Securing a Competitive Advantage through Industrial Symbiosis Development

The Case of Steam Networking Practices in Ulsan

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Keywords:

business strategy
case study
eco-industrial development
energy recovery
industrial symbiosis (IS)

Summary

Hyosung Yongyeon Plants
- Plant I: Operated since 1991
- Plant II: Operated since 1997
- Plant III: Built in 2009

Organization type: Production facilities of Hyosung, a public company
Headquarters: Seoul, Republic of Korea
Industries: Chemical
- Plant I: Polypropylene (PP)
- Plant II: TPA (purified terephthalic acid)
- Plant III: Optical TAC (cellulose triacetate) film

Employees: 450
Annual production:
- Plant I: 300,000 tonnes of PP
- Plant II: 420,000 tonnes of TPA
- Plant III: 50 million square meters (m^2) of liquid crystal display (LCD) TAC film

Introduction

Ulsan Metropolitan City has been the industrial capital of South Korea since it was designated by the national government as a special industrial district in 1962. Heavy industries located in Ulsan, including machinery, automobile, petrochemical, and shipbuilding, have contributed to the rapid economic development of Korea, but they have caused environmental problems, such as air and water pollution. The industries also consume enormous amounts of energy (20.8 million tonnes [t] of oil equivalent), based mainly on fossil fuels (FFs), which made Ulsan the third-largest energy consumer among 16 metropolitan cities and provinces in the country as of 2006 (Bae et al. 2007). Responding to these problems, Ulsan started the "Ecopolis Ulsan" initiative in 2004 to enhance environmental conditions and established the "Medium- and Long-term Comprehensive Environmental Master Plan" along with a "Regional Energy Plan" to reduce its energy consumption (Ulsan Metropolitan City 2002, 2004a, b). In addition to these local efforts, Ulsan was selected as one of five pilot sites under the national Eco-industrial Park (EIP) program started in 2005 (Park et al. 2008). The fifteen-year EIP program (2005–2019), which has three phases, was established to retrofit old industrial complexes and transform them into sites that harmonize industrial productions and environmental conditions.

The industrial ecology practice described in this article is one of the first-phase (2005–2009) EIP projects successfully implemented in Ulsan. Using residual heat from a waste-to-energy incinerator, steam is produced and supplied to a chemical plant that has faced high energy costs. The unique aspect of this project is that the incinerator increased the value of

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DOI: 10.1111/jiec.12158

Editor managing review: Andrew Hoffman

Volume 18, Number 5

incineration heat through steam networking, even though it has already been using the steam for its internal power use. For the expansion of steam networking, the incinerator even changed the design of a new boiler that was being built to incinerate an additional 250 t of municipal solid waste (MSW) per day. This article will show how this energy sharing, one form of industrial symbiosis (IS), has generated direct economic benefits for both facilities and indirect benefits in broader respects. The central focus of this article is the examination of this project as the basis for competitive advantage by addressing how the project makes the entities perform better than other equivalent facilities or competitors. This is one of a few studies that presents quantitative details regarding the practice and competitive advantage achieved through the IS development project.

Overview of Industries Participating in the Project

The Sungam waste-to-energy (WTE) incinerator owned by Ulsan Metropolitan City was constructed in 2000 to reduce the burden at the Sungam landfill. Before the project described in this article was implemented, two boilers at its first plant burned 400 t (2 × 200 t) of MSW per day, and from the incineration heat, it generated steam and power mostly for its own use. Of a total of 45 t of steam generated per hour, 23 t of steam were used to generate electricity for internal uses and 11 t of steam were sent to a facility composting food waste, which has been operating on the same site. The remaining 11 t of steam were collected as a condensate and used internally, such as for hot water. As of 2006, electricity generated from 23 t per hour of steam translates to 0.9 billion Korean won (KRW) or 900,000 U.S. dollars of avoided cost because the incinerator would have purchased electricity otherwise (Bae et al. 2007). The second plant that burns 250 t of waste per day was built during the project and started operating in October 2012. With the operation of the second plant, additional steam networking was established that comprised the second phase of the symbiosis project.

Hyosung, a chemical company that participates in the IS project, has three plants located near the incinerator. Hyosung Yongyeon's first plant is a vertically integrated system that manufactures a variety of products from raw materials to final products based on polypropylene (PP). Its own propane dehydrogenation process is an up-to-date technology to produce propylene, a raw material for PP. The second plant annually produces approximately 420,000 t of terephthalic acid (TPA), which is a core material for high-performance polyester textiles, tire cord, polyethylene terephthalate bottles, polyester film, and other industrial and consumer goods. The third plant, which was built during the project, produces a cellulose triacetate (TAC) film, which is an electronic material used to protect polyvinyl alcohol film in a polarizer, a liquid crystal display component in monitors, laptops, and televisions. It is the first domestic plant that commercialized manufacturing techniques for TAC films. Until the establishment of the symbiosis, all the power required for the three plants was supplied by the second plant, which has boilers that can burn heavy fuel oil (No. 6, 4% sulfur content) and liquefied natural gas (LNG) according to the market situation. For this reason, the second plant played a key role in the establishment of the steam network.

Table 1 Timeline of actions taken for project implementation

Year	*Month*	*Actions*
2006	July	The Ulsan Eco-industrial Park (EIP) center initiated conducting a feasibility study.
2007	March	Hyosung was selected as a steam user.
	June	A memorandum of understanding (MOU) was signed by Hyosung, Ulsan Metropolitan City, and the Ulsan EIP center.
	November	Steam pipeline construction began.
2008	June	Steam-sharing was started; **the first phase of the steam sharing (medium pressure) began.**
2009	January	Hyosung's third plant started to operate and receive steam.
2012	October	Sungam's second incinerator began operation; **the second phase of the steam sharing (high pressure) began.**

Implementation of the Project

Table 1 shows the timeline of important actions taken for project implementation. As a coordinating body of the national EIP program, the Ulsan EIP center proposed the idea of using steam from the Sungam WTE incinerator to develop a steam-sharing network. To examine the economic viability and environmental impact of this idea, the Ulsan EIP center initiated conducting a feasibility study in July 2006 with the support of Halla Energy & Environment Co., Ltd., the operator of the incinerator. Throughout the project, Halla Energy & Environment Co., Ltd. took broad responsibility by establishing an investment plan, providing technical services for the incinerator and steam pipelines, and providing security for the loan. In March 2007, the center selected Hyosung as a steam user after holding an information session and evaluating proposals from companies that could potentially use the steam. After 3 months, a memorandum of understanding (MOU) was signed by Hyosung, Ulsan Metropolitan City, and the Ulsan EIP center. For Ulsan City, this project was an opportunity to draw investments in an energy-efficient project and promote the growth of energy-efficient industries. Hyosung could save

costs without a big investment and associated economic and technical risks.

As a result of the feasibility study, the project was planned to take place in three stages according to the amount of steam shared between the two entities. In the first stage (May 2008–December 2008), 15 t per hour of steam was expected to be supplied to Hyosung. In the second stage (January 2009–December 2010), the amount of steam supply was planned to be increased to 34 t per hour. In this period, the annual revenue from the sale of steam was estimated to be 4.5 billion KRW ($4.5 million) and the annual cost savings for Hyosung was approximately 4.1 billion KRW ($4.1 million). From 2011 on, the amount of steam supply was expected to be increased further to 60 t per hour as the incinerator planned to equip an additional boiler. Accordingly, the estimated revenue for the incinerator increased to 7.9 billion KRW ($7.9 million), and the expected cost savings for Hyosung increased to 7.2 billion KRW ($7.2 million). As for the environmental impact of the project, the reduction in fuel oil consumption at Hyosung in the second phase was expected to reduce 6,834 t of carbon dioxide (CO_2) and 13.7 kilograms of sulfur dioxide (SO_2) per hour (Bae et al. 2007).

To implement the steam-sharing project, pipelines needed to be constructed to connect the incinerator and the chemical plant, approximately 1 kilometer apart. The construction of the pipelines was estimated to require 2.9 billion KRW ($2.9 million) of investment. For financing, the use of the Energy Saving Company (ESCO) fund, which was established by the Energy Use Rationalization Act (Korean Ministry of Knowledge Economy 2013), was proposed. Article 25 of this law specifies a policy to support energy-saving projects, and article 36 defines eligible endeavors to utilize waste heat produced in business facilities. According to the steam price assumption used in the feasibility study, the payback period was estimated to be 1 year and 6 months (Bae et al. 2007). Based on this plan, the construction of the steam pipeline was started in November 2007.

The implementation of the project faced two major challenges that required changes in the plan. Sungam's first plant could produce 35 t of steam per hour at a pressure of 16 kilogram-force per square centimeter (ksc), but Hyosung's second plant could only use 25 t of steam per hour. To match the supply, Hyosung proposed to build a third plant that could use the rest of the steam. The construction of Hyosung's third plant was started after the MOU was signed, and the plant started to operate and receive steam in January 2009.

The second challenge was the mismatch between the pressure of steam available and the pressure of steam needed. According to the original design of the new boiler, which was planned to be built by October 2012, Sungam's second plant could only produce medium-pressure steam (16 ksc) to generate electricity, the same as its first plant. However, there was no more demand for the medium-pressure steam at Hyosung because of the first-phase symbiosis. Instead, Hyosung's first plant needed higher-pressure steam with a pressure of 45 ksc. To meet this demand and therefore to expand the steam network, Sungam's second incinerator changed its boiler design to produce higher-pressure steam and abandoned the original plan to have an electric generator. Of 35 t of higher-pressure steam per hour that is generated at Sungam's second plant, Hyosung's first plant has, since 2012, used 15 t per hour of steam and has sent the rest of the 20 t per hour of steam to another chemical facility nearby. Additionally, Hyosung's second plant is planning to make available 10 t per hour of steam by increasing its energy efficiency and will sell it to the "Steam Highway," which is another steam-sharing project under construction. Figure 1 shows two steam flows established sequentially between Sungam's two incineration plants and Hyosung's three factories.

Table 2 Direct revenue and cost savings generated through the project

Participating entities	*Revenue or cost items*	*Changes between 2006 and 2012 (in billion KRW)*
Incinerator (Ulsan City)	Revenue from the sale of medium-pressure steam	6.5
	Revenue from the sale of high-pressure steam[a]	0.8
	Total revenue	**7.3**
Chemical plants (Hyosung)	Savings on fuel cost	3.7
	Savings from the boiler shutdown	0.48
	Total cost savings	**4.18**

[a]High-pressure steam has been sold since October 2012. The revenue presented here represents 3 months of data.

Implications of the Project: Direct Economic and Environmental Implications

Since the start of the project, steam sales have generated a revenue stream for the incinerator and its owner, Ulsan Metropolitan City, and the amount of revenue has increased every year (figure 2). The total revenue generated in 2009 was 2.5 billion KRW ($2.5 million), but it increased to 5.0 billion KRW ($5.0 million) in 2011. This increase of revenue occurred in 2 years and was a result of the increase in the amount of steam sold. From October 2012, the incinerator started to supply high-pressure steam in addition to the medium-pressure steam. This added another revenue stream for Ulsan City.

In 2012, Hyosung saved a total of 3.7 billion KRW ($3.7 million) in fuel costs by switching its fuel from FFs to steam (table 2). Before the project, fuel costs comprised 36% of total operating costs in the second plant, but this portion decreased to 33% through steam sharing. The percentage reduction was more significant in the third plant (21% to 15%), which has a different cost structure. In addition to 3.7 billion KRW of savings in fuel costs, there was an additional cost saving from shutting down a boiler at the second plant. In the same year, associated savings from the boiler shutdown was estimated to be 479 million KRW ($479,000), which included savings on

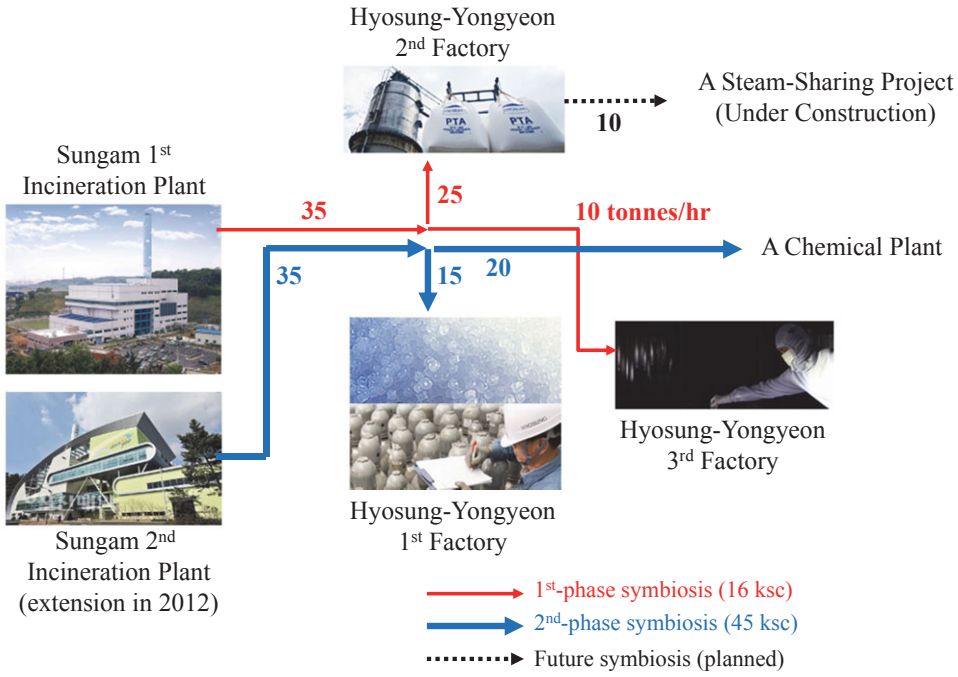

Figure 1 Map showing steam flows among Sungam's two incineration plants and Hyosung's three factories. The red thin and blue thick lines represent the steam flows in the first phase (steam pressure: 16 kilogram-force per square centimeter [ksc]) and second phase of the symbiosis project (steam pressure: 45 ksc), respectively. The dotted line represents the planned steam flow.

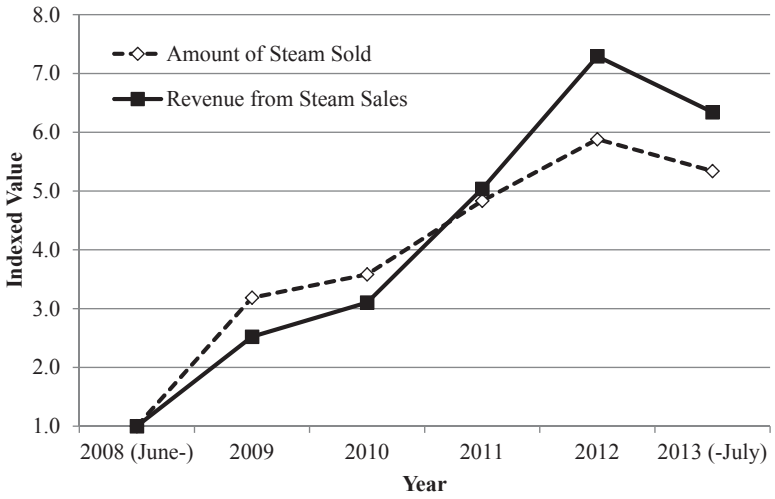

Figure 2 Amount of steam sold and the revenue from steam sales, indexed to the values of 2008, between June 2008 and July 2013.

secondary fuel costs, operational costs, labor costs, chemical costs, air pollution control equipment maintenance costs, monitoring costs, and compliance costs.

The reduction in fuel consumption was more than 18,850 t per year and this translates into emission reductions of 45,500 t of CO_2 and 427 t of SO_2 per year (KICOX 2013). If greenhouse gas reduction certification (Korea Certified Emission Reductions) is obtained under the auspices of the Ministry of Knowledge Economy, its value is equivalent to 275 million KRW ($275,000).

In addition to these direct economic and environmental benefits, the project engendered indirect positive impacts in several different ways. Construction of Hyosung's third plant was an opportunity that grew out of the first-phase symbiosis project. Hyosung selected Ulsan as the final site for its TAC film plant mainly because of the lower energy costs. Without the steam network, Ulsan may not have been able to attract the facility, which drew in new investments of 150 billion KRW ($150 million) and 140 jobs. Additionally, the construction of pipelines drew in investments of 5 billion KRW

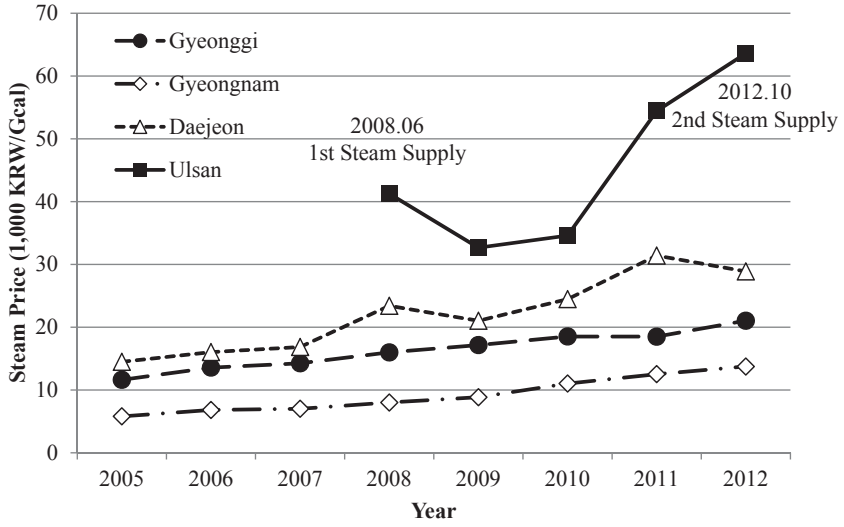

Figure 3 Unit price of steam sold from incinerators in four selected cities and provinces of Korea between 2005 and 2012 (unit: 1,000 Korean won per gigacalorie [KRW/Gcal]). The steam price data in the rest of the cities and provinces were omitted from the graph because the patterns and the levels of price were similar with data shown above, or the price was zero. The steam prices in Chungnam and Busan were in a similar range with those of Daejeon. Daegu, Seoul, and Incheon had similar patterns and ranges of steam price with Gyeonggi. Data were obtained from the Ministry of Environment (Korean Ministry of Environment 2005–2012).

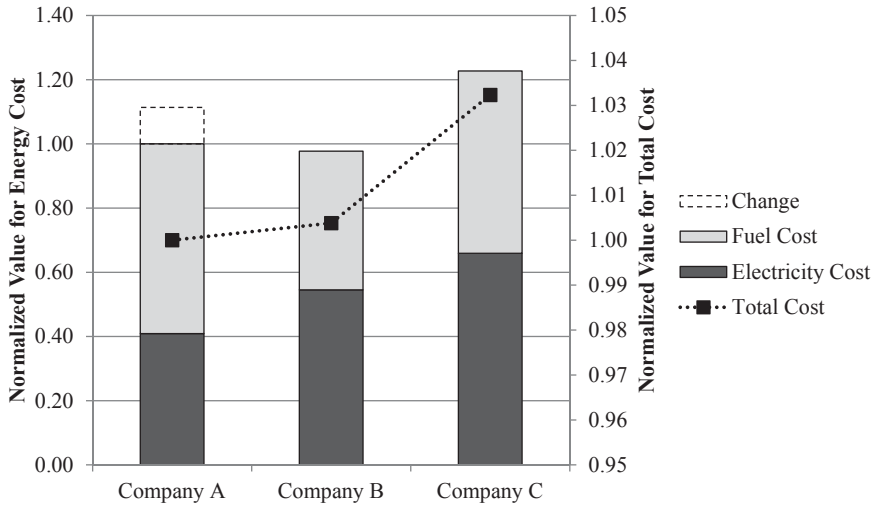

Figure 4 Comparison of energy cost (bar graphs, readings on the left axis) and total cost (line graph, readings on the right axis) in 2012 among three domestic companies in the terephthalic acid (TPA) chemical sector. All values were normalized with the after-project value of company A, which represents Hyosung's second plant. Before the project, the fuel cost of company A was higher by the amount of the white portion with the dotted line.

($5 million) from the ESCO fund and created 140 jobs. The redesign of a boiler at Sungam's second plant for steam sharing led to the abandonment of the original plan to install a generator, which reduced the original budget by 10 billion KRW ($10 million).

Further, as the first successful EIP project in Ulsan, it created momentum for further EIP projects. After successful implementation of the first-phase IS project, the local government and industries in the area were convinced that IS worked and became more supportive of further projects. Also, through this project, a systematic strategy based on the Research and Development into Business (R&DB) framework and Public-Private Partnership was developed by the Ulsan EIP and applied to subsequent EIP projects (Behera et al. 2012).

Competitive Advantage Obtained from the Project

The symbiosis project may have an indirect influence on the competitive advantage of a city by improving the quality

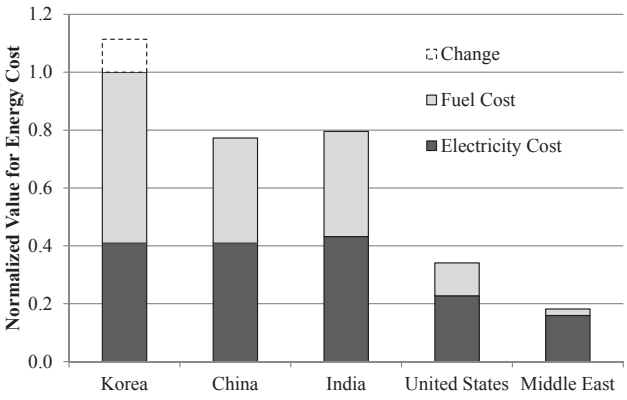

Figure 5 Comparison of energy costs in 2012, which were normalized based on the energy cost in Korea (Hyosung's second plant), for the terephthalic acid (TPA) chemical industry in Korea, China, India, the United States, and the Middle East. Before the project, the fuel cost of Korea was higher by the amount of the white portion with the dotted line.

of life for its residents. The first part of this section particularly focuses on analyzing how enhanced economic performance of Sungam, the only city-owned incinerator, benefited city residents in Ulsan compared to other cities. To contextualize the performance of Sungam, its steam prices between 2005 and 2012 were compared with steam prices of other incinerators in selected cities and provinces of Korea (figure 3). The steam price was selected as a basis of comparison because it is an indicator for sales revenue normalized with steam sold in calorific value.

Since the beginning of steam supply in June 2008, Ulsan has sold its steam at the highest range of prices, compared to all 16 cities and provinces of Korea (not all data were shown). This was possible because Sungam incinerator in Ulsan supplied a higher quality of steam, which replaced high-quality, more-expensive fuels, such as low-sulfur fuel oil. As a national industrial cluster, Ulsan has imposed stricter requirements on the type of fuels that can be used in the area. On the contrary, many incinerators in other regions of Korea provide steam at a lower rate for community district heating. In general, district heating is used as an effective strategy to locate incinerators in the city overcoming not-in-my-backyard issues. Also, the steam price in Ulsan increased more rapidly than in any other regions between 2010 and 2012, mostly because of the increase in fuel price. Between 2008 and 2010, the price was either decreased or stagnant probably because of the changes made in the revenue-sharing ratio between Ulsan and Hyosung. Throughout the steam-sharing project, the allocation of total revenue between two parties was adjusted according to market situation. From November 2012, the price increase was mainly a result of the supply of higher-quality (high-pressure) steam.

With the increased revenue, Ulsan could freeze the tipping fee, whereas the tipping fee at many other public WTE incinerators increases in general according to the inflation in consumer prices (Song 2013). No or little increase in the tipping fee at Ulsan made the fee close or lower to the average level in Korea. This, in turn, benefited residents through tax savings.

Energy costs comprised approximately 56% and 34% of total operating cost in Hyosung's second and third plants, respectively. Between fuel and electricity, Hyosung has a particularly larger share of fuel costs, compared to two domestic competitors, as shown in figure 4. Before the symbiosis project, their total energy cost was the second highest among three TPA plants in Korea, but steam sharing lowered their total energy cost to a level comparable to the lowest one. In terms of total manufacturing cost, Hyosung obtained a competitive advantage over other domestic competitors through steam sharing. However, when compared to the energy cost of TPA production in China, India, the United States, and the Middle East, energy costs in Korea are considerably higher (figure 5). This is mainly because of the difference in energy prices. As of 2012, the price of LNG in Korea was $982 per million t, which is ten times higher than the price in the United States ($98/million t). As a result of the high energy price, the reduction in fuel costs through steam sharing did not have a significant impact on the competitive advantage in the international market.

Fuel cost reductions did not lead to a change in the product price. Instead, the initial steam sharing opened up an opportunity for further cost reductions, which enabled Hyosung to invest in the construction of an additional production facility. Without the steam-sharing opportunity in Ulsan, the new film facility may have been built in another region that may rely on costly energy sources, such as imported heavy fuel oil with low sulfur content. With the increase in production lines using steam as an energy source, Hyosung could increase their sales revenue as well (figure 6).

Lessons Learned and Future Applications

Recovering heat from a WTE incinerator is not a new idea, but this opportunity has not been widely used to establish a business model that generates a value-added revenue stream. At least in Korea, energy recovery is commonly practiced, but in many cases, this does not lead to the generation of financial benefits. The case study presented in this article shows that an IS that couples an energy facility to an industrial facility through steam sharing can be a viable business model not only for the incinerator, but also for the partnering business. The revenue generated or cost saved through the steam-sharing symbiosis, in turn, has an indirect influence on the competitive advantage of participating entities. Ulsan did not need to increase the tipping fee as usually done in other cities. Hyosung could reduce total costs to the lowest level in the domestic market and built an additional facility to further benefit from steam use.

The case study showed how the successful implementation of the initial steam-sharing led to the development of the second steam-sharing project. Participating firms learned from the process and explored more opportunities. The steam-sharing

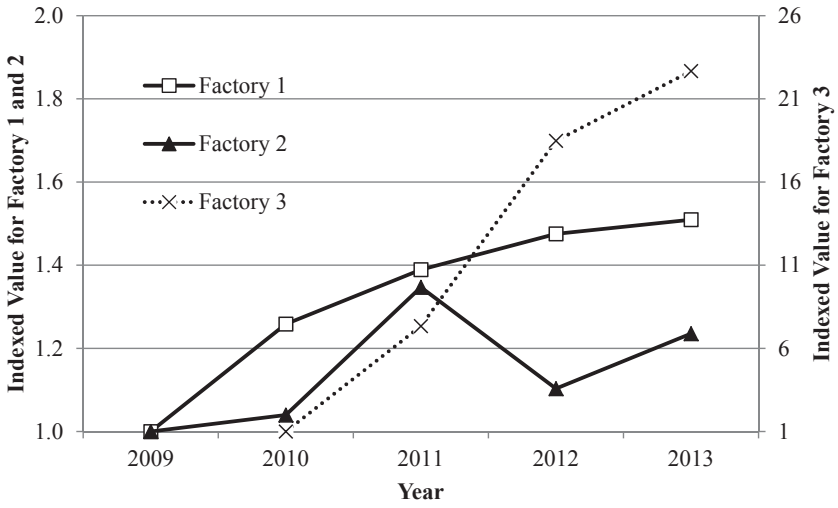

Figure 6 Sales revenue at Hyosung's three factories (Factory 1, 2, and 3) between 2009 and 2013. Sales revenue at Factories 1 and 2 (solid line graph, readings on the left axis) was indexed to their own sales revenue in 2009, whereas sales revenue at Factory 3 (dotted line graph, readings on the right axis) was indexed to its sales revenue in 2010, the year when it started operation.

network is still evolving as Hyosung plans to explore and sell more steam and more firms in the region are participating in the development. The energy coupling practice has also begun to spread to other regions in Korea, such as Chungbuk and Gyeongbuk. This type of energy sharing is applicable to any industry with the capacity to generate or use energy, but technical, economic, social, and institutional factors that may hinder implementation need to be addressed. In the case of Ulsan, the coordinating activities of Ulsan EIP center and its R&DB approach were effective to address potential barriers.

Acknowledgments

This project and research was supported by the program for the construction of EIP, which was implemented by the Korea Industrial Complex Corporation (KICOX) and the Ministry of Trade, Industry, and Energy (MOTIE). The authors have no conflict of interest to declare.

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