Michikazu Kojima, “Toward Regional Cooperation of Local Governments in ASEAN”, ERIA Collaborative/Support Research Report, IDE-JETRO, 2019

Chapter 2
Effectiveness and Challenges in Regional Waste Management in Japan

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Abstract

This paper examines the effectiveness and challenges in the regional waste management in Japan. Many studies show economies of scale in collection and disposal of municipal solid waste as a factor of effectiveness. This study conducts a simple econometric analysis to show economies of scale in setting up incinerators and the optimal incineration size. In contrast, one of the main challenges is the increase in transport costs and CO_2 emissions due to increase in transport distance. However, this issue can be solved by setting up transfer stations. Another challenge, which is more difficult to solve, is the NIMBY (not in my backyard) syndrome for setting up waste disposal facilities. This paper also discusses some possible countermeasures for NIMBY in regional waste management. The study suggests some hints for introduction of regional waste management in Southeast Asia.

Keywords: regional waste management, economies of scale, NIMBY, incinerator, waste-to-energy

1. Introduction

According to the summary report of United Nations Environment Program, waste generation is expected to continue to increase in Southeast Asia (UNEP 2017). The report further states that the municipal solid waste (MSW) generated in the ASEAN countries is composed mainly of organic waste, plastic, and paper. Although most of these are recyclable, the recycling rate is estimated to be less than 50% (UNEP 2017). While most ASEAN countries have set up sanitary landfills, open dumping and open burning are still practiced. Composting and incineration are still not commonly practiced in the Southeast Asian countries, while energy demand has grown by 60 % over the last 15 years and is expected to increase in the ASEAN countries (IEA 2017). I propose that using incinerators with energy recovery (waste-to-energy plants) can solve the problems of increase in waste and energy demand. Additionally, wide-area waste management in municipal areas, that is, regional waste management, can be effective in efficient energy recovery in the incinerators.

This paper examines the effectiveness and challenges in the regional waste management in Japan. Regional waste management was originally suggested for the reduction of dioxin emissions from waste incinerators in Japan. Large quantities of dioxins were generated from incinerators in the middle of the 1990s. The erstwhile Ministry of Health and Welfare in Japan had announced the basic guidelines for dioxin control in 1997 (Ministry of Health and Welfare 1999). The government later enacted a law on special measures against dioxins in 1999 to prevent environmental pollution by dioxins. It was found that 24 hours of continuous incineration at high temperatures would reduce dioxin emissions. Continuous incineration also requires more waste. Hence, the government implemented wide-area waste management in the municipalities in 1997 (Ministry of Health and Welfare 1999).

Regional waste management planning is an important pre-requisite for the advanced treatment of post-incineration ashes, material recycling, and thermal recovery, obtaining the required space for landfills, cost reduction, and dioxin emissions reduction (Ministry of Health and Welfare, Environmental Health Bureau, Water Environment Department, Environment Division Director 1997). The planning period was originally fixed at 10 years. However, it is behind schedule and still ongoing in most prefectures. The possible reasons for the delay are the timing of replacement of waste disposal facilities being different among different municipalities and a NIMBY (not in my backyard) attitude against setting up these facilities. The central government required each local government (prefecture) to allocate areas for regional waste management so that the incineration scale is greater than or equal to 300 tons per day or at least greater than or equal to 100 tons per day[1].

Some renovation of plants were undertaken to prevent and reduce dioxin emissions with a complete combustion in the furnace. Dioxin emissions from incinerators have dramatically reduced after the enactment of the law (from 6,505 g in 1997 to 636 g in 2002 and 146 g in 2004) according to the Ministry of the Environment (MOE 2012). It seems possible that Japan could eliminate the problem of dioxins. The main aims of regional waste management have now shifted from dioxin emissions reduction to promotion of material recycling and thermal recovery and cost reduction of public waste management.

This paper is structured as follows. Section 2 examines the strengths and weaknesses of regional waste management and suggests that setting up transfer stations can reduce transport costs and CO_2 emissions due to the increase in transportation distance. Section 3 reviews the current situation in regional waste management and energy use of incinerators in Japan. Section 4 explores the capture of economies of scale in waste management and reviews the relevant literature in collection and disposal of municipal solid waste. Section 5 conducts a simple econometric analysis to examine economies of scale in waste incinerators in Japan. Finally, section 6 discusses the possible countermeasures for the NIMBY syndrome in regional waste management and presents concluding remarks.

2. Strengths and Weaknesses of Regional Waste Management

Waste disposal facilities, such as incinerators and sanitary landfills, are used together in regional waste management (Figure 2-1). In this way, there is a saving on construction and management costs of these facilities and reduced environmental pollution caused by them. Many studies have demonstrated the scale effect of waste management in developed countries using econometric methods. The disposal facilities for regional waste management are often located further from residential areas than existing facilities. Hence, the transport costs and environmental effects, such as CO_2 emissions due to transporting waste is higher when compared to waste management by each municipality (Fujii 2005). Kondo and Nakamura (2002) indicated that concentrated incineration in a small number of large facilities with energy recovery in Japan slightly increases transport costs but reduces CO_2 emissions. Considering the amount of transported waste, these facilities should be located in densely populated municipalities to decrease transport costs and environmental effects[2].

< Figure 2-1 >

Table 2-1 summarizes the possible strengths and weaknesses of regional waste management. Setting up costs and management costs are called “private costs” in economics, which are direct monetized costs borne by the person or organization undertaking the activity, whereas, the damages by environmental effects are called “external costs”, which are borne by a third party. External costs are often difficult to monetize. However, it is important to consider both private costs and external costs, that is, social costs for socially efficient decision-making (Massarutto 2015 and Sasao 2011).

< Table 2-1 >

So, transfer stations should be set up to reduce transport costs and environmental effects caused by transport and to impose a burden on residents who bring waste (Fujii 2005, Kogita and Masuda 2010, and MOE 2012). By setting up transfer stations, (a) waste is transported to the transfer station in smaller vehicles (2-ton vehicles, for example) and (b) waste is transported to an incinerator in bigger vehicles (10-ton vehicles, for example). The sites for old incinerators that are no longer needed due to a shift to regional waste management are often used as transfer stations[3].

The decision of setting up transfer stations depends on the total collection and transport costs. According to MOE (2012), the cost structure is shown in Figure 2-2. “A” represents the costs for construction, maintenance, and management of transfer stations. When the total collection and transport costs of a transfer station is less than the costs without a transfer station (when the transport distance is greater than X km), it is reasonable to set up transfer stations. MOE (2012) suggests when the transport distance is greater than 18 km, a transfer station should be used. However, the appropriate distance can vary due to other factors, such as fuel prices.

< Figure 2-2 >

Setting up transfer stations not only leads to cost reduction, but it also reduces CO_2 emissions. Kogita and Masuda (2010) indicated that even when there is an increase in CO_2 emissions due to transportation, the total emissions from waste management are lower in regional management than when done by each municipality because of transfer stations. However, it depends on the total distance for transport, population, and the amount of waste generated. The size of the area must be decided so that an increase in the social costs of transport is less than the decrease in social costs of increasing disposal facilities.

In the social aspect, one of the biggest challenges is the NIMBY syndrome against locating waste disposal facilities. NIMBY means that people do not want something unpleasant to be built near where they live. Waste disposal facilities are typical examples of NIMBY. Sasao (2004a, 2004b, 2011) demonstrated that residents negatively evaluate the acceptance of waste originating from outside their community. Hence, NIMBY is a very important issue in regional waste management. While the benefits of regional waste management facility are spread over an area, the external costs, such as negative environmental effects are brought near the facility. Consequently, this causes a discrepancy between municipalities without a facility and municipalities with a facility. In section 6 some possible countermeasures against the NIMBY syndrome are discussed.

Two other challenges must also be considered. The disposal facilities for regional waste management are often located further from residents than existing facilities. This makes it inconvenient for residents who bring waste themselves if they generate a lot of waste at one time (while moving houses, for example). Response to disaster should be also considered here. If a disposal facility in regional management is damaged by natural disaster and is forced to stop accepting waste, the effects will spread across the region. Therefore, it is important to make the facility structurally robust. For example, placing facilities along the coast should be avoided considering the possible damages due to tsunamis. If situating along the coast is unavoidable, the facility should be built on high ground and a bank should be constructed to protect against possible damage.

3. Current Situation of Regional Waste Management and Energy Use of Incinerators in Japan

The Japanese government provides some financial support to municipalities for setting up waste disposal facilities[4]. However, since 2005, it does not subsidize incinerators without energy use or small incinerators. This is because the government aims to promote the establishment of a sound material-cycle society. It aims to ensure the implementation of the 3Rs (Reduce, Reuse, and Recycle) and proper waste management (MOE 2014). The grants-in-aid are paid for material recycling and energy recovery facilities etc. For incinerators especially, a higher subsidy rate is given to plants with higher power efficiency, as shown in Table 2-2.

< Table 2-2 >

Figure 2-3 shows the trend in the number of incinerators set up in Japan. The total number of incinerators is decreasing due to the use of intensive incinerators and waste reduction and is currently at about 1,100. The most popular incinerator is a stoker type in Japan. A stoker is a combustion system that consists of a series of stepped fire grates[5]. The most popular capacity is between 100 and 300 tons per day (MOE 2018).

< Figure 2-3 >

Figure 2-4 shows that the incineration capacity has increased gradually because of intensive incineration.

< Figure 2-4 >

Figure 2-5 shows the trend in the number of incinerators with heat energy use. About two-thirds of the incinerators use heat energy produced by the incineration inside and/or outside incinerators, as shown in the figure. The heat energy is often utilized for heating the water for swimming pools and hot springs, for example, near the incinerators. While old incinerators tend to supply only heat energy, new incinerators tend to supply more electricity.

< Figure 2-5 >

Figure 2-6 shows the trend in total power supply by incinerators and power generation efficiency, that is power generation divided by the calorific value of waste. The figure shows that the total power supply by incinerators is gradually increasing. This is equivalent to the electricity demanded by 2.95 million households in Japan (MOE 2018). However, the scale of power generation per incinerator is not as large as those of the incinerators in European countries and the USA (ISWA 2015). Moreover, the power generation efficiency, that is power generation divided by the calorific value of waste, is still low. The average power generation efficiency in Japan was 12.81 % in 2016 while that of the OECD countries was 16 % in 2012 (ISWA 2015).

< Figure 2-6 >

Regional waste management is conducted by organizing partial-affairs associations in Japan. Figure 2-7 shows the trend in the number of the partial-affairs associations for waste management. The most popular associations are organized for intermediate disposal or incineration. In contrast, the partial-affairs associations for waste collection are fewer. This means that most municipalities still manage waste collection for the respective municipality. The trend has been almost constant over the last decade.

< Figure 2-7 >

Figure 2-8 shows the number of municipalities in the partial-affairs associations for waste management in 2016. Most partial-affairs associations are organized by less than 5 municipalities.

< Figure 2-8 >

4. Economies of Scale in Regional Waste Management

4.1 Capturing Economies of Scale

There are three main indicators of economies of scale in waste management, according to Callan and Thomas (2001) and Bel and Warner (2014). The first indicator represents the percentage increase in the cost for every 1 % increase in the amount of waste generated. This is economies of scale in a narrow sense and is represented as:

$$\frac{\partial C}{\partial Q} \cdot \frac{Q}{C} < 1$$

where C is the cost, and Q is the amount of waste generated or disposed.

If it is less than 1, economies of scale exist.

The second indicator represents the percentage increase in the cost for every 1 % increase in population density. This is economies of density and is represented as:

$$\frac{\partial C}{\partial PD} \cdot \frac{PD}{C} < 1$$

where PD is population or housing density.

If it is less than 1, economies of density exist.

The third indicator is economies of scope. For example, let us consider traditional disposal, such as incineration or landfills and recycling.

$$\frac{C_1(Q_1, 0) + C_2(0, Q_2) - C_3(Q_1, Q_2)}{C_3(Q_1, Q_2)} > 0$$

where Q_1 is amount of disposed waste and Q_2 is amount of recycled waste.

Scope economies exist if the cost of one municipality providing both disposal and recycling is lower than if each of the two municipalities specialized in only one of these services for the residents of respective municipalities (Callan and Thomas 2001).

4.2 Relevant Literature

Many studies have conducted econometric methods to examine the scale effect in waste collection and disposal in developed countries. Table 2-3 summarizes the studies that studied economies of scale in the upper row and ones that did not in the lower row.

< Table 2-3 >

Most studies indicate that as the quantity of waste disposal or population increases, the average collection and disposal costs decrease. This is particularly observed in sparsely populated municipalities[6]. In contrast, some studies have not studied the scale effect. Bel and Warner (2015) indicated that different results can be caused by the differences in the average population of municipalities and governance of the cooperative arrangement among countries.

Table 2-4 summarizes the studies on MSW management that have studied economies of density in the upper row, and the ones that did not in the lower row.

< Table 2-4 >

Several studies have indicated that an increase in population density decreases the average collection and disposal costs though there is an exceptional study.

Callan and Thomas (2001) and Ishimura and Takeuchi (2018) have focused on economies of scope. Ishimura and Takeuchi (2018) indicated that regional waste management in Japan for recycling and landfilling as well as incineration contributes to cost reduction.

5. Economies of Scale in Incinerators

5.1 Data and Methodology

Some studies have examined economies of scale in waste disposal facilities in Japan. Aoyama (2004) demonstrated economies of scale in construction costs of incinerators of a capacity of less than 500 tons per day. Matsuto and Ohara (2010) demonstrated economies of scale of landfills. However, Matsuto and Ohara could not capture the effect of each possible factor on the costs because they did not use any econometric methods. Therefore, this section conducts a simple econometric analysis to examine economies of scale in waste incinerators in Japan. The study uses data from the MOE database of tenders and contracts for waste disposal facilities to examine the factors affecting construction costs of incinerators in Japan. The database was initiated in May 2011 and is available on the MOE website (https://www.env.go.jp/recycle/waste/3r_network/7_misc.html, in Japanese). However, the construction costs of some plants also include the operation costs for DBO (Design-Build-Operate) and PFI (Private Finance Initiative). I have replaced these with the construction costs (excluding the operation costs) obtained from relevant websites, e.g. municipalities and plant makers. However, since I could not obtain the construction costs for some plants, I removed those plants from the dataset. Moreover, I removed four incinerators of less than five tons per day capacity because the technical characteristics of the incinerators are different from the large and medium size incinerators. Consequently, the available number of incinerators is 77. Construction costs are adjusted through GDP deflators.

This study considers the technological and financial factors as the independent variables. The technological factors include the age of plants, incineration capacity, and whether with or without two melt treatments—gasification melting and ash melting—with stoker combustion. The study examines the effects of incineration capacity on construction costs to examine economies of scale of setting up incinerators. The age of plants can affect construction costs of plants due to innovation. However, it is difficult to expect that *a priori* because it might either reduce the costs due to innovation or increase them due to highly-developed technology and increased material and labor costs. Melt treatment can increase construction and management costs while it contributes to a reduction in incineration ashes. The financial factors include DBO or PFI. In Japan, most MSW is disposed of at disposal facilities, such as incinerators and landfills owned by municipalities. However, some municipalities adopt public-private partnerships for cost reduction in setting up and operating disposal facilities since the enactment of the PFI law in 1999. DBO is one such public-private partnership. In a DBO project, while a municipality (or a joint municipality) owns and finances the construction of new facilities, a private company (or a joint venture) designs, builds, and operates the facilities to meet certain agreed outputs[7]. PFI is also a type of public-private partnership. In a PFI project, a private company (or a joint venture) finances, designs, builds, and operates the facilities. The financial factors also include contract methods. These include facilities with or without competitive tenders[8]. The contract method is expected to decrease costs when compared with negotiated contracts. The independent variables other than age and incineration capacity are considered as dummy variables that is equal to one when it is applicable—for example, a dummy variable that equals one when a plant applies melt treatment.

Two types of dependent variables are examined. In Model 1, the total costs are transformed using logarithm to capture elasticity. In Model 2, the average costs, that is the costs per daily capacity in incinerators (tons), are examined to intuitively capture economies of scale. Both models are regressed using the ordinary least squares (OLS) method.

The correlation coefficients indicate that the relationships between the explanatory variables are negligible. Table 2-5 shows the descriptive statistics of variables considered in the analysis. It also shows the expected effects of each variable on the total costs or average costs.

< Table 2-5 >

5.2 Estimation Results

The estimation results of Models 1 and 2 are shown in Tables 2-6 and 2-7 respectively. The results that include all explanatory variables are shown in the column "Model 1-1" and the results after elimination of the insignificant variables are shown in the column "Model 1-2". Model 2 is the same as Model 1. The model specification is more suitable in Model 1 than Model 2 because the R-squared is higher in Model 1 than Model 2.

< Table 2-6 >
< Table 2-7 >

The significant variables that positively affect the costs are the daily capacity and PFI. For example, a 1 % increase in the daily capacity raises the total costs by approximately 0.75 % in the results of Model 1-2. This suggests economies of scale of incinerators, as expected. Model 2 assumes a quadratic curve for the daily capacity. The square of daily capacity is positively significant while daily capacity is negatively significant. Maximum reduction is observed at 428 tons per day approximately, assuming the other independent variables are held constant. This suggests that economies of scale are observed for incinerators with a capacity of less than

428 tons per day. This figure is slightly less than the calculation of Aoyama (2004). The incineration capacity (428 tons per day) is equivalent to the waste generated by 423,000 residents approximately[9]. In contrast, the results of PFI is contrary to expectations. The adoption of PFI raises total costs by approximately 72.5 % in the results of Model 1-2. The results of Model 2-2 also suggest that it significantly raises the average costs. As mentioned in the previous subsection, this study focuses on construction costs. However, in case of PFI, private companies tend to execute a bulk contract to build incinerators, including their operation, with municipalities. Some companies set off the operation costs against the higher construction costs while they manage to operate at lower prices. On the contrary, age is negatively significant. This means that newer incinerators tend to be more expensive. This seems to be caused by the demand for environmental high performance and increased material and labor costs.

6. Conclusion

This paper examines the effectiveness and challenges in regional waste management in Japan. It focuses on economies of scale of regional waste management as the main factor for effectiveness. A simple econometric analysis shows economies of scale for incinerators with less than 428 tons per day capacity. This paper also proposes that setting up transfer stations would reduce transport costs and environmental effects due to regional waste management.

However, to tackle the NIMBY attitude against setting up waste disposal facilities, some benefits other than environmental protection for affected residents can be effective. Incinerators, especially waste-to-energy, can provide electricity and heat energy to residents near the facility. Heat energy is available for agricultural use, such as greenhouses as well as for heating the water for swimming pools. If there is no heat demand near the incinerator, electricity would be more useful. Some incinerators are situated in the center of towns. For example, one incinerator in the Musashino city in Tokyo, Japan, is located next to the city hall. The plant supplies electricity and heat energy to the city hall and the gymnasium near it. Additionally, when a disaster strikes, the plant can operate a gas co-generator for a possible electricity shortage. These challenges have changed the image of incinerators.

Further, mutual trust between the public and local government is as important as environmental high performance. Sasao and Tsuge (2005) have suggested that offering information and Q and As (questions and answers) with people change public preferences and promote public acceptance of regional waste management. Moreover, it indicates that public participation in choosing a location for a waste disposal facility in the planning stages reduces public distrust and promotes consensus building. Tanaka (2012) suggested the slogan “PIMBY”, that stands for “please in my backyard” should be substituted for NIMBY. Not just environmental high performance but mutual trust between the public and government also would contribute to making waste disposal facilities PIMBY.

Japan’s experiences and challenges provided in this paper can also provide some hints for setting up waste disposal facilities for regional waste management in Southeast Asia.

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[1] 1 However, some areas, such as isolated islands are exempt from the rule.
[2] Yamanari and Shimada (2007) indicated that introduction of RDF (Refuse-Derived Fuel) power generation presents three advantages of reducing energy consumption: CO_2 emissions, and transportation costs in sparsely populated municipalities.
[3] Transfer stations also function as collection centers for material recycling.
[4] For further details, please refer to the MOE website of promotion of the establishment of a sound material-cycle society (Japanese); http://www.env.go.jp/recycle/waste/3r_network/.
[5] The website of Takuma Co. Ltd, a Japanese incinerator plant maker, (https://www.takuma.co.jp/english/product/msw/stoker_msw.html) says, “The stepped grates move back and forth to facilitate efficient contact between the waste and air, ensuring stable combustion of the waste despite its non-uniform properties.”
[6] Bel and Warner (2015) also reviewed empirical studies on inter-municipal cooperation and costs. They also indicated that solid waste is more prone to economies of scale and small municipalities are more likely to benefit from them.
[7] The website of World Bank Group provides further information on various public-private partnerships. Please refer to the website: https://ppp.worldbank.org/public-private-partnership/agreements/concessions-bots-dbos.
[8] I originally considered a comprehensive evaluation that considers performance, function, suggestion, and bid while competitive tenders consider bid only. However, I removed it from the independent variables because of the high correlation between comprehensive evaluation and competitive tenders.
[9] I assume that burnable waste and bulky waste after shredding are incinerated, and real rate of operation and rate of operation for adjustments are 76.7 % and 96.0 % respectively, according to MOE (2003). I use the data in 2016 (amount of burnable waste: 33,073 thousand tons; amount of bulky waste: 1,754 thousand tons; population in collected area: 127,912 thousand residents) from MOE (2018).

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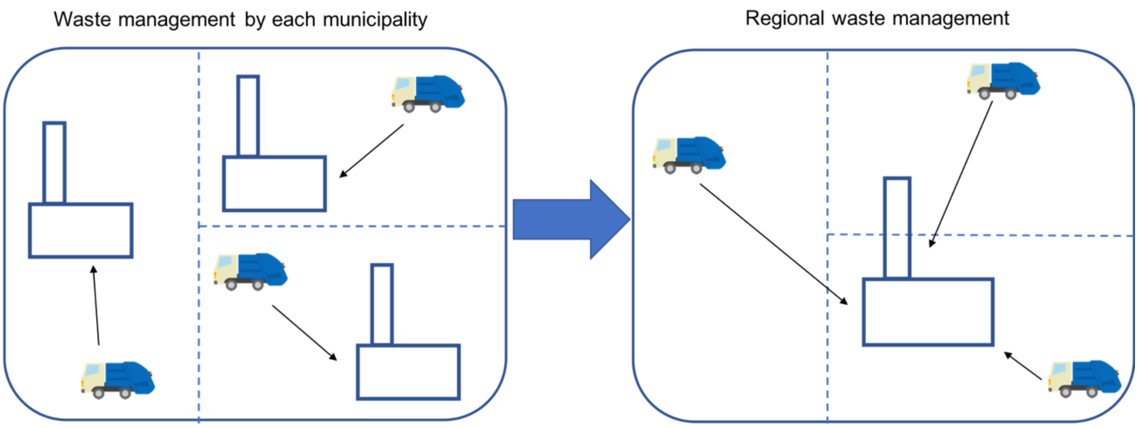
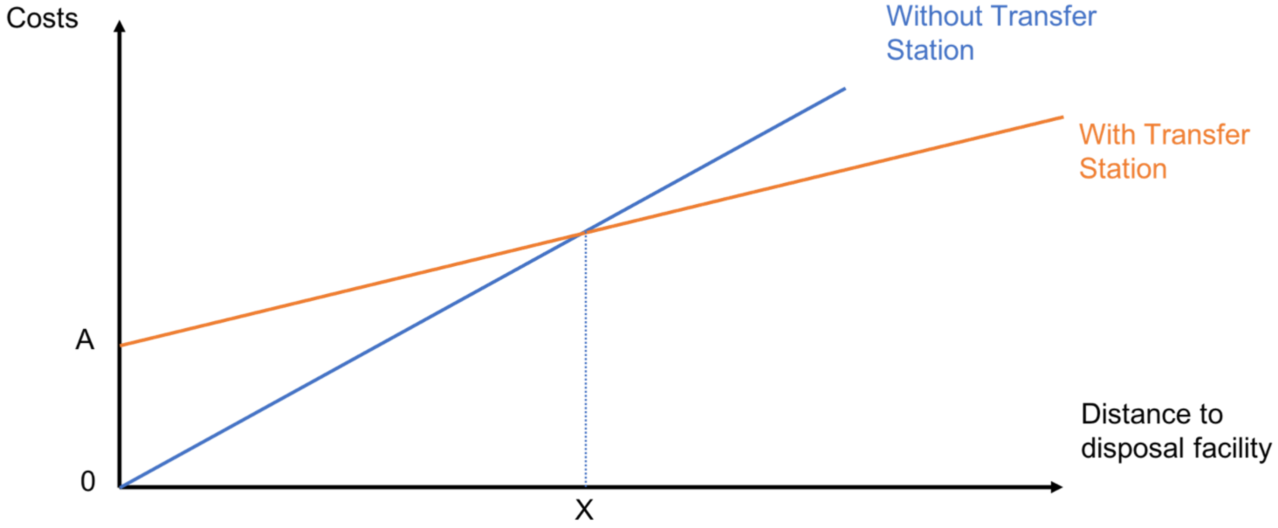
Figure 2-1: Regional Waste Management



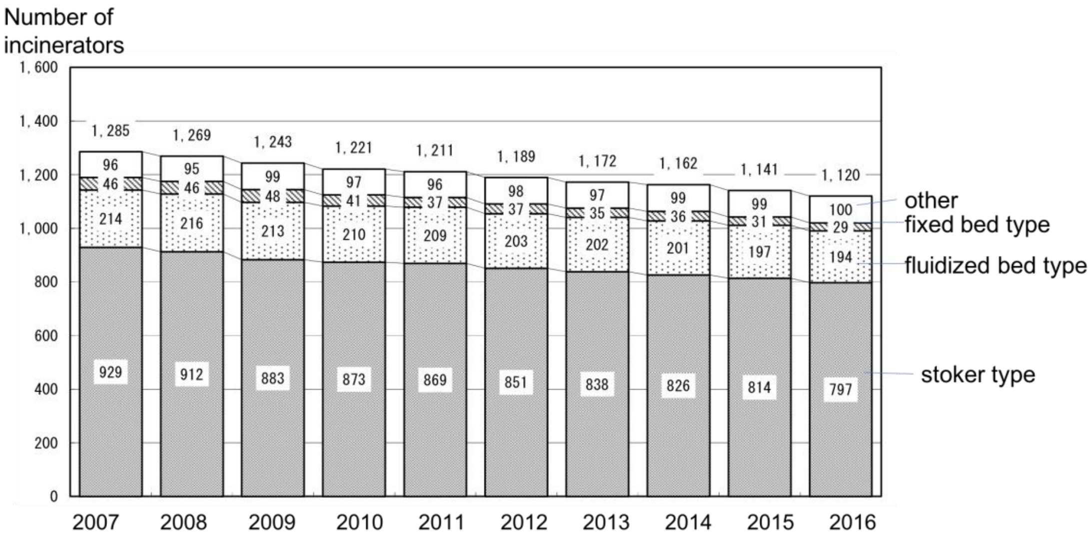
Source: Author's drawing

Figure 2-2: Cost Structure for With and Without Transfer Station



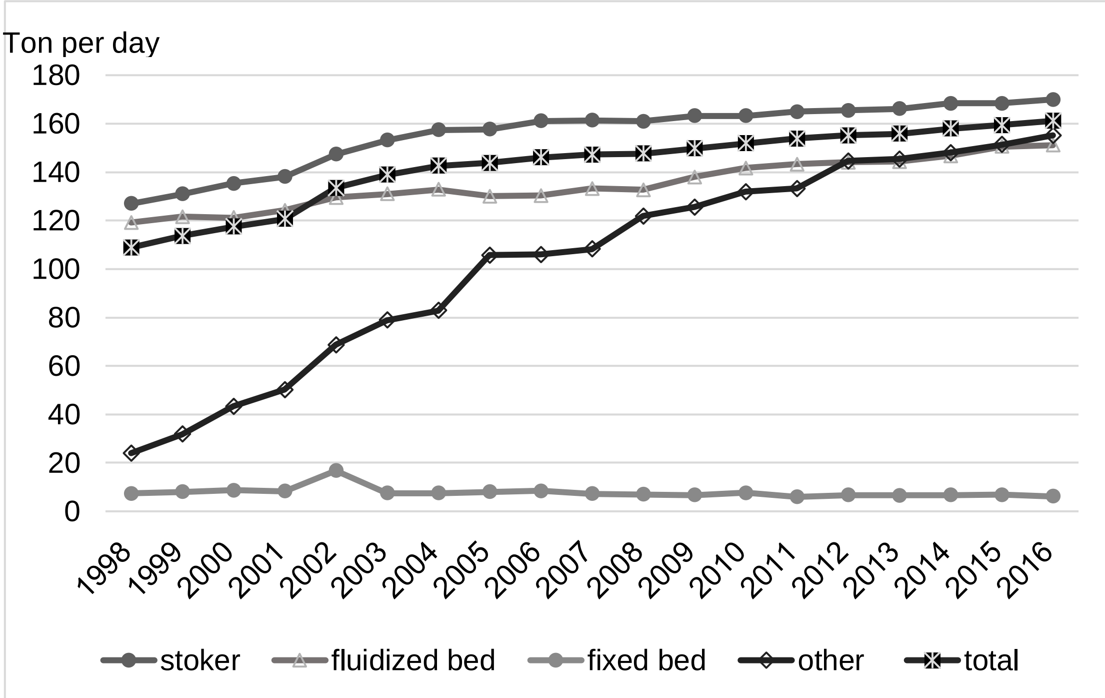
Source: Author's drawing from MOE (2012)

Figure 2-3: Trend in the Number of Incinerators



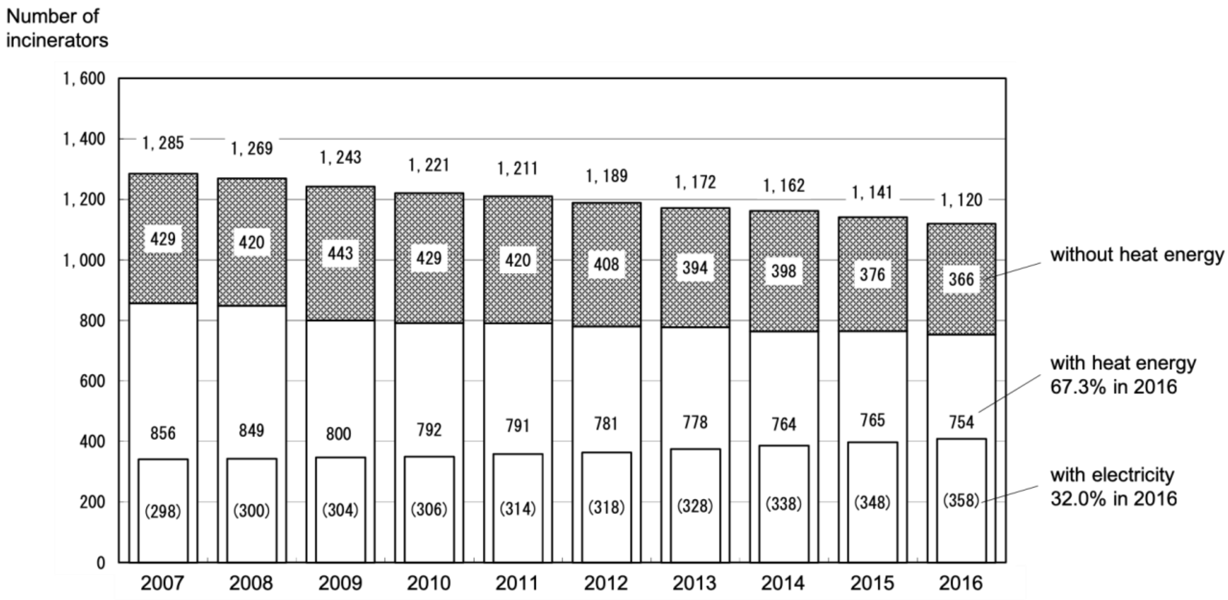
Source: Adapted from MOE (2018)

Figure 2-4: Trend in Incineration Capacity



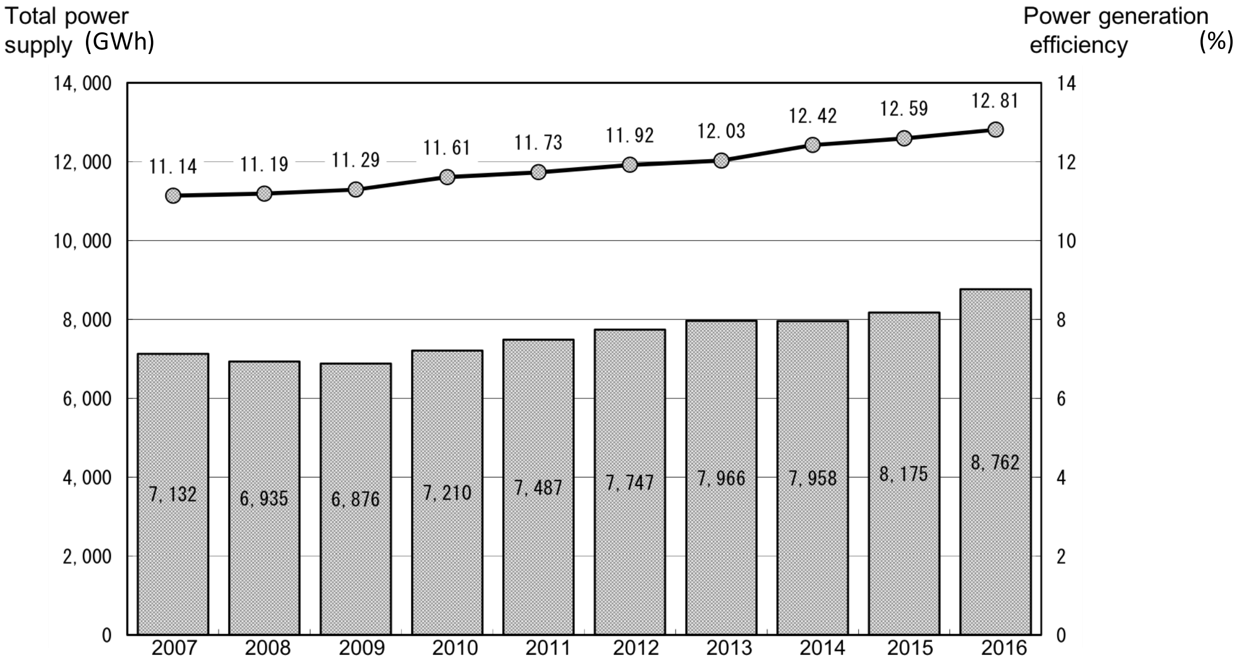
Source: Author’s drawing from MOE (2018)

Figure 2-5: Trend in the Number of Incinerators with Heat Energy Use



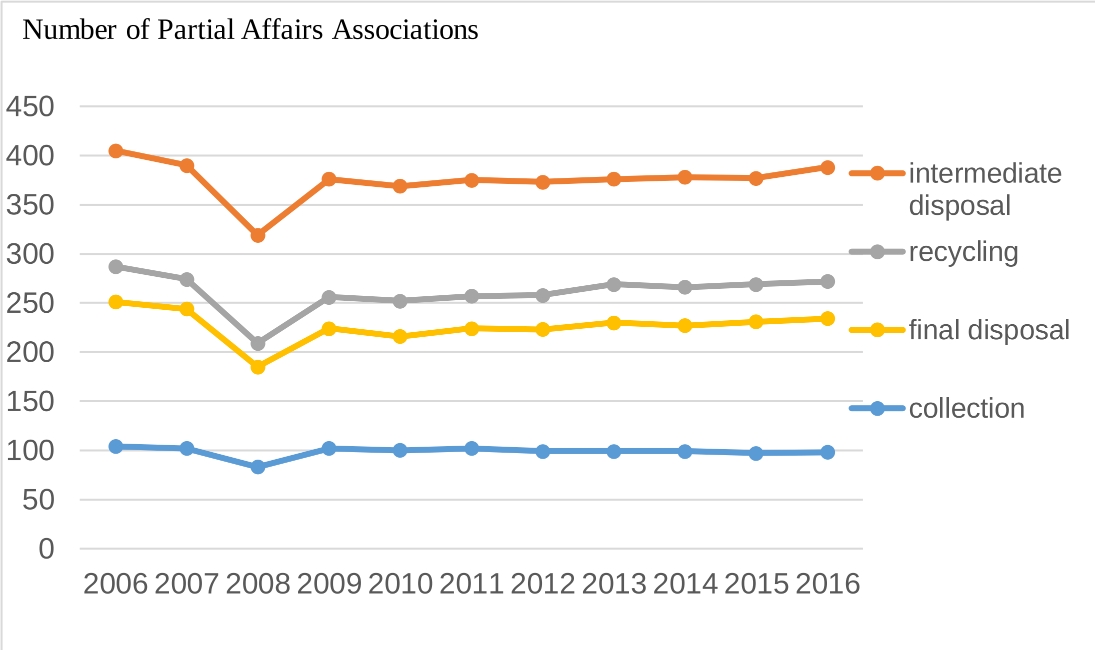
Source: Adapted from MOE (2018)

Figure 2-6: Trend in Total Power Supply by Incinerators and Power Generation Efficiency



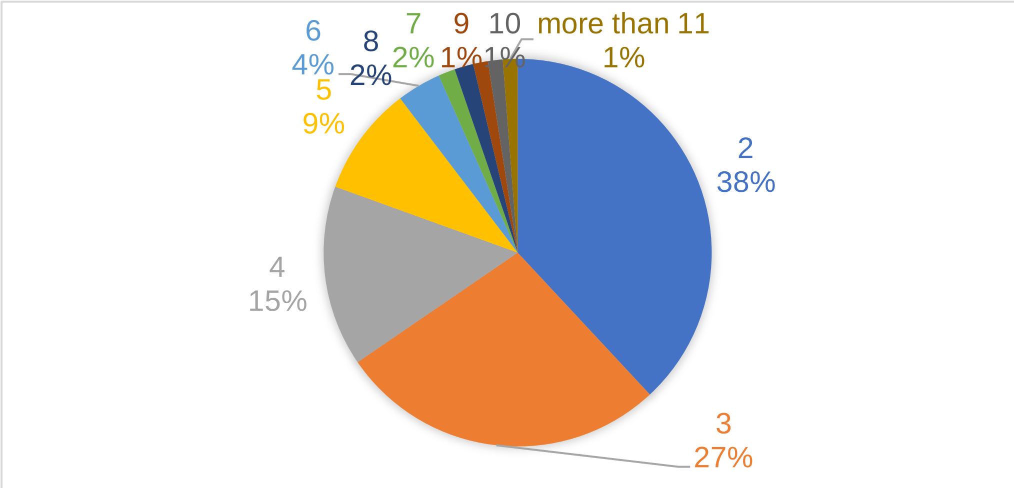
Source: Adapted from MOE (2018)

Figure 2-7: Trend in the Number of Partial Affairs Associations for Waste Management



Source: Author's drawing from MOE (2018)

Figure 2-8: Number of Municipalities in Partial Affairs Associations for Waste Management in 2016



Source: Author’s drawing from MOE (2018)

Table 2-1: Possible Strengths and Weaknesses of Regional Waste Management

	Strengths	Weaknesses
Economic aspect (Private costs)	Reduction of siting costs and management costs	Increase of transport costs
Environmental aspect (External costs)	Reduction of environmental effects (ex. CO_2) caused by disposal facilities Saving energy	Increase of environmental effects caused by transport
Social aspect		Strong NIMBY Inconvenience for residents who bring waste Response to disaster

Source: Compiled by the author

Table 2-2: Incinerators Eligible for Pioneering Projects

Incineration capacity (ton / day)	Power efficiency (%)
Less than 100	12
100–150	14
150–200	15.5
200–300	17
300–450	18.5
450–600	20
600–800	21
800–1,000	22
1,000–1,400	23
1,400–1,800	24
More than 1,800	25

Source: Compiled by the author from MOE (2018)

Table 2-3: Literature of Economies of Scale in Waste Management

1) Economies of scale was observed			
Relevant literature	Country	Disposal stage	Remarks
Stevens (1978)	USA	Collection	Less than 50,000 population
Antonioli & Filippini (2002)	Italy	Collection	Less than 95,400 ton / year (Optimal total trips 400 km)
Bel & Costa (2006)	Spain	Collection and disposal	Regional management less than 20,000 population
Usui (2007)	Japan	Collection and disposal	Less than 50,000 population remarkably
Bel & Costa (2009)	Spain	Collection and disposal	Regional management less than 10,000 population
Lombrano (2009)	Italy	Collection	Less than 100,000 population
Yamamoto (2009)	Japan	Collection and disposal	Less than 45,000 ton / year for collection
Bohm et al. (2010)	USA	Collection and disposal	Less than 10,000 ton / year for recycling
Chifari et al. (2017)	Japan	Collection and disposal	Collection > Intermediate disposal > Final disposal
Ishimura & Takeuchi (2018)	Japan	Collection and disposal	Regional management
2) Economies of scale was not observed			
Relevant literature	Country	Disposal stage	Remarks
Carroll (1995)	Wisconsin, USA	Recycling collection	Economies of density was observed
Dijkgraaf and Gradus (2005)	Netherlands	Collection	Competitive tendering can be effective
Sørensen (2007)	Norway	Wide-are collection	Inefficiency brought by large number of municipalities

Source: Compiled by the author

Table 2-4: Literature of Economies of Density

1) Economies of density was observed			
Relevant literature	Country	Disposal stage	Remarks
Carroll (1995)	Wisconsin, USA	Recycling collection	Economies of scale was not observed
Callan & Thomas (2001)	Massachusetts USA	Collection and disposal	Scope economies was also observed
Bel & Mur (2009)	Spain	Collection and disposal	Cost reduction due to collaboration with other municipalities was observed in small municipalities (less than 10,000 persons)
2) Economies of density was not observed			
Relevant literature	Country	Disposal stage	Remarks
Bel & Costa (2006)	Spain	Collection and disposal	Cost reduction due to collaboration with other municipalities was observed in small municipalities (less than 20,000 persons)

Source: Compiled by the author

Table 2-5: Descriptive statistics

	Mean	Median	Standard deviation	Max	Min	A priori expectation on total costs / average costs
Total costs (thousand yen)	10,700,000	8,617,108	8,262,058	44,100,000	18,061	
Average costs (thousand yen)	52,539.78	47,690.28	23,847.51	142,179.2	15,597.83	
Age of plants	12.66	13.00	2.40	16.00	8.00	+/–
Daily capacity (ton)	239.61	212.00	177.02	720.00	6.00	–
Gasification melting (D) *	0.4286	0	0.4981	1.0000	0.0000	+
Stoker + ash melting (D) *	0.2597	0	0.4414	1.0000	0.0000	+
DBO (D) *	0.2468	0	0.4339	1.0000	0.0000	–
PFI (D) *	0.0520	0	0.2234	1.0000	0.0000	–
Competitive tenders (D)*	0.5714	1	0.4981	1.0000	0.0000	–

Note: *(D) represents a dummy variable.

Source: Author’s calculation

Table 2-6: Estimation results by Model 1

	Model 1-1			Model 1-2		
	Coef.	t	p	Coef.	t	p
Age of plants	–0.04261**	–2.10	0.040	–0.0300*	–1.93	0.058
Daily capacity (log)	0.7461***	19.46	0.000	0.7536***	20.22	0.000
Gasification melting	0.1253	1.35	0.182	N.S.		
Ash melting with stoker	0.1332	1.13	0.263	N.S.		
DBO	0.0306	0.29	0.769	N.S.		
PFI	0.7506***	4.60	0.000	0.7251***	5.08	0.000
Competitive tenders	0.0735	0.73	0.466	N.S.		
Constants	12.4419***	34.76	0.000	12.3829***	41.87	0.000
F statistics	F (7, 69) = 82.27			F (3, 73) = 165.79		
R-squared	0.8727			0.8666		

Note: *** $p < 0.01$, ** $p < 0.05$.

N.S. represents not significant. T statistics are calculated by robust estimation.

Source: Author's calculation

Table 2-7: Estimation results by Model 2

	Model 2-1			Model 2-2		
	Coef.	t	p	Coef.	t	p
Age of plants	–2,294.11**	-2.10	0.040	–1,891.16*	–1.86	0.067
Daily capacity	–222.01***	-4.21	0.000	–218.25***	–4.39	0.000
Daily capacity squared	0.2575***	3.23	0.002	0.255***	3.22	0.001
Gasification melting	–312.82	–0.07	0.947	N.S.		
Ash melting with stoker	5,608.95	1.02	0.311	N.S.		
DBO	1,648.47	0.27	0.785	N.S.		
PFI	50,403.59***	4.29	0.000	47,318.16***	4.12	0.000
Competitive tenders	3,187.75	0.56	0.578	N.S.		
Constants	105,870.10***	5.33	0.000	103,775.70***	6.16	0.000
F statistics	F (8, 68) = 9.46			F (4, 72) = 12.12		
R-squared	0.5213			0.5081		

Note: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

N.S. represents not significant. T statistics are calculated by robust estimation.

Source: Author's calculation