in operation; however, they are in the process of implementing a sorting machine for plastic, glass, and metal containers (Tous, IFCO Recycling, personal communication). It is believed that once these businesses have the capability to process these materials, the markets for municipal recycling will naturally develop. Due to the relatively high consumer consumption of Puerto Rico, it is imperative that full scale municipal recycling programs for paper, plastic and metal container goods be implemented to reduce unnecessary waste and landfilling. Subsequently, we feel that a project of this scale would have major environmental and economic benefits in addition to a moderate degree of feasibility. The following are the major waste materials to be

considered are: Electronic components, Plastics, Scrap metal, Food waste material, Pharmaceutical wastes, Cardboard & Paper, Glass, and Wood pallets.

a.) *Electronic Component Recycling:* There are a host of companies within COIP who produce substantial amounts of electronic wastes, namely Avant Technologies and Cortelco. The computer related electronic equipment can be recycled through an environmental services company such as Onyx Environmental. Cortelco has a warehouse full of old telecommunications equipment that can no longer be used. These old phones and switchboards could also be recycled by an environmental services company.

b.) *Plastics:* Presently, plastics are not recycled in Puerto Rico. IFCO is in the process of establishing a sortment process line. Once this line is in operation, IFCO will process plastic containers from the surrounding municipalities. The current trade route for recyclables is presently bound for the United States. It would benefit Puerto Rico greatly for the business community to establish processing industries and uses for the recycled products.

c.) *Scarp Metal:* Scrap metal recycling markets are presently functioning on Puerto Rico. Several markets exist and depend on the type of metal. Scarp metal in the form of steel, stainless steel, copper, and other high quality metals are collected by material brokers like Onyx and Safety Clean. Within COIP, several companies produce high quality scrap: E.C.M.C, CNC 2000, C-AXIS, and Saint Jude's Medical. These materials are typically barreled on-site by the receiving firm and then sold oversees to be reconstituted and sold (Onyx, personal communication). Due to China's booming economic development, they command a majority of the market for high quality scrap. Domestic recycling programs for tin containers have yet to be established on Puerto Rico.

d.) *Food Waste:* An opportunity for "scrap" or waste food stuffs exists in the compost sector. Markets for clean, organic, topsoil and potting soil exist throughout the United States. Waste or scrap food stuffs from food industries such as bakeries, restaurants, grocery stores, etc., can be collected from within the industrial park and the municipality and utilized to create quality

composted soil. Examples of business models to follow are: Renewed Earth, Inc., and Biffa, Inc. The potential for used cooking oil in biodiesel production is discussed in the ensuing text.

e.) *Pharmaceutical Waste:* For the purposes of the paper and due to the lack of cooperation from the Somerset Corporation, we have chosen to utilize the Industrial Ecology course paper written on MOVA's Pharmaceuticals by Chan et al., 2002, as the foundation for information on Somerset. Somerset pharmaceuticals, formally know as MOVA "… exclusive(ly) focus(es) on manufacturing and packaging pharmaceutical products (and) has created a unique niche for itself on the island, where major pharmaceutical companies are abundant" (Chan et al., 2002).

According to Chan et al., the facility recycles their paper and aluminum. These steps will help the company to easily transition into a recycle economy. The facility presently produces 1,156,375 pounds of domestic non-hazardous waste per year. Today, this quantity is directly landfilled. Non-hazardous sludge can have many uses. It may be possible to utilize the sludge as fertilizer or for soil augmentation on agricultural lands, incorporated into use in the proposed compost facility, or as fuel for potential future waste-to-energy power plants.

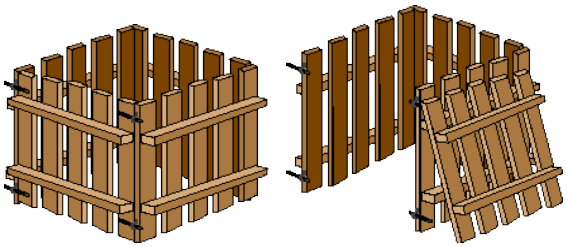
Somerset Pharmaceuticals is a more traditional pharmaceutical business in comparison to MOVA, in that it most probably has incorporated Research and Development into its model whereas MOVA was strictly a manufacturing business. A major barrier to establishing Somerset as an anchor tenet is the highly protective nature of this pharmaceutical company of its proprietary secrets. This was clearly the case when we attempted to make contact with Somerset Management.

f.) *Cardboard & Paper:* There exists a large market for the recycling of paper and cardboard products from COIP. IFCO Recycling, located in Caguas, deals primarily in the recycling of paper products. IFCO indicated that they would be interested in picking up and recycling the office paper, paperboard, and cardboard products from COIP. The only barriers to this remarkably easy task are: 1) IFCO making connections with each of the companies in the park, and 2) the activation energy required for each company to actually recycle within their own firm. Separating paper products from other materials requires separate bins and a degree of personal responsibility. To implement this, we believe that it might require IFCO to provide each

company with the necessary bins and also provide some support in the form of personnel to encourage employees to sustain their active participation in the program.

g.) *Glass:* The markets for glass container cullet can be divided into two broad categories: new glass containers, and all other uses (Reindl, 2003). However, recycling of glass for non-container uses is growing rapidly. "Industrial applications such as blasting abrasives, filtration medium and fusing to make consumer products, hold potential to create more profitable markets for recycled glass" (Kirby, 2000). Due to the proven uses of recycled glass, Puerto Rico can significantly gain from instituting programs and promoting businesses. For example, manufacturing glass pavers can be produced with less energy and generate less greenhouse gases then either brick or concrete. However, in today's markets there are significant barriers to marketing mixed colors and of transportation costs. Mixed color glass, typically gathered by curbside collection, is seen as a contaminating factor for many reuse products. Pavers present themselves as a solution to this issue, as their composition can be a mixture of colors. The majority of waste glass today is being landfilled along with everything else. Glass therefore, falls in line with the rest of the usual suspects as a proven and profitable material for reuse.

h.) *Pallet Recycling:* Wooden pallets are discarded to landfills by most of the companies in the park. The pallets are used for the delivery of their raw materials and often the delivery company will not accept the pallets back after unloading. This is a pervasive problem across industry lines and numerous solutions have been proposed both in the literature and in practice. Our first recommendation for wooden pallet recycling in COIP would be to contract pallet recycling to AQ Recycling in Cayey (15 miles from Caguas). They are members of the South American Recycling Marketplace and deal in the recycling of wooden pallets. Another possible, yet probably less feasible option for the recycling of wooden pallets is donating/selling the wooden pallets to the nearby school and residences for the easy construction of compost bins. The school could then compost their food wastes and/or provide other city schools with bins with which to start a county-wide school composting program. Possible barriers to the compost bin idea are a lack of financeal support or general interest within the school system.



Materials:
1. Four wooden pallets
2. 32 wood screws or bailing wire
3. Four bolt latches.

Assembly:
1. Screw or wire three of the pallets together.
2. Attach colt latches to the front edge of the bin and the last pallet to make a removable door.

**Figure 10. Wooden Pallet Compost Bin.**
(source: http://www.digitalseed.com/composter/bins/palletbin.html)

7) Biodiesel Operation: The University of Puerto Rico in conjunction with the Department of Energy … "is studying the transesterification process to convert waste greases, used cooking oil and animal fats into fatty acid methyl esters. This is an alternative diesel fuel known as 'biodiesel'" (Colucci and Panzardi, 2003). This study has evolved to the demonstration and trial stage (Task 8 & 9). Commercialization of the project has yet to take hold on Puerto Rico (Colucci, Personal Communication, 2005). Biodiesel refinement operations on Puerto Rico will take time to develop; however, collection of feedstocks for mainland operations can probably be situated in Puerto Rico with far fewer obstacles. We propose to situate a biodiesel collection facility within Caguas to act as the materials broker for waste greases, cooked oil, and animal fats to be sold to refineries on the mainland. The operation would consist of warehoused containment facilities with sortment equipment and delivery stations. The feedstock would be barreled and shipped to the mainland for refinement, blending, and sale as biodiesel for use in vehicles and home heating. Two Puerto Rican companies are looking to produce biodiesel within the next few years, however they are waiting for new EPA emissions regulations to kick in. Once the new standards are in place, the market for low sulfur and cleaner burning biodiesel will be able to take a foothold (McPhaul, 2004)

8) Fish Farm: The Somerset facility presently utilizes a back-up diesel generator. This generator serves as an emergency back-up power source in addition to producing steam for air conditioning and sterilization. In 2001, approximately 50% of the steam was used. The remaining 50% of waste steam presents itself as an interesting source of heat.

There are several instances around the world of fish farms taking advantage of excess steam from adjacent power plants (Christensen, personal communication, 2005). This situation presents itself as just such a case. A fish farm could be located adjacent to Somerset and utilize the excess steam to heat closed system pools for rearing such fish as: catfish, crayfish, baitfish, sportfish, tilapia and ornamental fish (per ASMAK.com).

Beth Feingold

**Comment:** I was trying to make the picture above have some sort of buffer so the text wouldn't hit it. but I couldn't. maybe you want to try/ also, it needs a caption. is it a fish farm?

also, what is Asmak? its not cited in the references. you should probably cite some papers saying the fish farms are good.

## BARRIERS TO INDUSTRIAL SYMBIOSIS

There are several factors that impede a tighter social knit among the members of the different entities operating in the park and the formation of true industrial symbiosis. The following factors affect the potential for industrial symbiosis within the park:

- The limited size of the park: The limited variety and size of industries make it difficult to have an appropriate quantity of waste materials available for exchange. It has been noted that "larger regional areas may be more suitable for closing loops and creating sustainable industrial ecosystems" (Sterr and Ott 2004). The case study of Pfaffengrund notes where the size of the site "proved to be too small for almost every kind of material cycle", but nevertheless a certain degree of interrelations developed, due to its privileged location within the larger industrial region of Rhine-Neckar. Therefore, park size influences the development of by-product exchange among companies.
- Secretive Corporate Cultures: The single industry with the greatest potential for by-product exchange and anchor for the park, Somerset, has a secretive culture that completely isolates it from its neighbors. According to Sterr and Ott: "stable eco-industrial regions…develop through a solid foundation of comprehensive information transparency. In order to realize suitable output-input connections, mutual trust among the industrial actors and the willingness to cooperate are essential" (Thomas Sterr et al.,2004).
- Lack of significant infrastructure sharing: Other than municipal provided infrastructure such as: the electric grid, roads, sewer and water distribution systems, there is no shared infrastructure.
- Pre-constituted allegiances: The COIP companies presently prefer to collaborate with their clients and/or distributors, rather than finding partners within the park.

- Lack of a COIP organization: As we mentioned before, there is not a single institution/organization that brings together the tenants of this park, with the exception of PRMA for which there is limited attendance.
- Certain policy practices: PRIDCO and other governmental institution discourage the installation of certain industries within their facilities, which could bring more variety to the mix, and interconnections among the established firms. In particular, the policy against installation of recycling companies (i.e. IFCO) within the Caguas Oeste Park prevents it from taking advantage of marketable waste materials.
- The lack of identified leaders/Champions: In our survey, we were able to meet with a number of good-intentioned and motivated managers, but none of them seem to have a vision to drive the park toward a path of sustainability and/or mutual collaboration in order to achieve a more tangible symbiosis among the various actors. However, outside COIP, IFCO General Manager Guillermo Tous, stood out as a leader in material recycling and brokering and was extremely interested in affecting policy change for a sustainable Puerto Rico.

## SUMMARY

The current state of Caguas Oeste Industrial Park does not lend itself easily to the implementation aforementioned industrial symbiosis suggestions. The largest barrier to implementing ideas of industrial symbiosis stem from the lack of social threads and communication among companies within the park. Despite the PRMA membership that many of the companies have, or the fact that many of the engineers studied together in university, the employees do not seem to have any interest in establishing more than a neighborly type of relationship with one another. This behavior is not abnormal, but neither does it lend itself to the creation of trusting relationships which can spark the examples of the industrial symbioses seen around the world.

We recognize that if PRIDCO and the companies in COIP are interested in implementing some of the strategies outlined in this paper, small steps will have to be taken to fully educate and gain support from the member companies. The first step we suggest is for park members to form a park club, where the concepts of industrial ecology can be disseminated, and ideas for business ventures discussed. A leader/champion of the COIP members must be looking to make

positive change. Without this 'Champion,' the past has shown that industrial symbiosis rarely succeeds. However, we do believe in the potential of the park. Potential for new business ventures do exist and can develop to aid in the evolution of symbioses if communication channels and public policy allow.

Puerto Rico must undertake major steps to become an island of sustainability. In addition to incorporating concepts of industrial symbiosis at the industrial park level, Puerto Rico must incorporate and implement environmentally sustainable policy that will act as the genesis for continual growth of environmentally conscious business opportunities. Some basic, but major improvements to be considered are: developing waste-to-energy power plants, biodiesel production, wastewater reuse and aquifer recharge policy, infrastructure improvement for wastewater, water, and power throughout the island, aid in the development of small scale agricultural, animal husbandry, and fish farming activities, and last but not least full scale recycling and material brokerage operations for the majority of products from residential to industrial. These are not small steps, however they are possible and markets opportunities exist for many of these recommendations. By incorporating these policies and implementing these improvements, Puerto Rico will limit much of its waste and as a result profit from invigorated business markets and environmental wellbeing.

Beth Feingold
**Comment:** K, I don't know if you want to leave this part in or what. you decide.

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**Interviews with the following (or representatives for them) were conducted during the week of March 7-11 , 2005:**

Avant Technologies of Puerto Rico, Inc.: Eric Eliza, Fran Dieppa
C-Axis, Inc.: Lisandro Rivera
CNC 2000, Inc.: Johnny Ramos
Comercial El Ebanista: Fidel Castillo
Cortelco: Jose Alvarez
Electrical and Control Manufacturing Mfg. Corp.: Julio Z. Guzmán,
Graficos, Inc: Jose Luis Cabezudo
Halcon Bakers: Pedro Hernandez
IFCO Recycling: Guillermo Tous
Laboratorio AAA Central: Maritza Merced
Onyx Environmental Services: Tomas Rivera
Quality Windows and Doors, Inc.: Jacquelin Miranda
Rainbow Optical: Wilkin (We don't have information on his last name)
Somerset Inc.: (Merck Pharmaceuticals: Maureen Sanchez)
Sportzone, Inc.: Plant Manager
St. Jude Medical: Hernan Lopez, Roberto Santiago, Aidelis Muñoz
Star Wire Products, Inc.: Jacinto Atanacio
Tres Leches: Eliot Cianchini
Veolia: Marcos Lasses
Waste Management of Puerto Rico: Ferdinand Rivera

# APPENDIX A

# PHARMACEUTICAL SECTOR

# APPENDIX B

# MEDICAL PARTS SECTOR

# APPENDIX C

## METAL & ELECTICAL
## & ELECTRONIC COMPONENT MANUFACTURING

# APPENDIX D

# OTHER MANUFACTURING

# APPENDIX E

# FOOD INDUSTRY SECTOR