SUSTAINING INDUSTRY ON SMALL ISLANDS BY HARNESSING OPPORTUNITIES FOR COLLABORATIVE RESOURCE MANAGEMENT

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ABSTRACT

The sustainability of any industrial activity on small islands is often bound by a limited natural resource base on which industries rely, as well as limited space for assimilating their waste flows. The field of Industrial Ecology analyzes the sustainability of industrial activity by focusing on how resource flows are managed at various geographic and organizational scales. Industrial symbiosis is a sub-area of industrial ecology that encompasses collaborative resource management by diverse firms in geographic proximity in order to achieve environmental and economic benefits. These benefits may include reductions in operational costs and emissions, more secure access to inputs and basic utilities, and increased longevity of the resource base. In general, firms choose to participate in symbiosis for a combination of external and internal reasons, including economic, organizational and strategic factors. This paper presents the current state of knowledge regarding industrial symbiosis, drawing on research from around the world. It also establishes the relevance of these activities to industrial sustainability on small islands, with a case study from the Caribbean island of Puerto Rico.

Keywords: industrial ecology, industrial symbiosis, eco-industrial development, sustainable development, island economies, Puerto Rico

1.0 Introduction

Industrial sustainability is of particular importance for islands where the most pressing challenges are often related to resource flows. On one hand, locally-available resources—energy, water, capital and labour – may be insufficient for large-scale industry (McElroy and de Alberquerque, 1990). Many resources must be imported at high costs to maintain industrial and human consumption, creating dependence on, and vulnerability to, external events. On the other hand, there is limited space for assimilating waste materials or escaping major environmental problems (Deschenes and Chertow, 2004). As a result, islands are likely to face sustainability concerns much earlier than continental areas. Island industry, whether it is agriculture, tourism or manufacturing, must be placed within the context of the island's carrying capacity in order for it to be sustained in the long term.

Researchers in the field of industrial ecology use a systems approach to consider and address the environmental impacts of industry within the broader context of the natural systems within which they are located (Graedel and Allenby, 1995). One of the general goals of the field is to create a scientifically-based understanding of how environmental sustainability may be achieved. Ehrenfeld asserts that achieving sustainability demands a paradigm shift in industrial organization. Aspects of this paradigm shift include changing the goals of business to better satisfy human needs, not wants, increasing collaboration among different groups of actors and increasing the cycling of physical resources in industrial systems (Ehrenfeld, 2005). Thus, for islands, sustainability will be predicated on the cooperation of human actors to use the available and imported resources more effectively to meet local needs.

An industrial ecology approach that monitors resource flows through island economies and devises collaborative management strategies to increase the cycling of resources may provide a useful way to examine the sustainability of industrial activities in an island context (Yale Center for Industrial Ecology, 2004). This paper is based on applying this research approach to the island of Puerto Rico. The next section details the theoretical background on industrial symbiosis and the reasons leading to inter-firm collaboration. The case study is then presented with an examination of the motivations that have led to cooperation and resource conservation outcomes. The conclusion relates the findings in the case to broader applicability in island settings.

2.0 Theoretical Background

Industrial symbiosis (IS) occurs when distinct, geographically proximate firms work together to improve the management of resources, including energy, water and waste, and in so doing create both private and public benefits (Ehrenfeld, 2004). There are three types of activities associated with industrial symbiosis: byproduct exchanges where one company's waste is used as an input by another, utility sharing where firms jointly own or manage common utilities such as energy or water, and service sharing where a third party provides a service with an explicit environmental benefit that caters to the needs of several firms (Chertow, 2007). The term eco-industrial development (EID) is broader than IS and includes planning and management efforts to facilitate the three IS-type activities among firms (van Berkel, 2006).

A network of firms engaged in industrial symbiosis is termed an industrial ecosystem, drawing on an analogy with a natural ecosystem in which different organisms produce and consume energy and materials. The most referenced industrial ecosystem, and location where the term "industrial symbiosis" was coined, is the Danish town of Kalundborg. A group of diverse process industries including a power plant, oil refinery, pharmaceutical manufacturer, wall board factory and the municipality share common resources and exchange byproducts in an innovative, environmentally benign and economically beneficial manner (Kalunborg Center for Industrial Symbiosis, 2007). Although each of the resource linkages was instituted for economic reasons, they have inherent resource conservation or environmental savings as well.

There are a few regions around the world with well-developed, mature industrial ecosystems including Rotterdam Harbour in the

Netherlands (Baas and Boons, 2004), Kwinana industrial region in Western Australia (van Beers et al., 2007), and the Tianjin Economic and Technological Development Area (TEDA) in eastern China (Shi, 2007). In these regions, the initial concerns of firms centred on opportunities for improving their individual and collective resource use efficiencies. Later, the firms utilized the opportunities for inter-firm communication to promote collective learning about more sustainable resource use practices. Finally, some of these industrial communities expanded their view to include those of other stakeholders (such as community groups) to develop and work towards shared visions for regional sustainability (Baas and Boons, 2004; van Beers et al., 2007). Eco-industrial developments, planned from scratch and modelled after Kalundborg, have had much less success as it is difficult to plan collaboration in a community of industrial actors who often have no shared history or trust (Gibbs, 2003; Chertow, 2007). Inadequate information, low economic or technical feasibility, regulatory hurdles that create rigid rules on treatment or disposal of byproducts, and a lack of motivation due to little trust or weak incentives are noted as the chief barriers to the implementation of these types of projects. (Brand and de Bruijn, 1999). A possible way to overcome these barriers is to build synergies around existing "kernels" of activity in a given location, typically involving one of the IS activities among a small group of actors (Chertow, 2007). Another successful model for facilitating IS hinges on the involvement of an independent third party that acts as a trust-worthy broker to build synergies among firms that have no prior relationship (NISP, 2006).

Industrial symbiosis is happening at a time when firms in general appear to have greater willingness to solve problems by working with others outside their walls. In the business literature, collaboration is seen as allowing firms to operate along a spectrum between complete vertical integration, where they exert major control over the resources that they utilize, and market transactions, where they have far less influence on the resources they purchase (Besanko et al., 1999). Internal motivations for seeking cooperative arrangements fall into three major categories: reducing transaction costs such as searching for suitable goods and enforcing contracts (Williamson, 1985); capturing financial, physical or knowledge resources (Pfeffer and Salancik, 1978); and achieving strategic advantage as regards suppliers, buyers, and rivals (Porter, 1985).

Both intra-firm motivations and external forces acting on firms, such as resource constraints, globalization, technological change and inter-firm competition, drive cooperation. In circumstances where natural resource availability or regulations constrain operations or make them very expensive, cooperative relationships can develop to enable firms to operate. It is expected that IS activities might develop in such circumstances. In addition, all firms exist within organizational networks that consist of others in their supply chains, as well as competitors, regulatory agencies, institutions and the public (Scott, 2004). At any time, a firm can belong to multiple networks that are defined geographically, sectorally or by some other means of association. Members of a network exert pressure on each other, and their actions are constrained by accepted social norms and behavioural expectations within the network (DiMaggio and Powell, 1983). Inter-firm networks evolve continuously as firms within them compete and cooperate to improve their individual and collective positions and profitability, both within the local network and globally.

Geographic proximity presents opportunities for frequent face-to-face interaction among individuals and for trust-building among them, with past experience being a critical factor in future collaborations among firms (Gulati, 1995; Scott, 2001). Supporting institutions play an instrumental role in this regard as they facilitate personal contacts between managerial staff at various levels and specialization areas. While a large proportion of business takes place across global markets, favourable local business conditions are needed to make operating in any particular region advantageous (Porter, 1990). Place-based partnerships therefore, remain significant for firms to realize competitive advantages that lie outside firm boundaries, even as they bolster their internal competencies.

3.0 Case study - Industrial Symbiosis in Puerto Rico

Puerto Rico is a commonwealth territory of the United States and subject to all US federal regulations. Its land area is approximately 9,000 km^2 and it has a population of approximately 3.9 million persons. Its major industries are manufacturing (pharmaceuticals, electronics, medical devices and food products) and tourism. Manufacturing activities generate greater export earnings, while tourism and other services employ a greater share of the island's workforce.

Key challenges to sustaining the island's natural and industrial ecosystems include heavy dependence on imported fossil fuel energy, high fresh water consumption and infrastructure losses, limited landfill capacity, and considerable dependence on material imports (Yale Center for Industrial Ecology, 2004). The tension between ecology and economy on the island stems from the fact that the economic activities place heavy demands on the island's limited water, energy and spatial resources. With diverse ecological and industrial systems, Puerto Rico is a setting where there is a pressing need to incorporate sustainability considerations into industrial development (Deschenes and Chertow, 2004). Facing high energy and transportation costs, limited natural resources, decreasing space for solid waste disposal, tightening environmental regulations, and increasing public pressure to decrease pollution, several businesses in Puerto Rico have begun to respond to resource challenges in innovative ways that exemplify the promises of industrial ecology.

3.1 Pharmaceutical Manufacturing in Puerto Rico

Puerto Rico boasts one of the densest concentrations of pharmaceutical manufacturing sites in the world, with some 65 facilities island-wide through 2005 (see Figure 1). Pharmaceutical manufacturing is the largest export earner for the island, accounting for approximately 64% of exports, or over US$35.2billion in 2004 (PIAPR, 2007). The manufacturing stage is at the core of a business cluster that includes pharmaceutical marketing and distribution, independent suppliers, and legal human resource, transportation, packaging and waste management service providers. The cluster also includes industry associations, academic institutions and government agencies that provide resources and services that support firms in the cluster.

Many US-based multinational corporations (MNCs) first located in Puerto Rico in the 1950s to take advantage of numerous tax incentives created under the US Internal Revenue Service tax code §936 (PRIDCO, 1995). These incentives expired at the end of 2005 and their loss occasioned island-wide anxiety about a potential mass exodus of manufacturing firms. Many labour-intensive industries such as textiles and food canneries did exit but the pharmaceutical cluster has remained intact, largely because comparable tax incentives have now replaced §936 (PRIDCO, 2006), but also as a result of the strength of inter-firm linkages that have developed within the cluster.

3.2 Barceloneta

Manufacturing facilities are located throughout the island; however, firms choose specific locations for the availability of important natural resources. One of these is the municipality of Barceloneta and its neighbours, Arecibo and Manatí,[1] located roughly 50km west of San Juan along the northern coast, with thirteen pharmaceutical manufacturing facilities operating through 2006 (see Figure 2). Its attractiveness hinges upon 1) expansive, high quality, deep and shallow freshwater aquifers and 2) easy transportation to San Juan and its air and sea ports. In addition to the pharmaceuticals, there are food, chemical, packaging, electronic equipment and metal fixture manufacturers, as well as a few waste management firms.

1 Barceloneta is often used to refer to the pharmaceutical cluster within the three municipalities.

3.3 Existing Industrial Symbiosis

Pharmaceutical manufacturing firms in Barceloneta form a dynamic network in which collaboration has been a key feature. Several of the collaborative initiatives in this local cluster can be classified as industrial symbiosis. The eco-industrial activities have developed over the last thirty years and among them are regular, occasional and proposed resource exchanges among the pharmaceutical firms and others (see Figure 3).

3.4 Wastewater Utility Sharing

The oldest and most formal synergy is a utility sharing arrangement at the Barceloneta Regional Wastewater Treatment Plant (BRWTP). In 1978, eight companies in the region spent USD$23.5 million to construct a secondary treatment facility that would be capable of meeting the expanding wastewater treatment needs of both industrial and municipal clients (PR-IEPCFFA, 1978). The facility was designed to treat 31,416 cubic metres per day (m^3/d) or 8.3 million gallons per day (mgd) of wastewater on average, with a biological oxygen demand (BOD) loading of 39,864 kilograms per day (kg/d) or 88,000 pounds per day (ppd) (PRASA, 1982). The eight "facility-agreement" companies entered into a 25-year contract with the government-owned Puerto Rico Aqueduct and Sewage Authority (PRASA) guaranteeing each of them entitlement rights, which totalled 40% of the facility's flow and 70% of its BOD load, while they agreed to provide 70% of the BRWTP's operation and maintenance costs (PR-IEPCFFA, 1978; Ortiz, 1995).

The introduction of secondary treatment in 1981 was a dramatic improvement over earlier practices when untreated industrial effluent was discharged into nearby rivers and the ocean (PRASA, 1982). The shared system proved to be a more cost-effective means of reducing the level of contaminants released to the aquatic environment than separate systems would have been. However, until the mid-1990s, the BRWTP failed to live up to environmental performance expectations and was the subject of

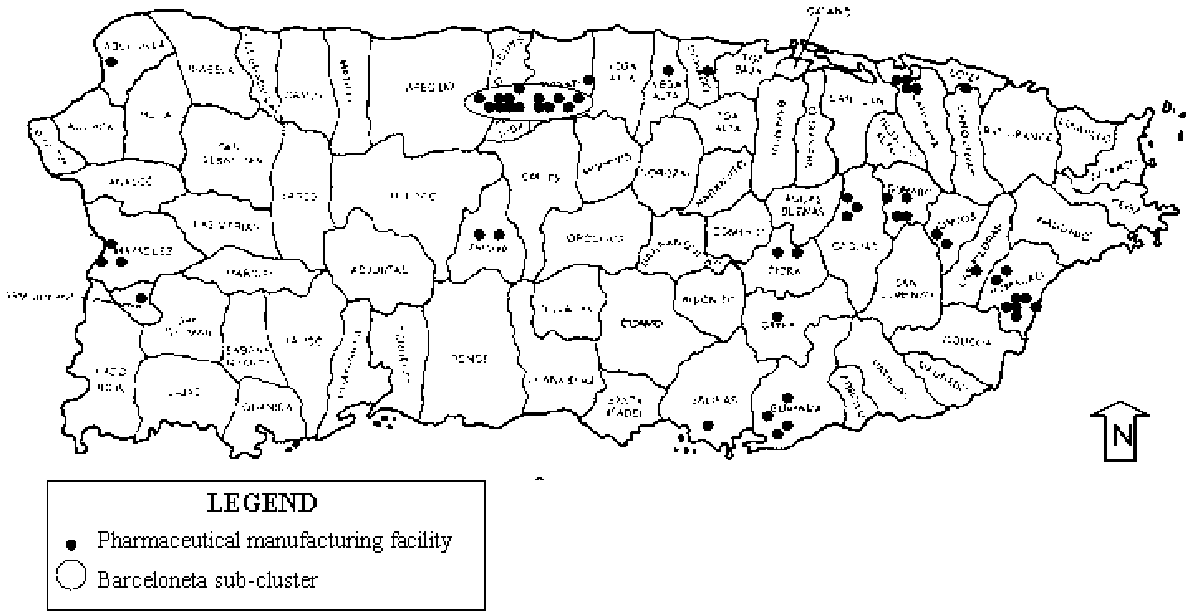

Figure 1: Location of pharmaceutical manufacturing facilities in Puerto Rico

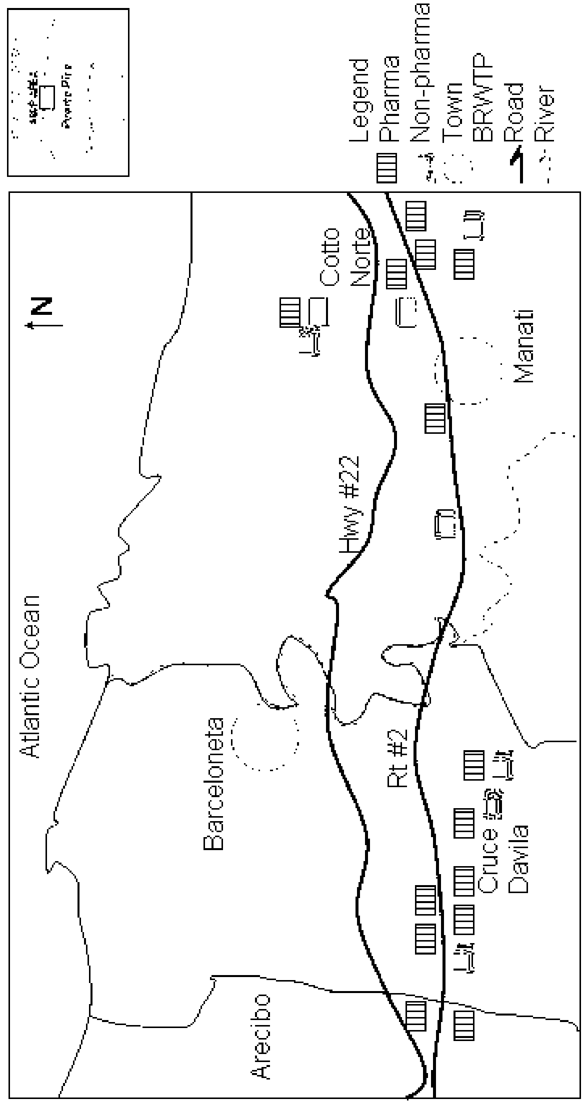

Figure 2: Location of manufacturing facilities in Barceloneta

numerous citizen complaints culminating in a class action lawsuit against the facility in 1992 (US District Court - Puerto Rico). Since 1998, pharmaceutical manufacturers discharging to the BRWTP have been required to meet federal effluent pretreatment standards. This rule change led to a dramatic improvement in the quality of the influent sent to the BRWTP and the treated effluent released from it.

Following early problems with improper plant operation and maintenance, the eight "facility agreement" companies assumed a more active role, providing technical guidance in the plant operations (Polybac Corporation, 1984). They formed an Advisory Council that was made up of general managers at one level, and plant, operations and environmental managers at another. Regular meetings provided venues for managers at both levels to discuss financial, environmental and operational performance and analyze new problems, issues and challenges of common concern. The frequent interaction among managers has created a culture of openness among these co-located firms. Numerous informal agreements were facilitated through these face-to-face interactions, such as benchmarking new processes against each other, and lending each other equipment and materials in emergency situations. In effect, the council created a common culture that has increased trust among the participating managers in these firms (Ashton, 2008a).

3.5 Treated Sludge By-product Reuse

Shortly after the BRWTP became operational, PRASA personnel realized that there was insufficient land for on-site disposal of the organic sludge by-product. The Advisory Council and PRASA implemented a land farming project in which the sludge is used as a fertilizer for growing hay that is regularly sold as feed for animals. As the largest industrial flows to the BRWTP come from fermentation lines at the pharmaceutical facilities, the sludge is rich in organic material. Both the sludge and soils are regularly tested for toxics and metals and have been found in compliance with the requisite standards on all but a few occasions. Approximately 2-3000 dry metric tons of sludge are applied annually.

Annual hay revenues are in the order of US $40-75,000, which offsets the farm's operating budget (Guardiola, 2005). By reusing the sludge at the land farm, consumption of landfill space–the most common method for sludge disposal on the island—is avoided.

3.6 Solvent Recycling Services

Pharmaceutical manufacturers use a wide variety of hazardous and non-hazardous solvents to facilitate chemical reactions, purify products, and clean equipment. Solvents may have significant hazard potential (flammability, explosiveness) and health impacts (carcinogenicity, toxicity) (Capello et al., 2007). In the United States, the handling, reuse, treatment and disposal of these solvents are regulated under the Resource Conservation and Recovery Act[2] (RCRA) (USEPA, 2000). Of the most common options for management, recycling offers superior environmental performance as it retains the embodied energy and utility of the material, from a life-cycle perspective. Energy recovery only retrieves the embodied energy in the spent material, and treatment merely offers safe disposal. Annual hay revenues are in the order of US $40-75,000, which offsets the farm's operating budget (Guardiola, 2005). By reusing the sludge at the land farm, consumption of landfill space–the most common method for sludge disposal on the island - is avoided.

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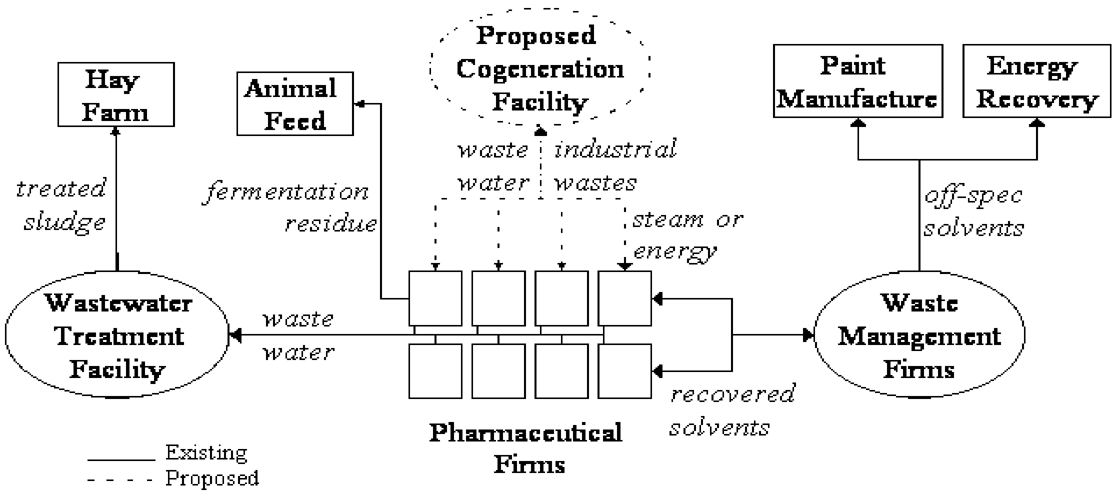

Figure 3: Industrial ecosystem in Barceloneta, Puerto Rico

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Solvent recycling was regularly performed in Barceloneta, either within the pharmaceutical facilities themselves or by a waste management firm. Solvent recycling involved collection of spent solvents, distillation to purify the solvents and reuse in the manufacturing processes. Since 1991, approximately 40% of the hazardous solvents used in the region (on average 6,798 tons annually) have been recycled and reused locally by the chemical manufacturers (Ashton, 2008b).

Occasionally, pharmaceutical firms contract the services of waste brokers to find uses for materials they can no longer use because the materials have expired or have become contaminated. These materials include previously recycled solvents that no longer meet the required specifications as well as acids, scrap metals and other hazardous and non-hazardous substances. The chemical solvents, including toluene and methylene chloride, find ready buyers among paint and cleaning compound manufacturers, while greater investigation is needed to "find homes" for the more specialized by-products (Sanchez, 2002). From a life-cycle perspective, by-product reuse creates environmental benefits by extending the useful life of materials rather than one time use and disposal. The low economic value of these materials, low levels of trust with third party buyers, and potential liabilities through mishandling are reasons why these exchanges are infrequent (Ashton, 2003).

3.8 Proposed Cogeneration Utility Sharing

Among the pharmaceutical firms there have been numerous informal joint and individual endeavours to develop local cogeneration capabilities. The high price of electricity has long been a major grievance of industrial clients throughout the island (Berrios Figueroa, 2002). In

Barceloneta, several facilities have on-site cogeneration capacity to either meet some of their energy needs, or for backup power during power failures and emergencies (such as the hurricane season).

The most recent proposal was made in 2002. Seven facilities conducted a joint feasibility study for the creation of a 120MW/291kpph (kilo-pounds per hour) cogeneration plant (Pharmaceutical Cluster, 2002). The plant was to provide electricity to the utility grid and steam to the facilities. It was also to incorporate by-product reuse by utilizing treated wastewater from the participating facilities for steam generation and in-plant use (Riollano, 2003). However, the project was not implemented due to a combination of economic, political (resistance by the utility) and regulatory factors. The need for more reliable power and less costly steam remains a critical issue facing the cluster. Currently, new proposals are being evaluated to introduce facilities that would utilize industrial solvent and hazardous wastes as feedstocks to generate energy—steam, propane or electricity – for the industry (Reyes, 2007).

3.9 Motivations for Engaging in Industrial Symbiosis

Managers in Barceloneta cite financial savings as the top motivation for their industrial symbiosis activities, with regulatory flexibility and the potential for improved environmental performance as the next most important factors (Ashton, 2003). Internal recognition of potential cost savings encourages firms to seriously consider resource sharing and cooperation. Firms that desire disposal cost reductions find local buyers for their by-products, converting these costs into revenue streams. Similarly, firms that receive by-products as input, do so to access those resources at lower costs, including both transaction and transportation costs (Ehrenfeld and Gertler, 1997). Those engaging in utility sharing access resources they might not have been able to afford on their own, as well as to lower costs through sharing. The arrangements may also lead to strategic advantages by increasing the stability of operations and opening avenues for future innovation and flexibility through "loose coupling" with others in the network (Grabher, 1993).

Barceloneta firms face common external resource problems with regard to water supply, energy generation and waste disposal. Diminishing groundwater supplies have encouraged some firms to undertake on-site treatment and recycling of wastewater, but there are no inter-firm synergies for water reuse (only shared treatment). High costs and tight controls by the electric utility have prevented industries from realizing more competitive energy costs. The co-generation project attempted to address this problem by pooling the effort of several facilities to meet their energy demand, but was not successful. Solid waste disposal has also evolved into a major problem for the island as its landfills are rapidly approaching capacity (Juarbe, 2003). Diversion of the BRWTP's treated sludge from landfills makes a small dent in this large problem and could be a model for other wastewater treatment plants on the island. There are also no on-island facilities for the disposal of hazardous wastes, which are typically exported to the continental U.S. By solvent recycling, the island reduces the amount of hazardous waste that needs to be exported and purchased as raw materials. The need for collective solutions is especially apparent where projects are economically justified at larger economies of scale. Both water treatment and energy generation require this large capacity to be feasible. By-product exchanges have also emerged due to the limitation on waste disposal options, suggesting that both natural and, to a lesser extent, regulated resource constraints are major motivations of such exchanges.

3.10 Limits to Collaboration

Several possible IS initiatives are not seriously being considered (Ashton, 2003) as there are many obstacles to realizing greater collaboration, including lack of awareness of opportunities for resource reuse and conservation, financial and technical uncertainties in potential projects, lack of trust between potential partners, and regulatory structures that devalue resources and penalize collaboration. At the most basic level, all synergistic projects first require some information exchange between parties so that they may conceive possible partnerships. Next, and most importantly, such projects must meet economic and technical feasibility criteria. Other barriers, such as motivations and regulatory structures, have played out in more complex ways in the region.

Motivational barriers to implementing symbiosis include internal firm strategies, limited decision-making powers and prior experiences that may have reduced trust. Even though the pharmaceutical firms are primarily competitors, their Puerto Rican operations are not at the core of where they compete (around drug research and development, and sales and marketing). Rather, the manufacturing focus of the island's operations gives flexibility to the firms to be more open about sharing information. On the other hand, as subsidiaries of MNCs, they lack substantial power to make changes outside of the local operations, which limits the extent of cooperation and information exchange. The joint liability faced by the firms from the residents' lawsuit has impacted the integrity of their collaborative effort. While it has not disrupted the willingness of the companies to cooperate both formally and informally, companies have become more cautious about their liability risks in collaborative ventures.

While there is a significant amount of collaboration within the pharmaceutical cluster, it is noteworthy that other industries are almost entirely left out of these initiatives. Related industries are contracted as needed, but often as service providers rather than decision-making partners. There appears to be barely any communication or information exchange with non-supply chain industries, except occasionally through institutions such as the Puerto Rico Manufacturers' Association. The pharmaceutical firms form an exclusive club, in which there are higher levels of trust and cooperation among members, but great difficulties for outsiders to access its benefits. The low level of trust afforded to outsiders is one of the main reasons for the infrequent occurrence of by-product exchanges with firms in other industries. Technical and economic factors are also at play in the limited amount of symbiosis among non-pharmaceutical firms.

Government regulations and policies, especially those that govern a firm's operations or set the prices for resources they need, can facilitate or prohibit industrial symbiosis. Anticipated regulatory changes preventing ocean dumping of wastewater in the 1970s was the impetus for the Barceloneta pharmaceutical firms to work with PRASA to build the wastewater treatment plant (USEPA, 1977). Resource Conservation and Recovery Act (RCRA) rules governing the management of hazardous wastes clearly advocates for recycling and reuse options as preferable practices to treatment and disposal. The high cost of electricity has made a co-generation plant to supply electricity and steam a priority issue for the cluster.

By-product exchange is not currently viewed as a priority by firms for several reasons. The regulatory environment in Puerto Rico has not given firms adequate incentives to recycle or the flexibility to implement innovative solutions to resource problems. Tipping fees remain low enough for landfill disposal to be the least-cost end-of-life option for materials that are no longer needed, despite diminishing capacity and badly-needed upgrades in the island's landfills (Juarbe, 2003). Regulatory barriers on the sale of "waste" products under the USEPA (RCRA) create a legal obstacle to selling by-products (Chertow, 2004). Finally, most environmental managers are so busy disposing of by-products in order to comply with current regulations that they fail to see them as potential revenue streams (Rivera, 2005), thus presenting a cognitive barrier. Several managers have indicated that they would be more inclined to pursue such exchanges if significant savings could be demonstrated.

4.0 Conclusion

Industrial symbiosis represents an approach for more strategic, collaborative resource management within a region. It offers a "collective approach to competitive advantage" that is focused on physical resources (Chertow, 2000). For small islands with limited resources, such an approach may be vital. Understanding the economic and environmental benefits of symbiosis, as well as the drivers of cooperation in regional networks can encourage greater adoption of such initiatives. Firms take internal decisions to access resources more cost-effectively from local suppliers, and reduce transaction costs with them by formulating long-term, stable contracts. Collectively, they improve strategic local advantage by increasing the stability of operations and enriching the networks through creation of a culture of openness and exchange.

Firms in Barceloneta are able to realize economic savings in the treatment of wastewater and solvent recycling, and environmental improvements through reductions in wastewater, sludge, solvent and byproduct disposal volumes. Besides these efforts, most firms focus their environmental performance and cost reduction activities within their facilities. The examples of coordinated resource conservation in a single region may not appear to be much, but they represent the beginning of a trend towards more sustainable practices in industry across the island (Yale Center for Industrial Ecology, 2004). There is growing willingness to consult and devise collaborative solutions with others in the industry, as seen in the proposed co-generation project, which despite its failure to move forward has not dampened managers' desire to work together. Some of the firms have begun sharing their experiences with peers in other parts of the island, which opens the possibility of making collaborative resource management more commonplace. Through these activities, islands' industries could well be on the way to becoming more environmentally sustainable.

Businesses have an important role to play in addressing environmental issues and working towards sustainable development. The industrial ecology framework enables firms to consciously situate their actions within the communities and ecosystems in which they are located. The concept recognizes that the ultimate sustainability of any economic activity depends on the ability of the natural system to support it. Industrial symbiosis presents numerous opportunities for companies to cooperate with others in relative geographic proximity, by examining their overall energy, water, and material flows. It can be used to find resource-based synergies, which can lead to innovation around those issues, as well as to identify gaps in current resource management and new business opportunities that can solve resource constraints. Eco-industrial development thus presents a means of making industrial operations on islands sustainable in the long-term by engaging firms in mutually beneficial, collaborative partnerships.

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