Determinant factors of industrial symbiosis: greening Pasir Gudang industrial park

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Abstract. Green industry has been identified as an important element in attaining greater sustainability. It calls for harmonizing robust economic growth with environment protection. Industries, particularly in developing and transitional nations such as Malaysia, are in need of a reform. Many experts and international organizations suggest the concept of industrial symbiosis. Mainly, there are successful cases of industrial symbiosis practices around the world. However, there are numerous cases of failure too. As industrial symbiosis is an emerging new approach, with a short history of two decades, a lot of researches are generally focused on narrow context and technical details. There is a lack of concerted efforts to look into the drivers and barriers of industrial symbiosis across different cases. This paper aims to examine the factors influencing the development of industrial symbiosis from various countries to supports such networks to evolve in Pasir Gudang. The findings show institution, law and regulation, finance, awareness and capacity building, technology, research and development, information, collaboration, market, geography proximity, environmental issues and industry structure affect the formation of industrial symbiosis.

1. Introduction

Manufacturing industry plays a vital role in economic growth and social development [1]. This sector contributes a significant portion to the national gross domestic product (GDP) and job creation. In year 2009, industry sector represents 25% of Malaysia's GDP, second largest contributor after service sector [2]. It has engaged 1,693,154 million employees [3]. The percentage of GDP contribution from industry sector is expected to remain around 25% in year 2020 [2]. Industrialisation accelerates development and raises the income of communities, enhancing their living standard. On the other hand, rapid industry expansions applied great pressure on environment as well. They consume vast natural resources and generate large volume of wastes. Deforestation for raw material extraction, air and water pollution, hazardous substance, solid waste and greenhouse gases emission from industry bring negative impacts to environment and harms the communities [1]. As sustainable development and climate change has become the prominent agenda for Malaysia, greening the existing industry sector to decouple business growth and environment protection is necessary.

Pasir Gudang, one of the largest industrial and manufacturing hubs in southern region of Peninsular Malaysia, is essential for the green industry transformation. To date, Pasir Gudang is the key flagship development of Iskandar Malaysia, envisions being sustainable metropolis with international standing in 2025 [4]. The concept of industrial symbiosis is embraced by experts in the efforts of green industry. [5] identifies industrial symbiosis as an excellent example of innovation idea for future green growth. Thus, industrial symbiosis will be one of the possible answers for Pasir Gudang to promote green industry. In response to the application of industrial symbiosis to promote green industry in Pasir Gudang, this paper reviews the factors that affect the development industrial symbiosis.

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Hopefully this paper could draw a new paradigm to move Pasir Gudang a step forward, closer to being a green industrial park.

2. An Overview on Industrial Symbiosis

Industrial symbiosis is similar to the concept of eco-industrial park in United States [6] and eco-town in Japan [7]. The terminology of symbiosis from industrial symbiosis is taken from the notions of biological symbiotic relationships in nature where at least two otherwise unrelated species exchange materials, energy, or information in a mutually beneficial manner [8]. In the application in industry system, it involves engagement of traditionally separate industries in a collective approach to gain competitive advantage through the physical exchange of materials, energy, water, by-products and shared use of utility [7-9]. Industrial symbiosis forms collaborative set of connections among the industry enterprises in benefiting each other via by-product exchange and utility sharing (Figure 1). As a group, these industries generate greater benefits than the sum of individual benefits that could achieved by acting alone [8]. Waste material of one industry becomes precious raw resource to another, it minimises waste generation and achieving higher resource efficiency. Besides, this is an attractive economic benefit for industries. New revenue is generated as the residue is sold to another industry and the elimination of residue helps the industry to reduce the cost for environment compliance - waste disposal and treatment. In addition, new industries are established to turn the waste in valuable resource and product. Industrial symbiosis is thereby reduce waste to landfill, carbon footprint and commercial risk, conserve resource, improves revenue, profitability, business expansion and employment and hence delivers sustainable green growth.

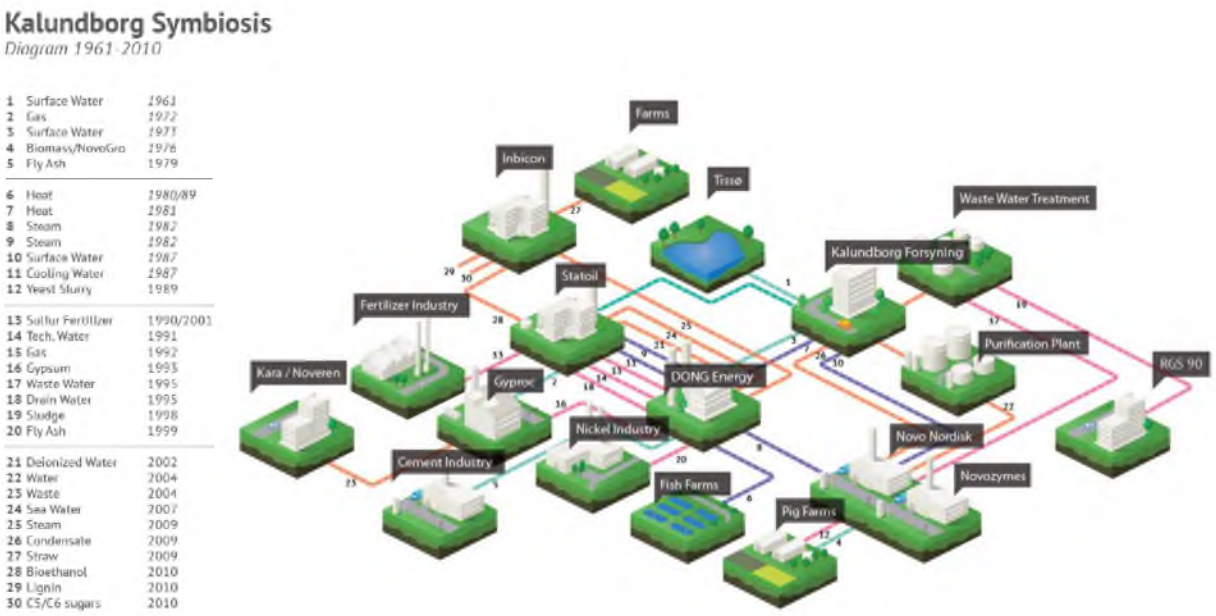

Figure 1. A network of industry synergies: flow of materials, energy, and water and by-products exchange in Kalunborg, Denmark. (Source: [11])

3. Determinant Factors of Industrial Symbiosis

There is a complex relationship of factors to inspire the formation of the industrial symbiosis. There are reviews from various industrial symbiosis papers across the practices from Denmark [12], Japan [7,13], United Kingdom [14], United States [15] and Australia [16]. There are as much as twelve crucial factors to be considered in ensuring the success of industrial symbiosis (Table 1). These factors consist of: (i) institution, (ii) law and regulation, (iii) finance, (iv) awareness and capacity building, (v) technology, (vi) research and development, (vii) information, (iix) collaboration, (ix) market, (x) geography proximity, (xi) environment issues and (xii) industry structure. These factors will be further discussed in the sub-sections below.

3.1. Institution

Government may not be the initiator to industry symbiosis, as the synergies are driven by the industries. Yet, they are imperative in creating an enabling environment to promote industrial symbiosis. A strong commitment of effective and coordinated government institutions (from all levels and across relevant sectors) to support the industrial symbiosis in various means is necessary [1]. Designing clear policy and setting up comprehensive environment law and regulation with sound implementation, monitoring and enforcement to increase environment compliance cost, create market for green products and make certain on adequate waste supply will push/ pull industries to exchange by-products and utility sharing [7,13,14]. The introduction of suitable financial instruments by government will hasten the diffusion of environment technology into industries. Public education and industry training about the importance environment and industrial symbiosis should also be provided. Also to be taken into consideration by the government bodies are: creating strong networks with industries and engaging them to apply industrial symbiosis; provide strong support to local champions (industry, academia, non-governmental organizations) in the field industrial symbiosis; as well as offer flexible approval on the infrastructure and utilities (E.g. pipeline) construction to encourage the synergies among the industries [12,16].

3.2. Law and Regulation

Environment laws and regulations can be introduced to encourage industry to adopt environmental technology and form symbiotic linkages. For example, Japanese Basic Law for Establishing the Sound Material Cycle Society consisting of various recycling laws and green purchasing law allows adequate supply of waste and good market for industry [13]. Industrial symbiosis became more economically feasible under the law. Avoid prescriptive waste regulations that specify treatment methodology since these restricts development of potential alternative applications for waste [12,14]. In addition, creating relevant taxes, fees and levies are important too. Landfill tax and climate change levy in United Kingdom promote industry to reduce the waste stream by diverting them to another industry and energy co-generation [14]. Environment taxes on certain raw resources foster the development of synergies to consume fewer raw materials [12]. Environmentally harmful subsidies which encourage the growth of irreplaceable utility resources (fossil fuel, energy, and water) should be removed as these weaken the industry's willingness to practice reuse, recycling and sharing [11].

3.3. Finance

The creation of synergy between industries requires new equipment, material flow studies and social interaction platform to enable the by-products exchange [7,13,14]. Installation of new equipment associates with high capital of investment especially for Small and Medium Enterprises (SMEs) [1]. Lack of financial capital often leads to SMEs being risk-averse and reluctant to invest in new equipment. Thus, financial aids in the form of subsidies and low interest loan with long term payback period for industry to access the new equipment are vital. Funding the local institutions to carry material flow studies for resource mapping is important for identifying potential symbiosis. Financial supports for social interaction platforms in public consultation allow business owners to be engaged and to be matched with the right partnership of industries in symbiosis. Last but not least, providing research grants for research and development in technology development and information management will facilitate the future expansion of industry symbiosis.

3.4. Awareness and Capacity Building

Enhancing the awareness level of local communities and industries about the importance of environment and resource conservation is crucial. High level of environment awareness will motivate them to practice recycling and buying green products (products made from waste). This will have a positive impact on waste supply and market of green products. It ensures that industrial symbiosis will happen. Disseminating and demonstrating the economic and environment benefits of industrial symbiosis and their success techniques (e.g. waste recycling, reusing wastewater and energy cogeneration) among industries can spark their interest to actively participate in material exchange. More to the point, development of symbiotic linkages involves adoption of new equipment and

alteration in production process. Therefore, training programmes are needed for industries to improve technical capacity (know-how knowledge to operate the equipment, processes, and maintenance) on their employees.

3.5. Technology

Replacement of out of date technology with more relevant environment technology is essential for by-products exchange to take place in industries. By adopting environment technology, industries are capable to turn waste into resources and productions of green products from waste material. Moreover, development of industrial symbiosis has need of various tools (industrial inventories, material flow analysis, life cycle assessment, input/output matching, and geography information system) to analyse, map and manage useful information in identifying the resources and potential synergies opportunities for more efficient resource use. As these new technologies are expensive and run by applying special technical skills, the availability of financial and human capital is pivotal.

3.6. Research and Development

Research and innovation bring new technology breakthrough helping in diversifying the synergies and green products. Encouraging technology developments allow greater number of types of waste that can be applied for substituting raw materials. Promoting creative green product design helps produce more variety of green products, relatively cheap in price and easy to reuse and recycling. Inventions of commercial viable technology with low capital and maintenance cost and easy in operation will boost up the attention to business and more adaptation to industry. Nurturing research and development requires huge capital investment and knowledge capacity. In this regard, many writers suggest the providence of research grants/ subsidies from government and strong links between industry and universities/ research institution.

3.7. Information

Information (type and quantity of raw material input and type and quantity of waste output) from the industry enterprises is important for the operation of industrial symbiosis. Disclosing of such reliable information allows better decisions and synergies. With good information, it raises confident level of industry to willingly conduct by-product exchange with another industry. The accessibility of this information is influence by strength of connections between these industries. Strong collaborations should be encouraged to build trust and eliminate unnecessary confidentiality, easing the access to information.

3.8. Collaboration

As industrial symbiosis involves group industries to exchange by-products and sharing utility, industries collaborations is the key. Social platforms (e.g. environment/ industry club/ association) that engage different industries to come together to share the common understanding and build networks with each other are important. To promote the industrial symbiosis, it is important for institution or external agencies (e.g. industrial symbiosis institute/ eco-town centre/ universities) to link with the social platform of industry to establish a good relationship and building trust with one another for easier information exchange and development of synergies. Holding periodical stakeholder discussions/ public dialogue with industries promotes industrial symbiosis and facilitates match making. This will help to cultivate their interest and willingness to actively participant in potential synergies. However, building strong social cohesion between industries and among industries would take time.

3.9. Market

Demand of green products from market serves as the pull factor to the development of industrial symbiosis. Public awareness and green procurement are important to stimulate the market of green products. As public become more aware of the importance between environment quality and the products they use daily, consumers of green products will increase. Besides, introduction of green procurement that promotes public and private sectors to purchase certain amount of green products will also boost the market. With the continuous strong demand of green products, it creates powerful interest for industries to practice waste recycling and reuse to capture more business profit.

3.10. Geography Proximity
Distance between collaborating industries affects the viability of symbiotic exchange. The shorter distance will be favourable as it involves low transportation costs. The synergy of energy (e.g. steam) is limited by distance to prevent energy degradation. Pipeline infrastructure for steam to convey from one industry to another is expensive, the longer the pipeline the higher the expenditure. The relationship between synergy and geography proximity varies by the nature and value of material/ by-products [12]. Only by-products of physical form and of high value should be considered for transportation over large distance.

3.11. Environment Issues
The negative consequences from the industrial development create eagerness and momentum for government, industry and public to recycling and recover the industrial waste for environment protection. Serious air and water pollution with shortage of landfill space issue has driven Japanese government to initiate eco-towns in various industry areas of Japan [7,13]. Besides, pollution issues raised environment awareness of public that voluntarily applied pressure to the Japanese government and industry for strong measures and efforts [13]. Scarcity of resources in Kalunborg, Denmark force industry to try alternative solution by using the by-products from other industry as replacement for virgin material.

3.12. Industry Structure
Diversity of industries influences the number and complexity of synergies. This phenomenon affects the authenticity of industrial symbiosis within a define industrial park. [12] reveals that thematic industrial parks (e.g. petrochemical cluster) are found to be in high degree of competition, creating barriers to the synergies. The great variety of synergies is believed to be due to a large and diverse blend of manufacturing industries [12]. Besides, involvement of anchor tenants in industrial symbiosis in crucial. Anchor tenants are the main industries (with large scale of capital and volume of material flows) in the industrial parks which possess great opportunities for synergies with other industries.

4. The Way Forward
In the efforts of investigating into the factors of industrial symbiosis for promoting the material exchange synergies in Pasir Gudang, twelve factors (institution, law and regulation, finance, awareness and capacity building, technology, research and development, information, collaboration, market, geography proximity, environment issues, and industrial structure) have been identified. Each of these factors contributes differently in the formation of industrial symbiosis. However, some of these factors are found to be inter-related to others (e.g. finance vs. technology, awareness and capacity building vs. market and collaboration vs. information).

Last, it is interesting to understand that they are diverse types of industrial symbiosis model. Categorized spatially, industrial symbiosis can exist among the firms in a define industrial park or among firms organized 'virtually' across the broader region. By implementation, it can be a bottom-up approach (self-organising symbiosis - initiated by local industries) or top-bottom approach (planned symbiosis – initiate by government) [10]. It is believed that different types of industrial symbiosis model will be affected by a different set of factors accordingly. Unresolved question is: What type of factors are needed to for these different industrial symbiosis models in respectively? To further understand these complex relationships, additional research work is needed.

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