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EVALUATION OF ECO-INDUSTRIAL PARK AS SOCIETAL DEMONSTRATION SITE IN JAPAN

Noboru Yoshida[1]
Tohru Morioka[2]
Hiroyuki Fujimura[3]
Masao Takebayashi[4]

Abstract

In the present research, a strategically combined input/output system is examined in an eco-industrial park (EIP) in Japan where associated societal experiments for recycle-oriented complex had been carried out under the authors' contributions. Firstly the tentative EIP model in Fujisawa is presented with strategic plannning approach. Secondly, environmental performance is evaluated for the EIP. A life cycle inventory analysis has revealed about one fourth of the energy efficiency in the EIP compared with the conventional type. In addition, simulation analyses for the EIP, to couple conversion technologies with various matabolism areas, indicate optimum scale is influenced by the efficiency of conversion technologies and the quality of waste. Finally, incentives and barriers are discussed to implement eco-industrial park policies in Japan.

KEYWORDS: *eco-industrial park, industrial symbiosis, conversion technology*

1. Introduction

Since "Industrial ecology" was advocated as a new concept emerging in the evolution of environmental management paradigm (Ehrenfeld, 1995), and springs from interests in integrating notions of sustainability into environmental and economic systems (Allenby, 1992, et al.), various attempts have been made to implement in the world as actual and concrete systems. The evolution of interdependence among industrial sectors at Kalundborg (Ehrenfrld and Gertler, 1997) has succeeded in the exchange of wastes, by-products, and energy among closely located sectors as one of the typical examples of industrial ecology application. Communities in the U.S. have adopted the concept of "Eco-Industrial Parks (EIPs)" as a concrete term in the report of the President's Council for Sustainable Development, and the U.S. has enhanced the creation of four EIPs where the firms are closely linked through waste and energy symbioses (PCSD, 1996).

In Japan, also "Eco-Town" projects have been implemented in Kitakyushu and more than 10 cities and regions subsidized by Ministry of Economy, Trade and Industry (METI) since 1997. In a

1 Dr.Eng, Assoc. Prof., Dept. of Environmental Systems, Wakayama University, Wakayama, JAPAN.
2 Dr.Eng., Professor, Dept. of Environmental Engineering, Osaka University, Osaka, JAPAN.
3 Dr.Eng., Chairman, Ebara Corporation, Tokyo, JAPAN.
4 M. Eng., Managing Director, Ebara Corporation, Tokyo, JAPAN.

process of legislation based on extend producer responsibility, other associated projects have also launched such as "Zero-Emission Industrial Park" by Japan Environmental Corporation, "Environmentally-Harmonized Energy Community" and "Recycle-oriented Mine Park" by METI and so on. For the time being, their environmental performances have not been evaluated although the plans and schemes have variety.

Therefore in the present research, an inverse manufacturing system for industrial pumps and a strategically combined input/output system are examined in an EIP in Fujisawa, where associated societal experiments for recycle-oriented complex had been carried out under the authors' contributions. The EIP model describes collaborative actions of recycling among factories, logistics and consumers sectors, which will establish mutual system to utilize by-products derived from their partner sector as their own resources in the regional community. In this paper, in particular, environmental efficiencies associated with conversion technologies were evaluated.

2. Fujisawa Eco-Industrial Park Model

In 1996, an idea of a resident-associated eco-industrial park was given together with a renewal plan of dormitories and company houses in a firm of fluid and gas transfer systems and equipments in central west of Fujisawa city in Kanagawa.

In the EIP, annually wastes of 280 tons and 5,000 tons are generated in a residence flat and a pump factory, respectively. When considering utilization of waste converted resources between residence and factory in the eco-industrial park, the conversion technology is determined depending on the type and quality of material and energy needed between.

As shown in Figure 1, a tentative inventory analysis on life cycle energy has revealed that 26% of the energy use in conventional type is saved with installation of conversion technologies such as a gasification plant etc., even when considering additional consumption of energy in installation of the plant-associated on-site infrastructure (Morioka, 1998).

Each conversion method has its optimal scale and merit. In the EIP, a gasification plant was installed for technological certification. Therefore simulation analyses were attempted to couple each conversion technology with the gasification technology for improvement eco-efficiency in the EIP.

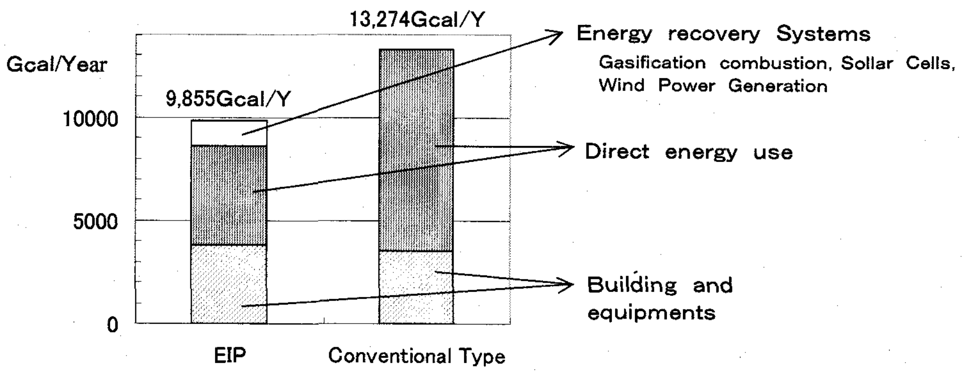

Figure 1. Life cycle energy use in residential flat in Fujisawa EIP

3. Evaluation of Environmental Performance with Gasification

In this paper, we carried out the study along the evaluation process as shown in Figure 2. Firstly we analyze material and energy flow in the EIP site and also in the neighboring district, and consequently the course of action to improve environmental efficiency is obtained. Secondly, environmental efficiencies are evaluated for various alternative actions using process functions related with conversion technologies.

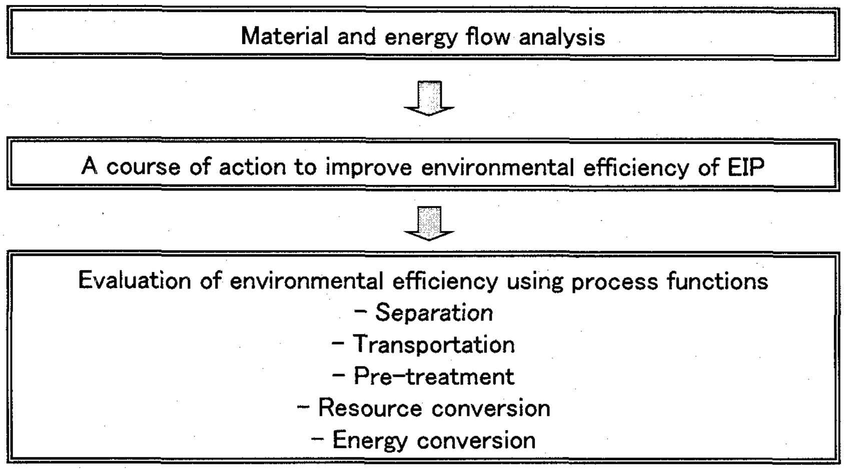

Figure 2. Evaluation process of environmental performance of the EIP.

3.1 Material and energy flow analysis inside and neighboring EIP

Fujisawa EIP is located in Fujisawa district, center of Fujisawa city as illustrated in Figure 3. Fujisawa city has various areas of housing, agriculture, commerce, factory, etc. with a population of around 370,000.

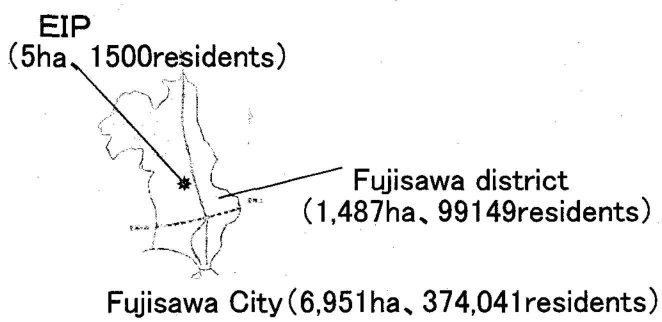

Figure 3. Location of Fujisawa EIP and Fujisawa City

Figure 4. shows material and energy flows in EIP. Energy demand for residential flats and pump factories are estimated to be about electricity of 1,560 MWh and town-gas of 170 thousand m^3, and electricity of 4,800 MWh and town-gas of 220 thousand m^3 respectively. The renovation to an "environmentally sound" factory will achieve the reduction to electricity of 3,500 MWh and town-gas of 214 thousand m^3. By-products of 280 tons is generated out of the residential field, and 40 % of the by-products is recycled. Metal scrap released amounts to 27% of whole by-products in the EIP, followed by waste paper and woods.

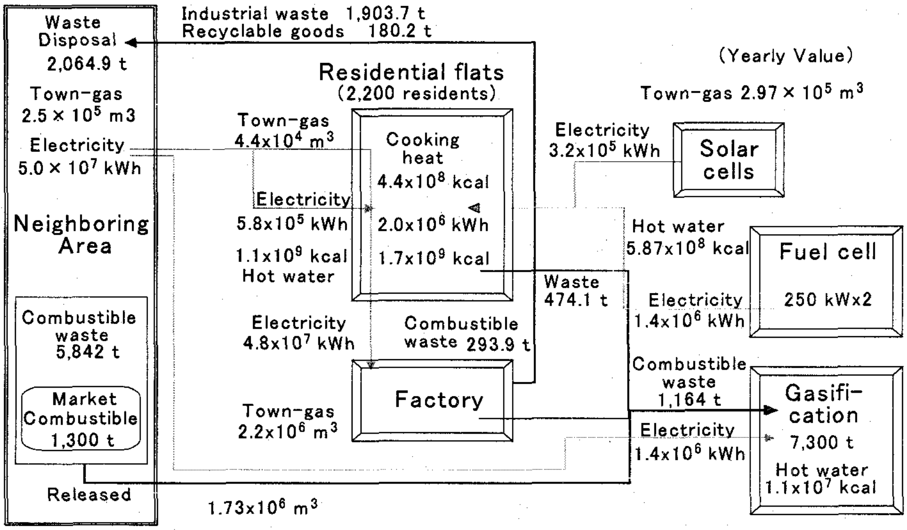

Figure 4. Material and energy flow in EIP.

Scale of the gasification demonstration plant installed in EIP is 20 tons/day. This equipment scale is not enough big for electricity generation. Although even in this case more combustible waste than that generated in EIP is collected from the neighboring area and disposed at the gasification plant, collaboration with further more waste might improve environmental efficiency depending on the scale-related effect of resource conversion. As the same as usual residential area, there are various sectors that generate combustible waste or demand for energy delivered from gasification plant around the EIP. Actually, organic and packaging waste are released from a wholesale market near the EIP, agriculture-derived plastics from farm lands, municipal combustible waste is collected in a public incineration plant 500 m far from EIP. Such situation of the waste generation will change in important to keep an eye on waste-related legislation, life style change, etc for improving efficiency and stability of metabolism in the EIP.

Subsequently, lower calorific values of various sectors' combustible wastes were compared with energy demand of the sectors in Figure 5. As a whole, the amount of energy consumption is greater than the lower calorific values of combustible wastes in all sectors. However, differences between both are gradually decreased with expansion of the area scale. This indicates improvement of the environmental efficiency to some extent with collaboration among appropriate sectors. In addition, there is much wet waste of low calorific value such as organic sludge in Fujisawa as the same as other residential area. Therefore combination of conversion technologies should be considered depending on quality and volume of the waste.

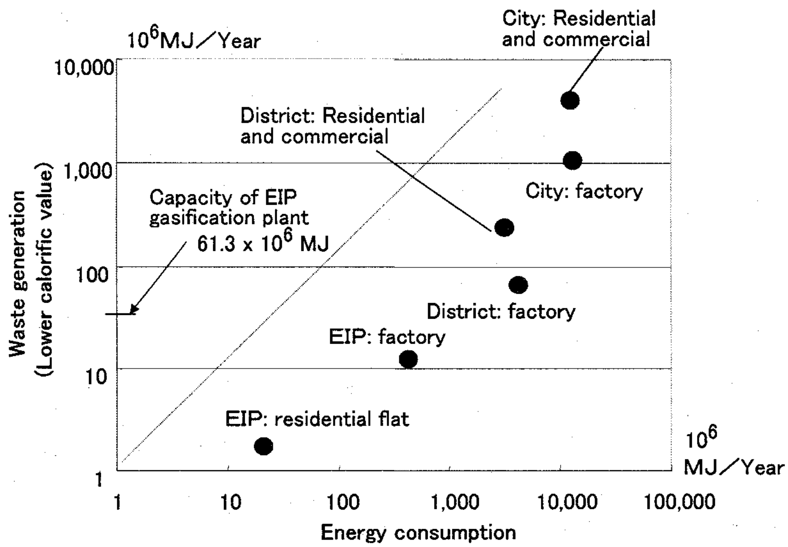

Figure 5. Balance of waste and energy consumption in calorie with expansion of the area scale

3.2 Obtaining a course of action to improve environmental efficiency

It is known that "Strategic Choice Approach (SCA)" (Friend J. and Hickling A., 1987) is used to solve ill-defined problem in a comprehensive and explicit way. In this study, we apply the similar approach to obtain a course of action to improve environmental efficiency. SCA is usually executed through shaping, designing, comparing, and choosing mode. In this study, we set up three phases, i.e. scoping, linkage analysis, and packaged options.

Based on the material flow analysis, first as illustrated in figure 6, we extracted major 6 planning elements, i.e. by-products, collection, conversion, metabolism scale, reutilization, disposal. Then each planning element was sub-divided and specified as a dot within each circle. Possible combinations of sub-divided elements were connected in lines. This kind of approach would stimulate the imagination. Sometimes new sub-divided elements can be found in this process. As a result, 3 types of planning element groups were found according to the scale of metabolism in Figure 7. Moreover several alternative packaged options were set up for evaluating environmental performance of the EIP as shown in Figure 8. In this study, we examined the case of energy recovery according to gasification, except for the other conversion such as material recovery, etc. Therefore, in the next subsection, environmental efficiency was evaluated depending on the metabolism scale.

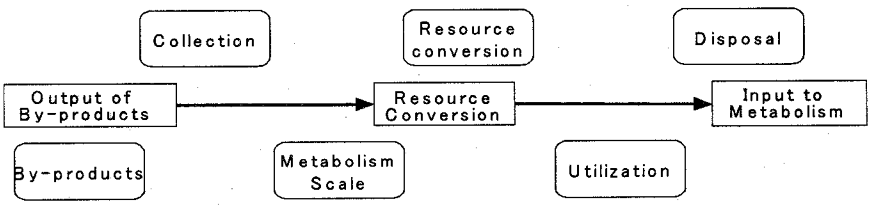

Figure 6. Extraction of major planning elements

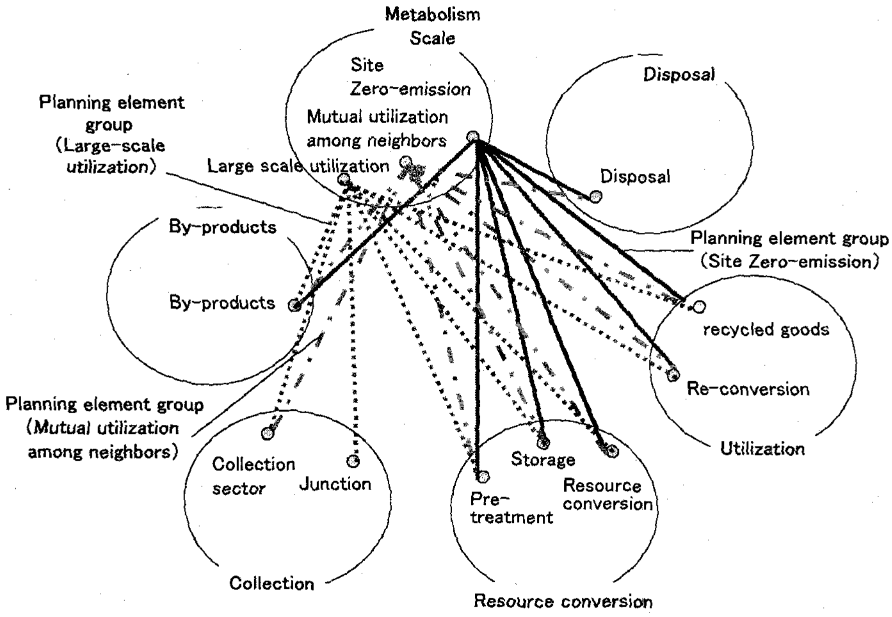

Figure 7. Linkage analysis of planning elements

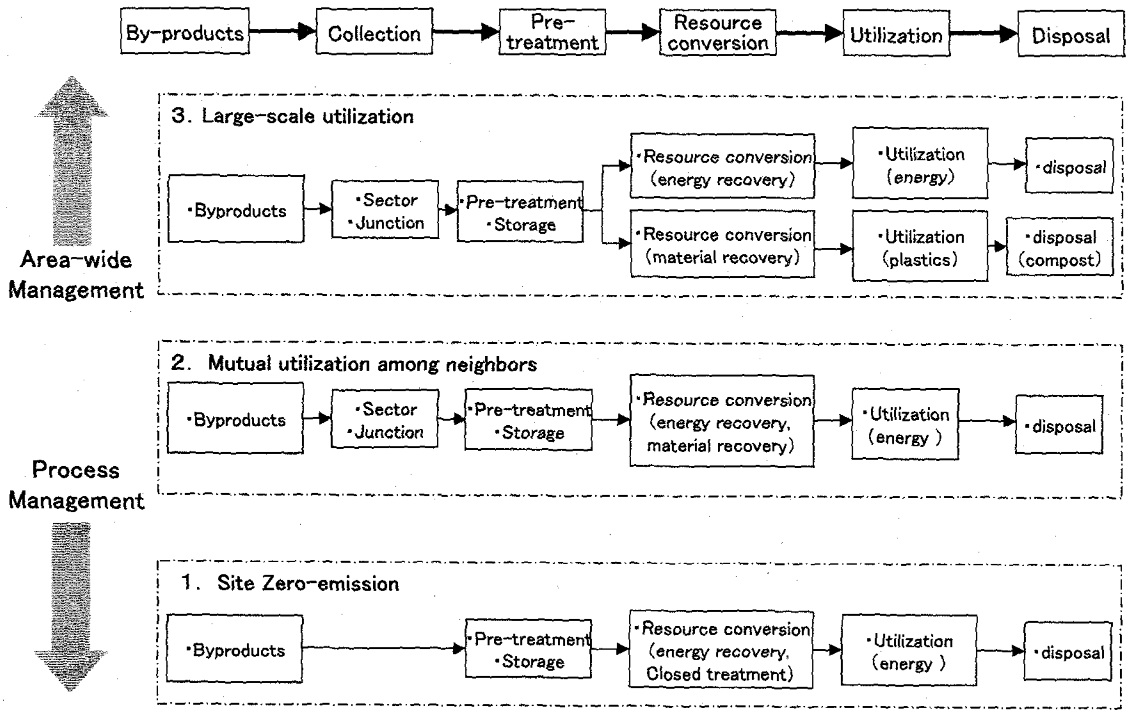

Figure 8. Extraction of packaged options

3.3 Evaluation of environmental efficiency depending on the metabolism scale

For the time being, the amount of generated by-products is comparatively less than energy demand in this kind of residential area, examined in the previous subsection 3.1. This situation seems not to be changed drastically in near future. This means that considerable amount of by-products can be utilized in this area with appropriate conversion technologies. Therefore we applied by-product oriented process function model as illustrated in figure 9. Separation function was not considered in this study due to luck of statistical data in district level, but constant ratio was applied based on statistical data in Fujisawa. Distance of transportation was calculated using grid function model (Ishikawa M., 1995). Pre-treatment was not considered in the case of gasification. As for fuel cells, carbon dioxide emission in a process of hydrogen refinery was added to the resource conversion. Non-linear curve of efficiency in energy conversion was adapted for each generation system as shown in Figure 10. Detailed coefficients were listed in Table 1. These five processes were treated independently each other and summed up in order to evaluate carbon dioxide emission.

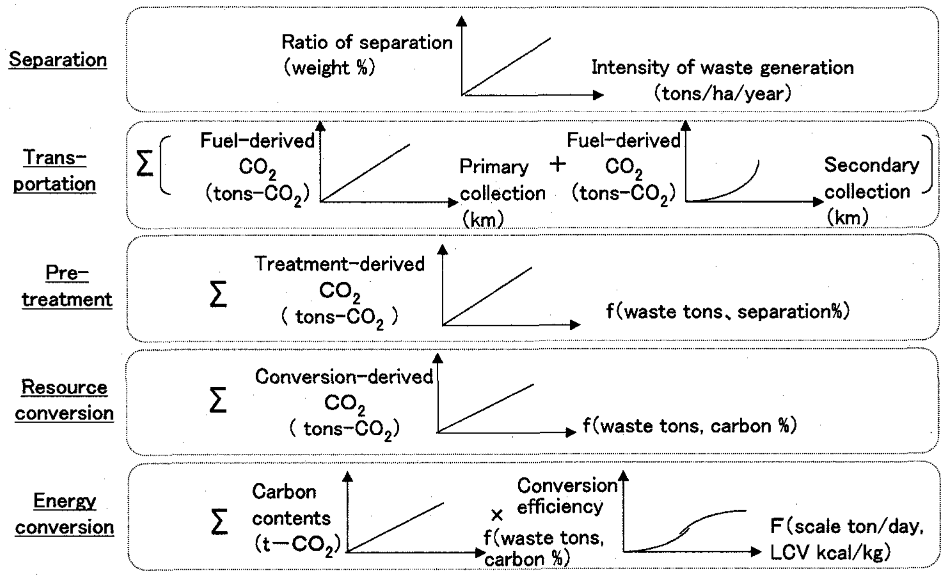

Figure 9. Structure of by-product oriented process function model

Table 1. Major coefficients of process functions

Coefficients	Value	Unit	Source
Transportation-derived CO_2	0.69	kg-CO_2 / litre (4km/litre)	(NIES, 1997)
Separation-derived CO_2	0.345	kg-CO_2/kg-waste	Interview
Combustion-derived CO_2	0.6378	kg-CO_2/kg-waste	(NIES, 1997)
Generating power (steam turbine)	Figure 10		(Ishikawa R, 1996)
Ratio of refinery-derived CO_2	0.7	–	Interview

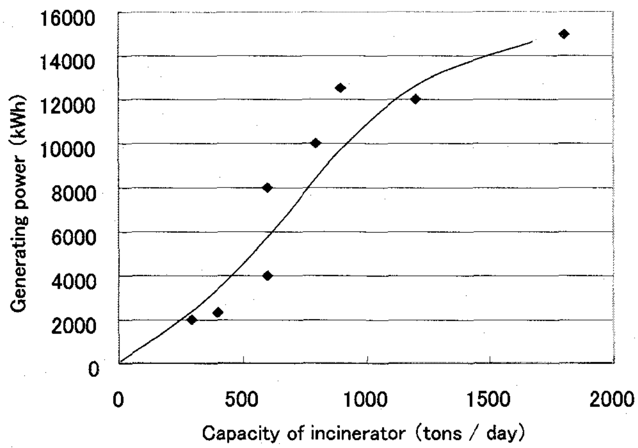

Figure 10. Generating power with scale of incinerator

In a previous research, initial installation-related environmental load is considerably small and negligible compared with the whole life cycle environmental loads except for cost problem (Ishikawa R., et al., 1999). Therefore this study focuses mainly on operation stages. Gasification is a scale-effective conversion technology that increases efficiency of gasification and electricity generation with increase of the amount of treatment capacity. On the other hand, the conversion efficiency differs with quality of by-products, especially wet conditions. Collection of wet garbage together with other dry combustible waste will decrease the conversion efficiency although environmental load related with transportation of by-products is considerably small. In this context, separation of wet and dry waste will be efficient. Therefore we compared (1) Large-sized gasification, and (2) Smaller-sized gasification with fuel cells (FC) & non-aerobic digestion as illustrated in Figure 11. The Large-sized gasification system expects improvement of electricity generation with increased volume of the waste although the average lower calorific value is decreased to some extent. As for the smaller-sized gasification system, the level of efficiency is higher than that of large-sized with comparatively smaller generating power.

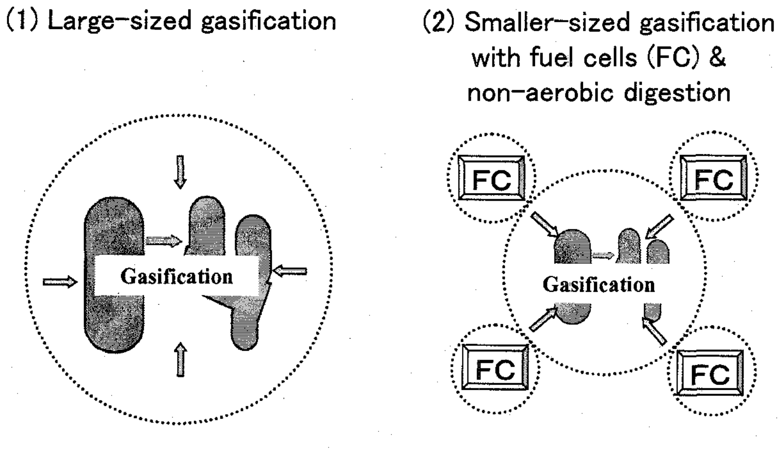

Figure 11. Alternative conversion technology systems

Figure 12 shows changes of material flow and carbon dioxide emission between conventional industrial park and EIP with gasification. In the EIP, a 20tons/day gasification plant generates hot water from combustible wastes in EIP and the neighboring sectors. This case can reduce carbon dioxide emission by 20% than the conventional type.

Subsequently, material & energy flows and carbon dioxide emission in Fujisawa city including the EIP were presented in Figure 13, with the large-sized (300tons/day) gasification. The expansion of material scale gave the reduction of 1% carbon dioxide emission despite of increased wet waste with less calorific value.

Furthermore, Figure 14 shows that smaller-sized gasification with fuel cells & non-aerobic digestion system enabled to reduce further carbon dioxide emission of 7%, followed by increased environmental efficiency of 9%. Here environmental efficiency was defined as service per environmental load, i.e. organic material consumption over carbon dioxide emission.

In the above two cases, both boundaries of the system were fixed as the whole area of Fujisawa city. Then, changes of the environmental efficiency were examined with expansion of the metabolism scale as shown in Figure 15. In the case of large-sized gasification system, and the efficiency became highest in the scale without west district because the west district had comparatively much waste of lower calorific value. The case study of small-sized gasification with fuel cells & non-aerobic digestion system indicated that environmental efficiency was higher than that of large-sized gasification system with any metabolism.

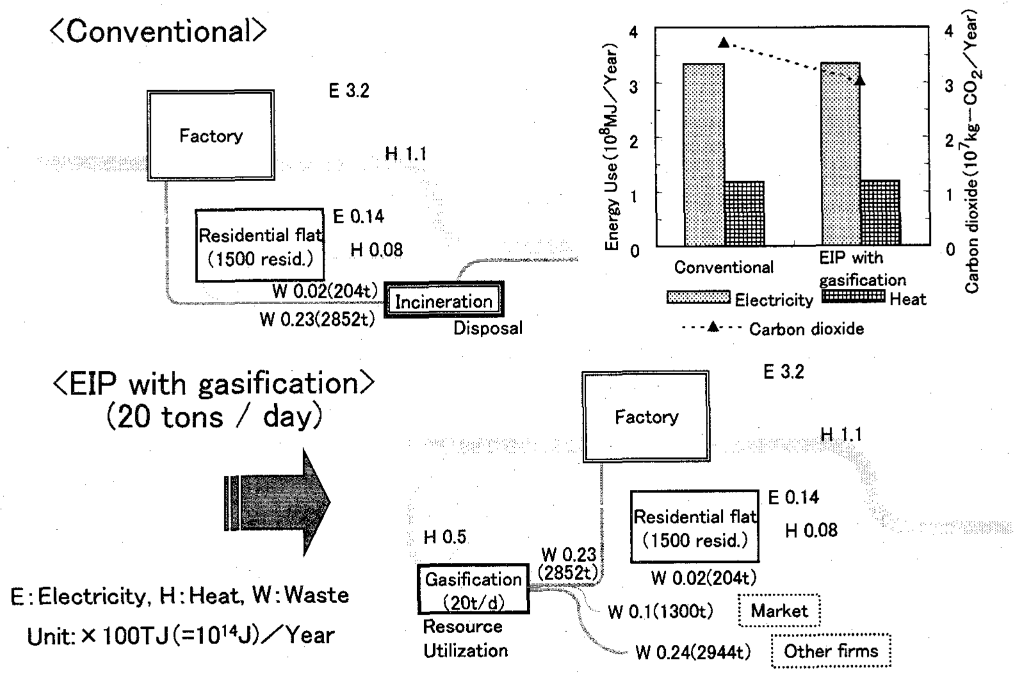

Figure 12. Environmental efficiency of EIP with gasification (20tons/day)

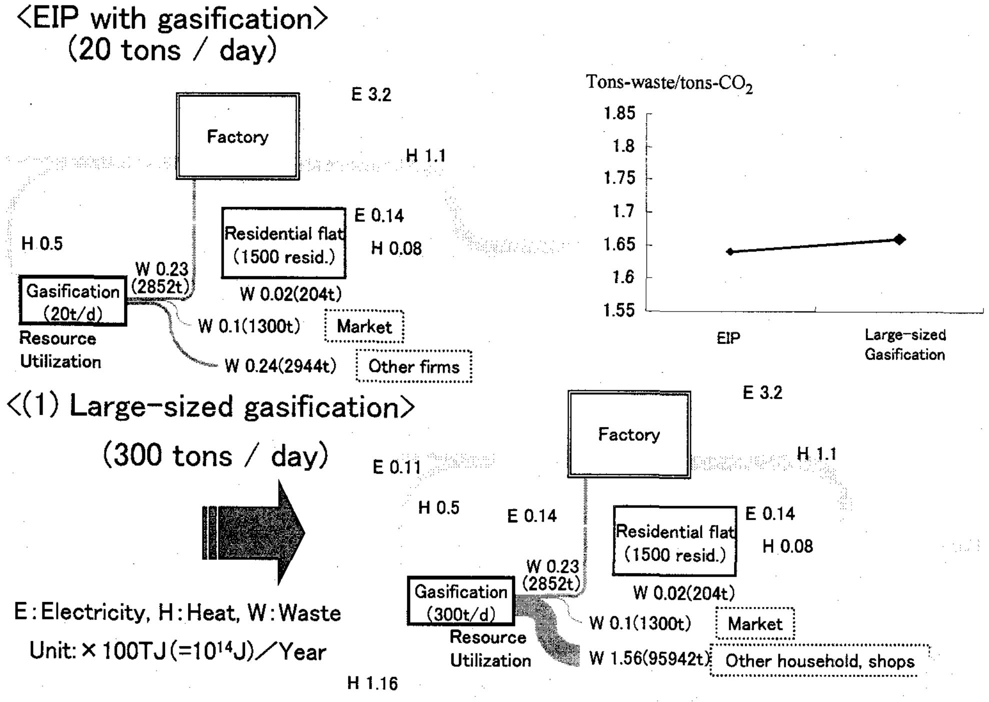

Figure 13. Environmental efficiency of Large-sized gasification (300tons/day) systems

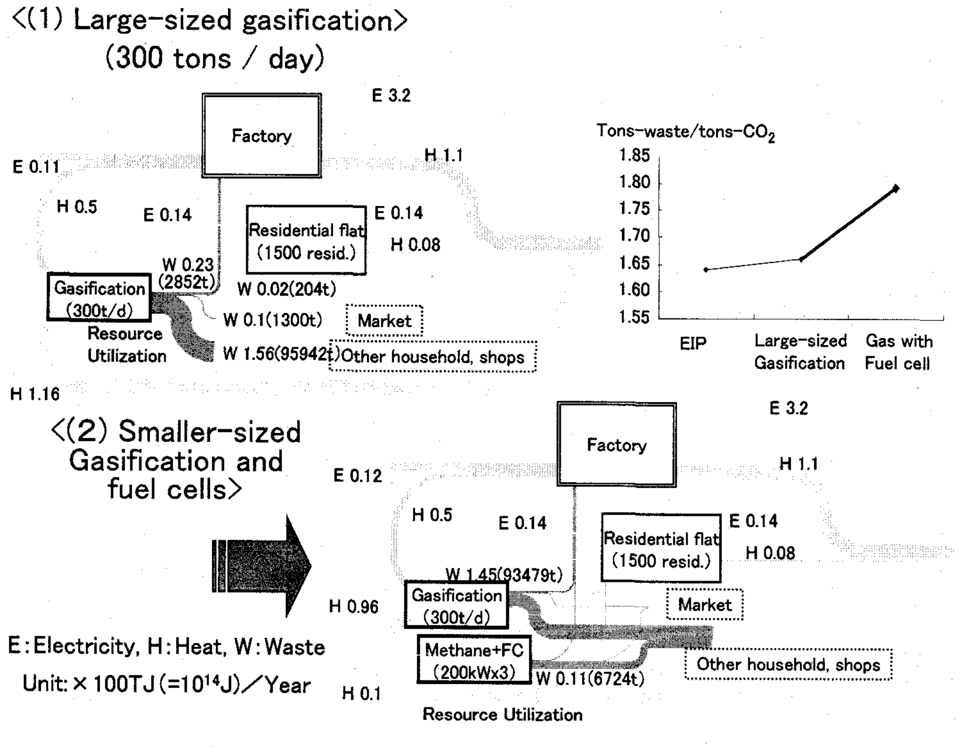

Figure 14. Environmental efficiency of Gasification and fuel cells systems

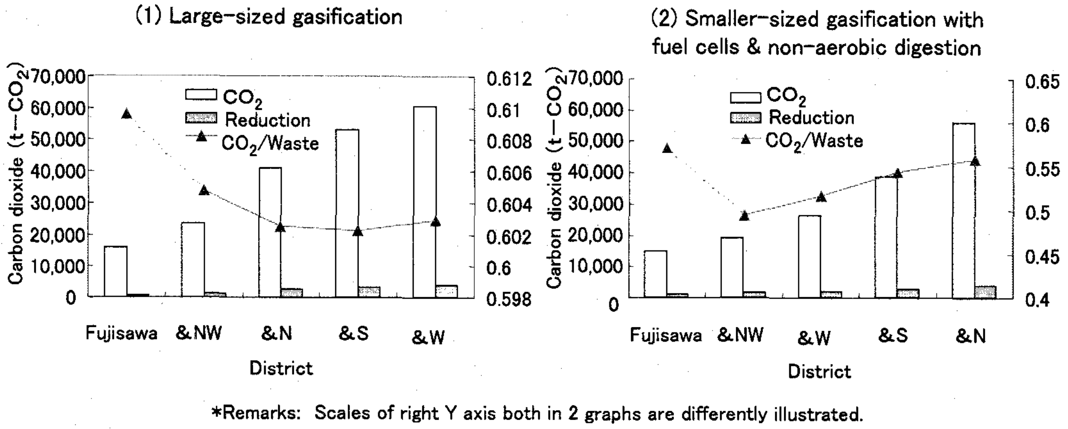

Figure 15. Environmental efficiency with expansion of the metabolism

4. Incentives and barriers in Implementation of EIP

The results of these case studies in EIP indicate that efficiency of conversion technologies give great influence on environmental performance. It is often said that renovation of conversion technologies does not advance without strong regulation or financial incentives on environmental preservation. "In terms of up-stream technologies, high value-added technologies with high return are easily traded in economic market. However it is not certainly true or applicable in the case of down-stream technologies."(Hosoda E., 1999)

This is a serious barrier against the spread or distribution of conversion technologies into the economic market. Although it is easy to emphasize that government should establish strict environmental regulations, more flexible and rather self-evolutional mechanism should be implemented as technology itself has rapidly renovated. One suggestive example of actual application can be observed in renovation of gasification technologies in a firm. In the case of renovation in a gasification technology, renovation process went ahead successfully and also effectively from financial point of view. It was owed by simultaneous renovation was applied gasification both of coal and solid waste (Oshita T., 1999). This indicates that application of existed up-stream technology to down-stream technology or mutual renovation project would reduce cost of renovation in a company.

Another discussion is about public participation or commitment on EIP. The above analysis clarified a potential for further improvement of environmental efficiency with change of sectors combination and metabolism boundaries. However in actual societal system in Japan, public participation or commitment seems not to be so flexible enough for such continuous, step-by-step development of EIP. Actually, "Eco-Town" project sectors have received subsidy for installation of conversion technology plant s etc. by government. This is a typical example of public commitment as previously applied to usual or "not eco" industrial park policies. Such a subsidiary system requires concrete specification of a set of conversion technologies. Therefore it is difficult to change the scale or type of conversion technologies followed changes of metabolism boundary under this subsidy system depending on collaboration among economic sectors and technological renovation etc. so far.

Here, we can recognize an unique attempt made by Hyogo prefecture. At present Hyogo prefecture support to create a soft infrastructure called area-wide recycling council that stimulates collaboration and communication among private sectors. This council has succeeded in incubation of several autonomous recycling complexes. Rather soft support system would be useful for the EIP schemes proposed by this recycling council, for example, de-regulation, zoning with financial incentives, etc. as the U.K. applied "enterprise zone" policy.

5. Conclusions

Simulation analyses were attempted to couple conversion technologies including gasification with metabolism areas for improvement of environmental efficiency in Eco-Industrial Park. As a result of life cycle inventory analysis, EIP with conversion technologies give reduction of 26% in primary energy consumption compared with a conventional scheme. Furthermore effects of combination of conversion technologies and boundary scale on environmental efficiency were examined. As a result, the combination of small-sized gasification and fuel cells with non-aerobic digestion gave great reduction of 9% carbon dioxide compared with large-sized gasification. Regarding metabolism boundary, the efficiency became highest in the scale without west district in the case of large-sized gasification. Finally, incentives and barriers were discussed for implementation of EIP policy.

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