Industrial Symbiosis in China

A Case Study of the Guitang Group

Qinghua ZHU, Ernest A. LOWE, Yuan-an WEI, and Donald BARNES

Keywords

by-product exchange
eco-industrial networking
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industrial ecosystem
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Summary

The Guitang Group (GG), which operates one of China's largest sugar refineries, has been developing and implementing an internal and external industrial symbiosis strategy for more than four decades. The GG first invested in developing its own collection of downstream companies to utilize nearly all by-products of sugar production. This strategy has generated new revenues and reduced environmental emissions and disposal costs, while simultaneously improving the quality of sugar.

Internally, the GG's complex consists of interlinked production of sugar, alcohol, cement, compound fertilizer, and paper and includes recycling and reuse. Externally, the GG has established a strong customer base as a result of its product quality, has worked to maintain and expand its supply base through technological and economic incentives to farmers (and even to competitors), and has had to react to a strong government presence that fundamentally affects its operations.

Operations to date support some of the fundamental concepts of industrial symbiosis. Significant challenges exist, though, if the company is to continue to prosper in the volatile globalized sugar market.

Address correspondence to:
Ernest A. Lowe
Indigo Development
2815 Spring Creek Drive
Santa Rosa, CA 95405 USA
<ernielowe@indigodev.com>
<www.indigodev.com>

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Introduction

Industrial Ecology and Symbiosis

Since 1989, industrial ecology has created a new perspective on industrial development: industrial complexes should be designed to resemble natural ecosystems in order to use energy, water, and material resources optimally while at the same time minimizing wastes (Heeres et al. 2004). As a part of industrial ecology, the study and promotion of industrial symbiosis have gained increasing attention. Building on the notion of biological symbiotic relationships in nature, industrial symbiosis consists of place-based exchanges among different entities (Chertow 2000). By working together, businesses strive for a collective benefit that is greater than the sum of individual benefits that could be achieved from acting alone. This kind of collaboration can improve social relationships among the participants, which can also extend to surrounding neighborhoods.

Chertow (2000) proposed that industrial ecology can operate at any of three levels: the facility level, the interfirm level, and the regional or global level. Industrial symbiosis occurs at the interfirm level, including options for exchange of by-products and other forms of collaboration among several organizations.

Progress toward developing programs of industrial symbiosis is significantly influenced by a number of factors, including the nature of a company's operations, the industrial history of the region, the extent of peer pressure, the positioning of a coordinating body in the region, and the company's approach to awareness-raising and recruitment.

The term "industrial symbiosis" was actually coined to describe a group of interconnected industries in the Danish town of Kalundborg that saw a network of by-product exchanges and other forms of collaboration evolve spontaneously over three decades (Chertow and Ehrenfeld 2001). Schwarts and Steininger (1997) identified a large and complex pattern of by-product exchange in the Austrian province of Styria, suggesting that the pattern of interplant exchanges may occur often, but without self-awareness by the participating firms. In this article we report on the case of a sugar refinery in China that has been practicing a form of industrial symbiosis for more than 40 years. The aim is to investigate whether this unintended experiment supports some of the fundamental notions in the field.

The Sugar Industry in China

The sugar industry in China has a long history and has seen significant changes in recent years. In a recent analytical review, Wei noted that the industry has grown more than 300% since the pivotal economic reforms that began in 1979 (2004). This growth was accompanied by stresses, both internal and external, that have resulted in significant restructuring in operation of the industry across the country. The government is pursuing a series of policies aimed at sustainable development for the sugar industry, more sharing of profits between farmers and manufacturers, increased product quality, and greater environmental protection. Creative management and innovative technology will have to be brought to bear in order to meet these ambitious goals.

Sugar and the Guitang Group

This article builds on previous work (Zhu and Côté, 2004) regarding the Guitang Group (GG), a sugar company in southwestern China, which operates one of China's largest sugar refineries, a complex covering more than 2 km^2. Over the past four decades, the GG has developed and implemented a system that can be fairly characterized as internal and external symbiosis. This article summarizes the background of the GG, introduces the model of symbiosis it has created, and discusses the benefits, challenges, and responses associated with the company's efforts.

Industrial Symbiosis in the Guitang Group

Overview

The Guangxi Zhuang Autonomous Region (Guangxi province in southern central China) produces more than 50% of the entire sugar output of China (Wei 2004). As noted by Zhu and Côté (2004), the GG was established by the state in 1956 and currently employs over 3,000 workers to operate one of the largest sugar refineries in China.

Over the past five decades, the GG has gradually evolved from a stand-alone refinery to an industrial symbiosis complex. The GG initially developed this complex internally by setting up new processing plants as profit centers that utilized by-products of upstream plants. Later, the GG extended the complex externally by establishing close relationships with the suppliers—principally the sugarcane farmers—and with the local government, which plays a key role in the functioning of the system (see below). The GG also has made efforts to keep and gain markets for its traditional products, such as sugar, and for its new products, such as a widening range of paper goods. The goal of the initiative has been "to reduce pollution and disposal costs and to seek more revenues by utilizing by-products" (Duan 2001). At the same time, the GG sought to improve both product quality and environmental performance, reflected in its ISO9001 certification in 1998 and current efforts to achieve ISO14001 certification (Chen 2005, 2006).

Since 2000, the State Environmental Protection Administration of China (SEPA) in Beijing has promoted the GG for its strong economic performance and its responsible use of environmental resources. With this approval and guidance from the SEPA, the GG has committed itself to promoting and expanding its operation as a model of an ecoindustrial park (EIP). SEPA's goal is to encourage other sugar companies to consider similar industrial symbiosis approaches to meeting environmental standards. In July 2001, SEPA formally approved the Guitang Group and its network of relationships in Guigang as an EIP demonstration park (The Guitang Group, 2004; SEPA, 2004). This designation implies a loose definition of EIP, independent of more accepted terminology in industrial ecology. It would be more appropriate to call the regional initiative, led by one enterprise, an ecoindustrial network (Lowe 2001, 2005).

In 2001, the GG facilities were sold to Shenzhen Huaqiang Holdings Limited in Shenzhen, a private Chinese company that appears committed to maintaining the vision of Guitang as a model of internal symbiosis and a leader in a regional ecoindustrial network for future sustainable development in south China (Chen, 2005, 2006).

Internal Industrial Symbiosis at the Guitang Group

The essence of industrial symbiosis is taking full advantage of by-product utilization, while reducing residual products or treating them effectively. The term is usually applied to a network of independent companies that exchange by-products and possibly share other common resources. It is appropriate to apply it to the GG because of its mix of internal practices and new business units and its external supply chain relationships. The GG's evolution into an integrated system has been summarized in an earlier article (Zhu and Côté 2004). It was established as a State-owned company in 1956 with a sugar refinery and an alcohol plant that used the molasses by-product from the sugar operation. The GG added three paper mills over the years, which now use bagasse (fiber residue from the crushing and grinding of raw sugarcane) as a raw material, and has developed additional new business lines that would simultaneously generate profits and reduce environmental burden through expansion of the internally integrated by-product chains (see figure 1). The result is the creation of a new business model rooted in higher quality, allowing the GG to establish its own brands in the marketplace, as well as to be a supplier to other marketers.

The current process is illustrated in the process diagram, figure 1. As the diagram shows, the sugarcane enters the sugar mill and is processed along one of two product chains: the sugar chain (containing the originally conceived sugar refinery and the alcohol plant) or the paper chain (containing the pulp and paper mills). Each downstream (internal) company uses the by-products from upstream companies as secondary material inputs. In addition, careful attention is given to reducing the residual waste and to its ultimate disposal.

The sugar chain results in the ultimate production of sugar, alcohol, cement, and compound fertilizer (i.e., fertilizer with a specific ratio of nitrogen, phosphorus, and potassium). In the sugar refinery, the sugarcane "juice" that is released in the crushing and grinding assembly in the sugar mill is refined in a carbonation process that yields a higher quality refined sugar than does the

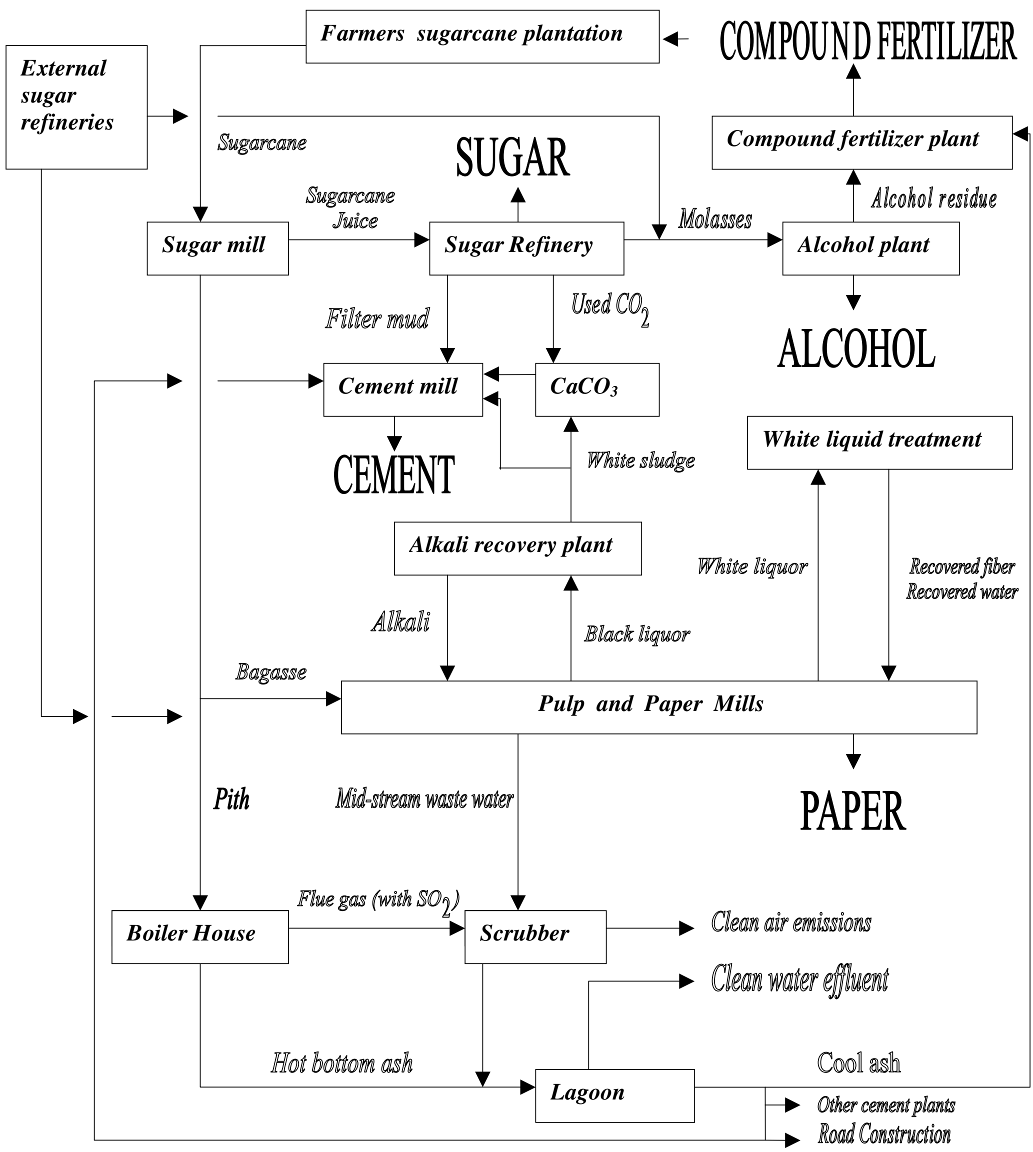

Figure 1 Guitang Group Process Diagram.

sulfitation process that is used by the majority of cane sugar plants in China (Wei 2004). Wei notes that sulfitation is favored by the GG's competitors, in part, because the filter mud (one of the wastes from the refining process) from sulfitation can easily be disposed of as a direct application fertilizer. Filter mud from the carbonation process, on the other hand, can have a significant negative effect on the local soil if it is applied directly to the land.

The GG has addressed this problem by using the carbonation filter mud as an input to the State-owned cement production facility it manages, rather than as a fertilizer. The GG contributes the filter mud and pays for transportation costs, balancing the savings from not having to pay for disposal. The fuel for the cement plant is coal, introducing an added environmental burden on the symbiosis. The residues from the alcohol plant (molasses)—which once would have been released into the environment—are now used as input to the production of compound fertilizer, which goes back to the sugarcane fields, thus closing this loop.

The paper chain is driven by the input of bagasse, which is the residue from the sugar mill, minus the pith; that is, the soft interior potion of the cane. Sixty percent of the bagasse has fibers long enough for paper-making. The short fibers of the pith are used as fuel in a cogeneration power plant. Earlier, the GG burnt the bagasse in its power plant and sold it to homeowners for cooking and heating.

The pulping operation that prepares the bagasse for conversion into paper requires a significant addition of alkali, which ends up in the residue of that operation. The GG has constructed an alkali recovery plant that recycles the waste from the pulping operation (black liquor), generating a white sludge that can be used as input to the cement mill, which is primarily a part of the sugar chain. The pulp is processed by one of the three paper mills, where a major waste (white liquor) is generated and subsequently treated to recover major portions of fiber and water, which are recycled to the paper mills.

As the figure shows, in addition to the production chains, there is an energy recovery chain in which the pith is burned in the GG boiler house to power the plant. The air pollution control equipment on the boiler house consists of (1) a Venturi scrubber (a.k.a. "dry" scrubber) for large particulates, (2) a wet scrubber utilizing alkaline water to neutralize sulfur dioxide (SO_2), and (3) an electrostatic precipitator (ESP) for small particulates. The wet scrubber and the ESP reduced SO_2 emissions in 2003 from 11,200 tonnes[1] per annum to 7,840 tonnes per annum. An ESP removes 99% of boiler dust. Gypsum from the wet scrubber is provided to farmers to reduce soil acidity. The recovered ash is used for cement making (both at the Guitang plant and at other cement plants) and in road construction. Baghouses in the cement plant remove particulates from this process. Burning of pith for energy lowers emissions (SO_2 emissions are approximately half those from burning coal) and eliminates disposal costs of this residue.

The internal symbiosis of the GG operations has resulted in increased efficiency and productivity per unit of input. The annual total production in 2003 includes plantation white sugar (150,000 tonnes), raw sugar (300,000 tonnes), pulp (150,000 tonnes), paper (200,000 tonnes), alcohol (10,000 tonnes), cement (330,000 tonnes), alkali (35,000 tonnes), and fertilizer (30,000 tonnes) (The Guitang Group 2004). The GG recovered its investments in the paper mills and fertilizer plant in six to eight years.

Historically, production of these products has often been the source of significant environmental pollution elsewhere in the world. In this case, however, the GG is meeting all applicable local and national environmental standards (Chen 2005, 2006) while enjoying significant financial benefits resulting from its wider product mix, which can respond to changing market forces.

External Industrial Symbiosis at the Guitang Group

In addition to the internal symbiosis described above, the GG has evolved a network of external relationships including the government, customers, suppliers, and competitors that affects the overall operation of the complex. This pattern of external symbiosis has developed through a dynamic relationship between the government, the GG, and other sugar producers.

Relations with the Government

The city of Guigang, within whose jurisdiction the GG lies, is located in a generally rural area of eastern Guangxi Zhuang Autonomous Region, just outside of the "Gold Tourist Zone" that connects the port city of Beihai, the capital of Nanning, and the international tourist attraction of Guilin. Sugar cane is a significant part of the Guigang economy, despite its relative invisibility to tourists. The sugarcane refinery and related industries employ about 30% of the 5 million residents of the Guigang administrative area and account for about one-third of the area's 14 billion RMB (US$1.7 billion) Gross Domestic Product (GDP). Due to this heavy dependence on one industry, the city is conscious of multiple factors such as relations between farmers and processors and China's entry into the World Trade Organization (WTO) that might affect the industry and, consequently, the region.

In the contemporary Chinese social and economic system, government entities play an active role in the conduct of business and markets. The Guigang city government establishes a floor price that the company must agree to pay the farmers. This direct price support provides greater income and security for the farmers, in line with national policy of helping rural populations share in the benefits of China's rapid and continuing economic expansion. In setting the floor price, government must be sensitive to the economic effect of its policies on this key industry.

In 2004–2005, the Guigang government set the sugarcane price that the GG had to pay farmers at 170 RMB (roughly US$20.50) per tonne, which was 50% higher than the average 110 RMB (US$13) per tonne price paid to farmers in the rest of the world, thereby reducing the GG's competitiveness. As a result of poor rainfall and a reduced harvest, the GG's actual average price paid was 215 RMB. The government's rationale for setting the higher price was twofold: (1) a policy determination to increase farmers' income and (2) a pragmatic determination to provide added incentive to encourage farmers to plant sufficient sugarcane to meet the needs of the sugar processors, because a number of farmers in the region had switched to other, presumably more profitable crops.

Beyond setting the floor price, the city government used other policies to manage the scale of sugarcane production and to restrict the area in which the GG may buy sugarcane. In short, the government acted as an intermediary between factories and farmers, seeking resolution of issues in matters such as price and quantity. Farmers who planted sugarcane on reclaimed marginal or barren land that was not being farmed received a reduction in local taxes. The government also encouraged local banks to provide no- or low-interest loans for farmers who planted on a larger scale and provided employment opportunities to farmers whose land had been purchased by larger-scale farmers (The Guitang Group 2002).

Although the Guigang government actively intervened in sugarcane production, it also set policies that supported symbiotic relationships by requiring smaller sugar producers to send their by-products (bagasse and molasses) to the GG as inputs for the production of paper and food grade alcohol. In turn, the government required the GG to meet by-product utilization targets such as "Utilization of bagasse reaches more than 80%, use of molasses reaches 100%, use of alcohol residue reaches 100%" (Lowe 2001, Appendix).

These arrangements have set up a dynamic tension among the government, the farmers, and the processors (including the GG) that motivates all parties to increase productivity and efficiency, as they seek their fortunes in a collective way – even though significant differences in points of view can occur along the way: the farmer aims to maximize his price; the factory, to maximize its profits; and the government, to maximize economic well-being in a manner that maintains equity among the players, as well as achieving some measure of environmental protection. The GG and other players are taking steps to learn from the experience of other sugar-producing countries, such as Thailand. For example, in Thailand there is a very powerful nationwide cane growers association that negotiates the cane price with the sugar producers on a region-by-region basis. The Thai government also plays an important role by establishing and assigning specific quotas for production for both the national market and the international market. In addition, the government has set up a foundation to enter the market in an attempt to stabilize the market price and to conduct research that will generate advanced technology for the industry (Wei et al. 2004).

Relations with Customers

The GG has achieved some success in expanding its sugar sales based on the quality of its products, winning prizes for the past 11 years in recognition of its low levels of sulfur dioxide (SO_2) and color. The higher quality of its carbonation-refined sugar, compared with the sulfitation-refined sugar of its competitors, has enabled the GG to gain significant contracts with major soft drink companies, including Coca-Cola and Pepsi-Cola, as well as with Wahaha, the largest domestic beverage producer in China.

For the past few years, GG's greatest success in the market has been in paper manufacturing, which has become its major profit center. Again, the quality of its office and publishing paper enabled the company to establish a presence in the paper market, with opportunities for higher profits than its sugar business. Since 2001, its office and publishing paper production has exceeded 50,000 tonnes per year. In another segment of the paper market, the GG Technology Center has developed new technologies protected by patents and obtained new equipment to produce high-quality toilet paper, allowing it to quickly rise to rank third in domestic output. Further expansion of its paper production capacity began in late 2005 and, although expected to focus on toilet paper, the new plant may end up producing office paper instead. The input material for the new production plant is expected to be 70% bagasse from sugar cane grown within a 600-km radius of Guigang and 30% longer-fiber wood pulp sourced from domestic suppliers and imported from a range of wood producers in Canada, Russia, Indonesia, and Chile.

Guitang must remain flexible in order to respond to changes in the market. For example, due to changes in the world sugar market, there was a shortfall in the production of sugar worldwide between 2005 and 2006. As result, the price of sugar rose by over 50% in one year, thereby changing the profit mix of the company (Chen 2005, 2006).

Relations with Suppliers/Farmers

A steady supply of high-quality sugarcane is important for the GG to maintain and improve its competitiveness in its markets. Therefore, the company continually seeks new ways of working with its suppliers to insure adequate supplies of feedstock. This has not always been easy.

Among the steps taken to generate and nurture its relations with its suppliers, the company has signed long-term contracts with farmers for sugarcane production. The company has also provided seeds and some organic fertilizer at a nonprofit price, as well as technological support to sugarcane farmers in the area. In 2000, the company announced plans for helping farmers convert to organic production as a strategy for increasing competitiveness and profit margins (Lowe 2001). Lacking funding for an immediate conversion to organic farming in the region, it has focused its research and provided support for farmers to move towards this goal. The company has worked with farmers to establish the use of a pheromone-based pesticide and has developed and distributed two organic fertilizers. Both are made from alcohol residue, with one mixed with nitrogen, phosphorus, and potassium, whereas the other includes white sludge and bottom/fly ash derived from the GG's production processes. Research by the GG has demonstrated that these fertilizers, compared with typical inorganic fertilizers, have increased the sugarcane yield by 12 to 15 tonnes per hectare (to 81 tonnes/hectare), while slightly increasing the sugar content of the cane by 0.5% (Chen 2005, 2006), benefiting both the farmer and the company (Zhu and Côté 2004).

Relations with Competitors

The construction of new paper mills has resulted in production capacity that exceeds the supply of locally available bagasse. This has led the GG to source two-thirds of the bagasse it uses from local competitors, which had been discarding or incinerating the by-product. Some of its larger competitors are considering developing their own paper mills, which would upset the stability of the GG's supplies. But they would have to match the GG's technical leadership in order to compete. The company, in cooperation with the government, also purchases bagasse from smaller competitors, providing them with revenue for what was previously a waste. These smaller operations are less likely to duplicate the GG's papermaking capabilities (Yang 2001).

Benefits

In theory, industrial symbiosis should generate benefits for all participants. In this section we examine the impact of GG's approach on the company, its suppliers and customers, the region, and the people.

Impacts on the Guitang Group

For large and medium-sized enterprises that provide intermediate products to other enterprises, it is advantageous to become long-term suppliers to large downstream enterprises with large market shares and high profit margins (Zhu and Geng 2002). Progress can be made toward this goal by producing a higher quality product than competitors. In this case, the GG has been able to improve its quality, in part, as a result of its internal symbiosis among subsidiary companies.

The GG's use of carbonic acid technology results in better sugar quality, thereby meeting requirements of foreign and domestic beverage companies, while increasing the cost of production by about 200 RMB (US$24) per tonne and producing more waste such as filter mud. By choosing to approach its "waste" as a business opportunity, the GG solved a traditional disposal problem by using the sludge as the calcium carbonate feedstock to a new cement plant. This in turn generated profits that helped offset the higher cost of the carbonation and increased the company's competitiveness in the sugar market. The quality of the Group's sugar product allowed it to receive a premium of about 300 RMB (roughly US$38) over the average domestic price, or about 3,000 RMB per tonne (roughly US$375); that is, a "quality premium" of 10% (Chen 2005, 2006). In effect, its willingness to build a cement plant allowed it to market better products that sold at a higher price and generated improved profits, while reducing pollution. A similar investment in higher quality paper production based on bagasse and the decision to incorporate an alkali recovery plant resulted in reduced input costs (recovered alkali is half the price of purchased alkali—2,000 RMB (US$250) per tonne versus less than 1,000 RMB (US$125), reduced pollution (the GG recovers 80% of alkali from the black liquor), and lower production costs [by 240 RMB (US$29)], all of which contribute to its competitive advantage in both domestic and international markets (Duan 2001). The diversified range of products resulting from its approach to industrial symbiosis helps the GG maintain stable relationships in volatile international sugar markets.

Impacts on the Surroundings

The dominance of the sugar industry supply chain—farming, processing, production, and related suppliers—in the Guigang region means that the success of the GG and its 3,000 workers also generates financial and environmental benefits throughout the local economy. The many small sugar refineries located in or around the city of Guigang produced pre-2000 levels of 300,000 tonnes of molasses and 200,000 tonnes of bagasse that required disposal. The use of these by-products by the GG as raw materials, supported by government policies, allowed it to improve its production scale for alcohol and paper, which helped address regional economic and environmental problems that were a major bottleneck for the continued development of the Chinese sugar industry (Liu 2001).

The comparative success of the GG has also altered the local labor market, as it has sought young, well-educated employees for its research and production staff. A significant number of graduates from Guangxi's universities, colleges, and technical secondary schools would have formerly migrated to more developed regions in China. The GG investments in student and adult education through its support of institutes, including the Sugar Refinery Institute, Paper Institute, Environmental Protection Institute, Biotechnical Institute, and Automation Institute, have meant that students have opportunities to stay and work in the region.

Challenges and Responses

Challenges

The volatile worldwide sugar market is likely to become even more competitive as the regulations of the World Trade Organization take hold over the next few years. Compared with major sugar-producing countries such as Brazil, Thailand, and Australia, China's sugar industry is dominated by small-scale farms and facilities with higher production costs. Low sugar prices in recent decades have eliminated the industry in once leading areas such as Hawaii and Puerto Rico in the United States. Chinese industry is at risk if the market should become flooded with significant surpluses. The Chinese government protected its domestic sugar industry through high tariffs and a strict quota system in the middle 1990s, but with its approaching WTO entry in 2002, it reduced the tariff to 30% (Zhang 2002). Subsequent to joining the WTO, tariffs were lowered several times such that the price for imported sugar was cut by 60 to 70 RMB (roughly US$8) per tonne and quotas increased from 1.6 million tonnes to 1.945 million tonnes by 2004 (State Information Center 2003). This combination of decreasing tariffs and increasing mandated imports will have an increasing impact on the sugar market in China.

The principal domestic problem facing the GG is maintaining adequate supplies of sugar cane to provide feedstock to the complex. For example, in the 2004–2005 harvest season, the plant processed 600,000 tonnes of cane to produce 75,000 tonnes of sugar. This supply stream is one-third lower than it was in the 2003–2004 harvest year, in which GG processed 900,000 tonnes of cane. Due to changes that have already been made, for example, increased incentives to farmers and accessing supplies some distance from the plant, the company hopes to process up to 1,000,000 tonnes of cane during the upcoming (2005–2006) season. Challenges exist due to the limited land available. Most recently, 200,000 Chinese mu (13,333 ha) were planted in sugar cane in the region around Guigang. The expected maximum expansion is to 250,000 mu (16,667 ha), creating a limit to future local expansion.

The capacity of the GG paper plants has already outgrown local sources of bagasse. Although capable of utilizing 600,000 tonnes of bagasse, in 2005 it processed only 400,000 tonnes, of which 100,000 tonnes came from the surrounding area and 300,000 tonnes were purchased from outside the region. The economic consequences are significant. The price of bagasse rose to 220 RMB/tonne (US$27/tonne) for local bagasse and to 330 RMB/tonne (US$40/tonne) for bagasse grown elsewhere and delivered to the plant, the difference reflecting primarily the cost of transportation.

The GG is also at risk as farmers become attracted to higher near-term returns from other, higher revenue crops, such as fruits and vegetables. Because these crops are more vulnerable to adverse weather and are highly perishable, farmers may switch back to sugar cane. Other significant risks include the GG's continued use of older refinery technologies and equipment and farmers bringing more marginal land into production, both of which adversely affect productivity and increase environmental risks (The Guigang Eco-industrial Park Office 2004). In addition, the role of the Guigang government in the tricky process of setting sugar prices to assist the farmers without killing the golden goose will be an even more difficult maneuver as the WTO agreements come into effect.

More fundamentally, is the internal symbiotic model, founded as it is on two production chains (sugar and paper), sufficiently robust to meet the challenge of sustained pressure on one or both of those chains? On the positive side, the presence of two chains allows one chain (e.g., paper) to offset losses to the company if there is a downturn in the other (e.g., sugar). If, on the other hand, the sugar refinery suffered a continuous loss over several years or if more than one plant met with marketing problems, it would be difficult to maintain the economic performance in the whole GG. According to Korhonen, the potential problem of the long-term loss for one of the plants could be solved by diversity, namely, creating redundancy in the chains (Korhonen 2002). In response, the GG has attempted to establish cooperative relationships with other groups, as well as consuming by-products from small sugar refineries. Unfortunately, increasing diversity may also prove to be a problem for the industrial symbiosis, because increased diversity creates a more complex system, which may or may not be more difficult to manage.

Finally, the former State-owned group was turned into a stock company in 1994 and the stock began trading on the Shenzhen Stock Exchange in 1998, which led to the ownership change in 2001. It is too early to know how this change in ownership will affect the GG's relationship with the local government or sugarcane suppliers, although the current management insists that the operating philosophy and business plan remain unchanged (Chen 2005, 2006).

Responses

The GG's competitive success is a function of its embrace of industrial symbiosis and its willingness to invest in its technology center, which spearheaded the development of techniques for more efficient sugar production and comprehensive utilization of by-products. To meet new business challenges, the company is exploring other fiber sources besides bagassse, such as readily accessible rice waste and bamboo from local sources, and value-added product lines based on sucrose ester and fructo-oligosaccharide research at Guangxi University (Wei 2004). It has invested in computer-controlled crushers and grinders for more efficient production. Opportunities also exist to reduce water use. Currently, five tonnes of water are used to produce one tonne of sugar and two hundred tonnes of water are required for one tonne of paper. Recycled cooling water from the power plant is used in production lines, but the majority of process water is discharged following pretreatment (Wei 2004).

The GG is exploring becoming active in the Clean Development Mechanism (CDM) of the Kyoto Protocol (Article 12). The CDM seeks to use market forces in the developing world to promote sustainability by reducing excessive carbon dioxide emissions. Greenhouse gas emission credits are available through the CDM for first world investments in second and third world development (UNDP 2003).

Conclusions

The Guitang Group approximates a relatively simple, idealized industrial complex model. Nemerow (1995) proposed just such an enterprise in his groundbreaking work outlining 15 models for by-product utilization, anchored by different primary plants. To the extent that the GG is—and continues to be—successful, it supports the validity of Nemerow's thesis. Ramaswamy and Erkman have reported a pattern parallel to the GG case in India, where Seshasayee Paper and Boards Ltd. mill faced a growing shortage of wood for pulping. There, the paper industry invested in a new subsidiary sugar refinery as a source of bagasse, which in turn contracted with an alcohol refinery and a methane generator to use the spent molasses. Seshasayee supported the conversion of regional farms to sugar cane production and supplied farms with treated water from both the paper and the sugar mills (Erkman and Ramaswamy 2003).

In both the Chinese and Indian cases, companies have spontaneously developed patterns of industrial symbiosis, first through internal investments, and then through cooperation with partners in their regions. Although efforts to develop by-product exchanges within a region may benefit from emulating the Chinese and Indian companies, such internal symbiosis runs counter to business trends for firms to focus on their core competence ("stick to their knitting") and avoid development of "distracting" profit centers. Much as in resistance to pollution prevention and eco-efficiency, managers may view take a skeptical view of efforts to utilize by-products when the costs of waste disposal are buried in overhead.

Despite the example of the GG turning its industrial symbiosis approach into a profitable advance over traditional industrial practices, its future requires ever greater business and technical innovations. Supply issues, national and international economic issues, and production issues provide strong motivation for the owners and operators to seek ever greater efficiencies in the system if they are to achieve an ongoing return on their investment. Beyond the fate of the GG, the development of a regional industrial symbiosis structure poses significant risks for its industry network, its partners, and the city of Guigang.

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Note

1. One tonne (t) = 1 megagram (Mg) = 10^3 kilograms (kg, SI) $\approx$ 1.102 short tons.

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About the Authors

Each of the four authors has made major contributions to this article and should be considered as an equal coauthor. **Qinghua Zhu** is an associate professor in the School of Management at Dalian University of Technology, People's Republic of China. She received her bachelor's and master's degrees in electrical engineering and her Ph.D. in systems engineering. Her main research interest is integrated green supply chain management and environmental management systems. She interviewed company and city officials in June of 2004. **Yuan-an Wei** is vice president of Academic Affairs at Guangxi University, as well as the director of the Sugar Research Institute at the University. He received his Ph.D. in organic chemistry, is a principal investigator at the Guangxi Key Laboratory for Subtropical Bioresource Conservation and Utilization at Guangxi University, and serves on a technical advisory committee for the Guitang plant and has discussed these issues with plant leaders on a number of occasions. **Donald Barnes** is visiting professor of Chemistry at Guangxi University. He retired early from the U.S. Environmental Protection Agency after a 22-year career, which included directing the Agency's Science Advisory Board and participating in several of the Agency's industrial ecology and "alternative futures" activities. He visited the Guitang plant in late 2004 and had subsequent conversations with the Vice Director of the facility. **Ernest A. Lowe** is director of Indigo Development. He is the author of *The Eco-Industrial Park Handbook for Developing Countries* and co-author of *Discovering Industrial Ecology*. He is co-author of a Chinese language handbook revision, *Industrial Ecology and Eco-Industrial Parks*. He visited the Guitang Group's complex in April 2001 to review the eco-chains described in this article.