

Waste Heat Recovery Project

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Writer

Shin Lee / Yoo Gyeong Hur

Affiliation

University of Seoul

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Policy Implementation Period

- 1960~1985: General waste disposed at local landfill sites
- 1978~1993: Waste disposed at Nanji landfill site
- 1986: Mokdong incineration facility begins operations
- 1991: Seoul City – Basic Waste Disposal Plan established
- 1992~2005: 4 resource recovery facilities constructed
- 1993: Waste disposed at capital area landfill site
- 2007~2010: 4 resource recovery facilities – sharing agreements signed

General Information

In Korea, the economic development of the 1960s prompted an increase of waste as well. Waste was used as landfill at housing sites in suburban areas. Nanji Landfill opened in 1978, and waste was simply thrown away.

Through rapid development, Seoul was able to hold the 1986 Asian Games and the 1988 Olympics on its way to becoming an international city. However, it faced internal problems in waste management (such as the near-capacity Nanji landfill) which was becoming a society-wide problem.

In response to this, the Seoul Metropolitan Government (SMG) established a 'Basic Waste Disposal Plan' in 1991, and planned the construction of major incineration facilities.

Importance of the Policy

Large, densely-populated cities throw away a disproportionately large volume of waste, restricting use of city land if the city seeks to handle this waste on its own. On the other hand, if the landfill site is far from the city, the cost of transportation grows considerably.

Incinerating waste within the city limits has many benefits. Waste can be disposed of in 1 to 2 days, therefore demanding a lower facility capacity. Incineration greatly decreases weight and volume of the waste, which does not emit much odor, and in turn makes landfill management easier in terms of space.

Moreover, the heat generated during incineration can be used in urban areas. These benefits combined make incineration an important waste management tool for cities.

Relevance with Other Policies

Modern waste management consists of three steps: First, the amount of waste is restricted through recycling and reducing. Second, waste that is generated goes through energy recycling or is recycled as a future resource. Finally, any waste remaining can be safely disposed of through incineration or as landfill.

Total amount of waste, total amount of recyclable waste, and total amount of waste that must be incinerated or buried need to be estimated, with an overall balance in mind.

During its time of rapid growth, Seoul first considered incineration as the most appropriate way to reduce use of landfill sites, rather than reducing the total amount of waste. However, the volume-based waste fee (VBWF) system in 1995, the extended producer responsibility (EPR) program in 2003 and ban on food waste going directly into landfill helped reduce the overall amount of waste, and reduced the city's dependence on incineration and landfill.

Policy Objectives & Process

- Maximize waste treatment to minimize the amount disposed at landfill sites.
- Install a suitable number of waste disposal facilities to maximize the resource recovery rate.
- Minimize creation of toxic materials during the incineration process and improve safety for local residents.
- Coordinate on supplementary facilities with local residents to improve welfare.

Main Policy Details

1) Shared Incineration Facilities

There are four incineration sites in Seoul: Yangcheon Facility, Nowon Facility, Gangnam Facility and Mapo Facility. These all operate within the city of Seoul (with a capacity of at least 400 tons a day). Plans for these facilities began in 1991.

The original plans were to build 11 incineration facilities to handle 16,500 tons of waste per day, but only 4 facilities have been constructed. Construction started in October 1992, and the first one to be completed was Yangcheon Facility in February 1996. This was followed by Nowon in January 1997, Gangnam in December 2001, and Mapo in May 2005.

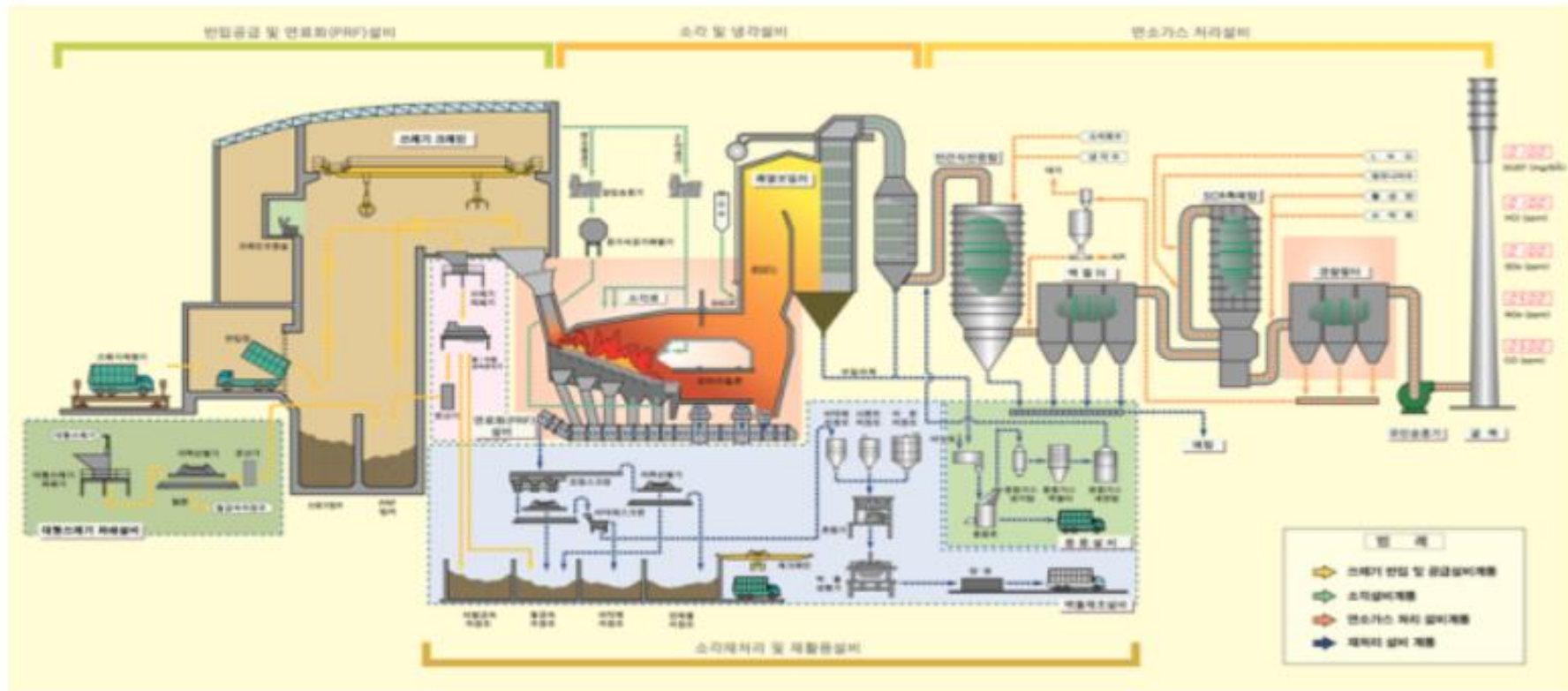
Construction of Yangcheon Facility began in December 1992, and was finished in February 1996. It has a capacity of 400 tons per day, with 2 incinerators that each process 200 tons. Construction of Nowon Facility also began in December 1992 and finished in January 1997. It has a capacity of 800 tons: 2 incinerators that can process 400 tons each per day. Construction of Gangnam Facility started in December 1994 and finished in December 2001. It has a capacity of 900 tons per day, the largest of the 4 facilities, and its 3 incinerators each can process 300 tons per day. Construction of Mapo Facility began in December 2001 and completed in May 2005. The facility has 3 incinerators, each of which can handle 250 tons per day, for a total capacity of 750 tons.

Table 1. Construction of Incineration Facilities in Seoul

	Yangcheon	Nowon	Gangnam	Mapo
Capacity	400 tons/day (2 units)	800 tons/day (2 units)	900 tons/day (3 units)	750 tons/day (3 units)

Construction Period	Dec. 1992~Feb. 1996	Dec. 1992~Jan. 1997	Dec. 1994~Dec. 2001	Dec. 2001~May 2005
Area	14,627 m ²	46,307 m ²	63,813 m ²	58,435 m ²
Construction Cost	KRW 32.1 billion	KRW 74.3 billion	KRW 115.5 billion	KRW 171.2 billion
Incinerator	Stoker	Stoker	Stoker	Stoker +Rotary Kiln
Air Purification Facilities	Wash tower Semi dry reactor Bag filter SCR catalyst tower	Electric precipitator Wet wash tower Bag filter SCR catalyst tower	Wash tower Semi dry reactor Bag filter SCR catalyst tower	Semi dry reactor Bag filter SCR catalyst tower Police filter

Figure 1. Structure of Mapo Incineration Facility



These incineration facilities can process a total of up to 2,850 tons per day. The capacity was estimated based on the amount of waste expected at the time they were designed, and the amount estimated for the future. When comparing the original 1991 plans (11 facilities, 16,500 tons processed per day) to the actual capacity (4 facilities, 2,850 tons per day), only 36% of the facilities were built and together they have only 17% of the intended capacity. On the surface, they do not seem to be enough to handle the city's municipal solid waste (MSW). However, various waste reduction policies (introduction of VBWF, expansion of recycling, and turning food waste into a resource) were put in place while the facilities were being constructed. In the 2000s, when all 4 facilities were in operation, the amount of waste generated had significantly decreased, meaning the 4 facilities could cover more MSW in Seoul. Yangcheon Facility, for example, was

designed while expecting about 400 tons of waste from Yangcheon-gu. But the district only generated 212 tons in 2002 and 101 tons in 2012: 53% and 25% of the capacity, respectively. The Nowon Facility also used about 25% (2002) and 15% (2012) of its capacity, while 33–34% was recorded for the Gangnam Facility. Mapo Facility had been designed to process MSW for Mapo-gu, Jung-gu and Yongsan-gu, with a capacity of 750 tons per day. However, the amount generated was only about 60% of its capacity in 2012.

Table 2. Capacity of Incinerator facilities in Seoul & Actual MSW Volume

	Assigned Area in Design Phase	Capacity (Tons/Day)	MSW in 2002 (Tons/Day)	MSW in 2012 (Tons/Day)
Yangcheon Facility	Yangcheon-gu	400 (1.00)	212 (0.53)	101 (0.25)
Nowon Facility	Nowon-gu	800 (1.00)	201 (0.25)	121 (0.15)
Gangnam Facility	Gangnam-gu	900 (1.00)	294 (0.33)	305 (0.34)
Mapo Facility	Mapo-gu, Jung-gu, Yongsan-gu	750 (1.00)	–	453 (0.60)

Reducing MSW enabled expansion of the area to be handled by the 4 incineration facilities. From 2007, the facilities began accepting MSW from neighboring *gu*-districts. Yangcheon Facility took MSW from Yeongdeungpo-gu and Gangseo-gu as well as from Yangcheon-gu. Gangnam Facility also began processing MSW from 7 other districts. Today, the 4 incineration facilities in Seoul handle the MSW from 22 of the 25 *gu*-districts in the city.

Before the facilities were shared, they were not utilized as much. As shown in the 2005 records, Yangcheon Facility processed only 33% of its capacity, Nowon Facility 19%, Gangnam Facility 24% and Mapo Facility 59%. This is because the local district and residents did not want the facilities to process waste from other areas. Reducing MSW was a success, but this affected the incineration facility utilization rate, and concerns increased about the aging and malfunctioning of incinerators, pollution prevention facilities and controlling devices. While the facilities in Seoul remained underused, MSW from the city was still sent to the Sudokwon Landfill Site (the capital region landfill site), 45 km from Seoul. The cost in money and energy for transportation increased, causing problems for the SMG, which had its

own incineration facilities.

However, it is not advisable for *gu*-districts to build and run their own incineration facilities, especially when considering the difficulty of securing the needed expert personnel. Waste incineration facilities require high-end technology and need to run 24/7, which demands a large number of people. Each facility employs about 70 persons, and there are many tasks that require staff with national certification, between 12 and 20 per facility. Of course, operational costs are huge as certified employees are required for industrial safety, electronic, energy utilization, preventing environmental pollution, firefighting, management of high-pressure gas and more. The facilities themselves are also large. The cost to run each ranged from KRW 8.3 billion to 21.3 billion in 2012. Three of the 4 facilities (Mapo excluded) recorded losses between KRW 0.5 and 1.5 billion. This means overall operations resulted in losses of KRW 15.5 billion, which was partially covered by the SMG, which also shared the KRW 393.1 billion cost of construction of the facilities with the central government.

Table 3. Seoul’s Incineration Facilities: Operating Profits (in 2012)

(Unit: KRW 1 million)

	Revenue	Expenses	Profit (Revenue – Expenses)
Yangcheon Facility	3,236	8,384	-5,148
Nowon Facility	4,659	14,606	-9,947
Gangnam Facility	19,794	21,338	-1,544
Mapo Facility	14,472	13,378	+1,094
Total	42,161	57,706	-15,545

Considering the above, it is more efficient for the SMG, rather than the local *gu*-districts, to run large, technology-intensive facilities like incinerators in terms of securing expertise and reducing costs.

To resolve these problems and reduce overall operating costs, the SMG began regionalizing its incineration facilities in 2001 – sharing them with neighboring *gu*-districts. However, this was not easy. First of all, agreement had to be gained from residents living near each incineration facility. Through agreements with the SMG, a resident consultative group was

formed, through which residents were able to address concerns over facility operation and their health and welfare, and monitor the composition of waste. It took between 1 and 9 years for the residents, SMG and resident consultative groups to meet and negotiate agreements for shared use of the facilities.

Sharing each facility was beneficial in many ways. First of all, 22 of the city's *gu*-districts now had access to the facilities by 2014. Sharing the facilities improved the overall utilization rates significantly – from 19–59% (or an average of 33%) in 2006 to 77–92% (or an average of 85%) in 2012.

Once the agreements were signed, 4 incineration facilities were secured as regional facilities for local districts, dividing Seoul into 4 areas for processing MSW. The *gu*-districts now send their trash to 1 of the 4 incineration facilities, by region: Southwest Region (Yangcheon Facility), Northeast Region (Nowon Facility), Southeast Region (Gangnam Facility) and Northwest Region (Mapo Facility).

Figure 2. Facility Utilization Rate & Changes in Coverage after Agreements Signed to Share the Incineration Facilities

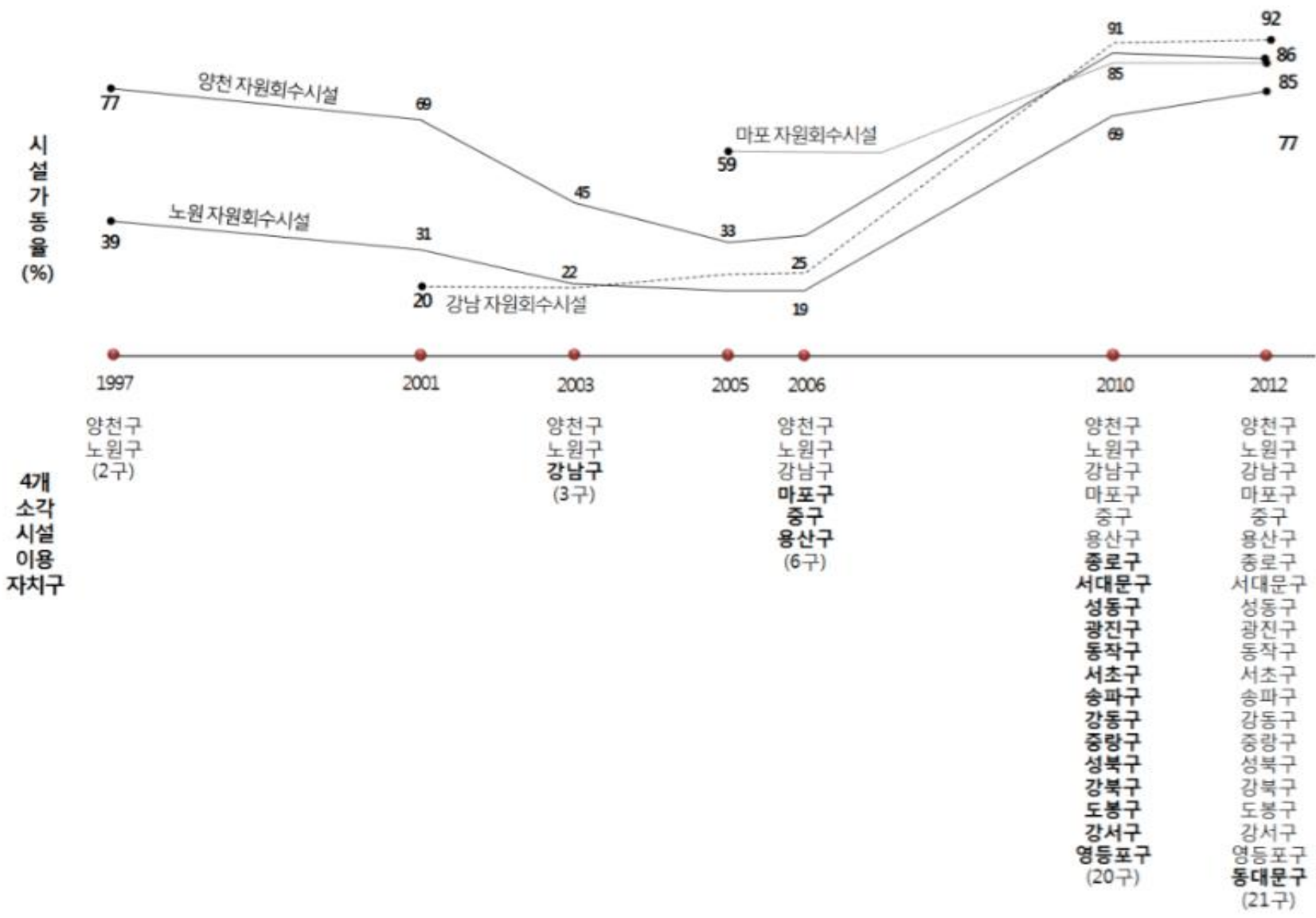


Figure 3. Incineration Facilities in Seoul & their Assigned Areas



Figure 4. Construction of Incineration Facilities in Seoul & Major Changes in Waste Management Policy



2) Construction of New Towns & Cooperation with Incineration Facilities & District Heating

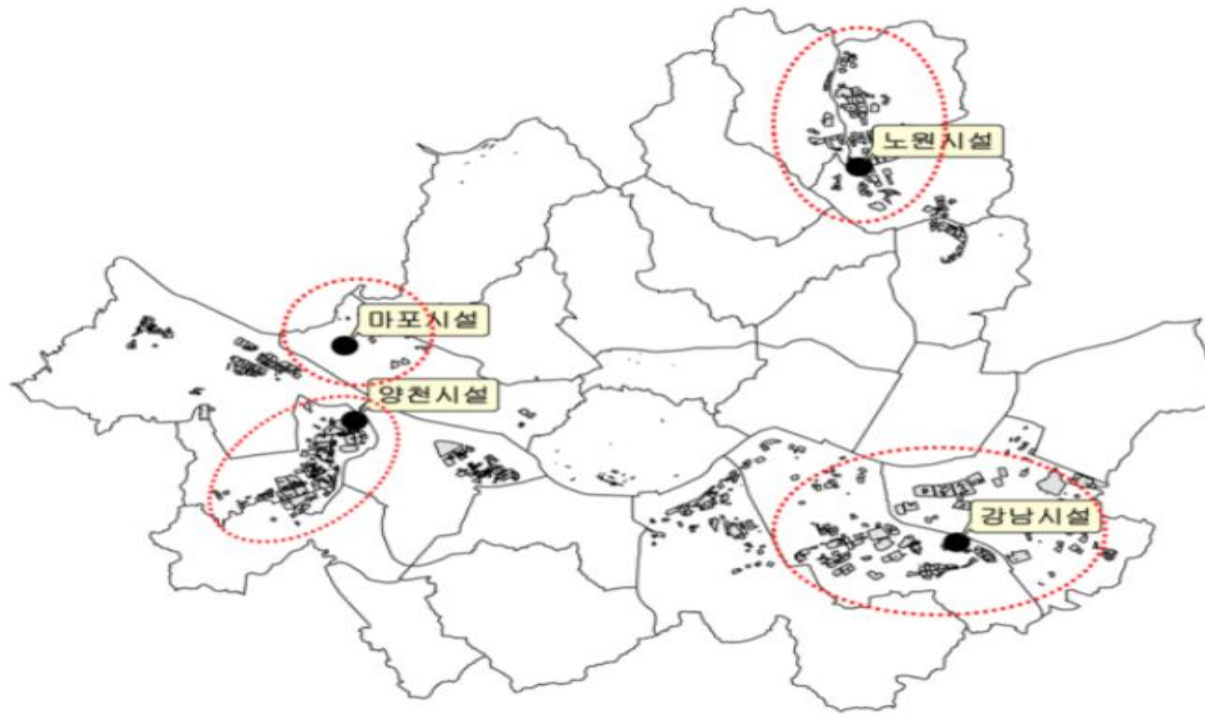
Cities in Korea developed rapidly over the last 60 years. The suburbs were developed as residential areas to accommodate the population influx from the rest of the country. Yeouido (1967) and Yeongdong (1967) were developed in the 1960s. In the 1970s, Jamsil (1971) was developed to disperse the concentration in Jongro and Junggu. In the 1980s, Gaepo (1981), Godeok (1981), Mokdong (1983) and Sanggye (1985) were all developed as large-scale residential areas.

During the construction of these “new towns”, 2 incineration sites were secured where the Yangcheon Facility (May 1983, construction decided in Mokdong New City Development Plan) and Gangnam Facility (January 1986, city facility decided as waste disposal facility) were built. The other two incineration facilities have undergone similar situations. Mapo Facility was constructed in World Cup Park, part of the Sangam Housing Area which began construction in 2000. Nowon Facility was assigned as a waste disposal facility in December 1977, before the Sanggye area was developed in 1985.

As this shows, construction of incineration facilities connected to new town development makes it easier to find sites for those facilities, and reduce opposition from local residents. Moreover, utilizing the heat from incineration as energy for district heating is another benefit of connecting the construction of incineration facilities with new town development. District heating began in Lockport, New York, U.S.A in 1877, and spread to other parts of North America, Europe and Japan. In Korea, the first such approach was a feasibility study on remodeling of the Seoul Thermoelectric Power Plant into a cogeneration plant to provide heat to Yeouido, Dongbuichon and Banpo in 1981. The actual start was in Mokdong and Shinjeongdong, which provided heat to 20,000 houses. After the first and second oil shock, interest in energy efficiency was high in the 1970s. In 1987, remodeling of the Seoul Thermoelectric Power Plant into a cogeneration plant was determined. In 1989, a district heating scheme was decided for Ilsan and 4 other cities. Along with this trend, the 4 incineration facilities in Seoul could also be connected with district heating facilities. Yangcheon-gu provides heat to 140,000 homes, and the incineration heat ratio for district heating is 16%. Nowon provides heat to 128,000 homes at a 23% rate, and Gangnam to 176,000 homes with a 27% incineration heat ratio. The Mapo area shows the highest incineration

energy rate, as much as 57%. Heat is provided to 70,000 homes.

Figure 5. District Heating & Incineration Facility Locations



In other words, all four incineration facilities in Seoul have district heating facilities, providing heat from waste incineration. The heat recovered makes up 16–57% of the energy used for district heating.

Table 4. Cooperation between Incineration & District Heating Facilities

	Yangcheon	Nowon	Gangnam	Mapo
No. of Homes Receiving District Heating	140,000	128,000	176,000	70,000
Energy Recovered from Incineration Facility	Heat Electricity	Heat	Heat	Heat Electricity
District Heating Energy Source (2012)	Heat from incineration: 15.7% Heat from energy generation 51.0% Produced heat: 33.3%	Heat from incineration: 23.2% Heat from energy generation 37.8% Produced heat: 39.0%	Heat from incineration: 27.0% Heat from energy generation 12.7% Produced heat: 60.3%	Heat from incineration: 56.8% Heat from energy generation 33.8% Produced heat: 9.4%

3) Management of Environmental Pollution

MSW processing emits a variety of pollutants through incinerators, storage systems and transport vehicles. The pollutants include foul odors, dust, nitrogen oxide, hydrogen chloride, sulfur oxides and dioxin.

Dioxin, in particular, was a cause of concern in the early 1990s around the world once the stories came out of soldiers exposed to defoliants during the Vietnam War, and their children who suffered from it. Waste incineration facilities were known as a major source of dioxin.

As a result, people began questioning incineration methods, and concerns arose among neighboring residents regarding environmental safeguards. In response, the SMG has put in place facility installation and operating measures to protect against environmental harm.

First of all, the city has installed and operates extremely complex air purification facilities. The greatest concern for local residents is regarding contaminants that are emitted with gas from incineration. These include heavy metals such as mercury, caustic substances such as sulfur oxides and nitrogen oxide and other toxic materials such as dioxin. Seoul's incineration facilities have neutralization, dust reduction and catalyst facilities to remove such substances, which were responsible for more than 50% of the construction costs. Even during operation, considerable money is spent in such chemicals and energy used in the facilities and replacement of air purification equipment.

The gas emission report in 2012 showed that all 4 facilities emit less than 1/2 of the allowable limit for some substances, and 1/10 ~ 1/1,000 of the limit for others, suggesting that emissions are strictly controlled.

Table 5. Gas Emission Report from Seoul's Incineration Facilities (2012)

	Allowable Limit	Yangcheon	Nowon	Gangnam	Mapo
Dust (mg/S m ³)	20	2.07	1.74	1.14	0.88
Sulfur Oxides (ppm)	30	0.43	0.14	0.29	0.34
Nitrogen Oxide (ppm)	70	23.00	23.78	12.39	16.67
Carbon Monoxide (ppm)	50	10.30	7.16	10.55	1.07
Hydrogen Chloride (ppm)	20	2.26	0.48	2.73	1.15
Dioxin (ng/N m ³)	0.1	0.000~0.009	0.000~0.003	0.000~0.002	0.000~0.000
※ Dioxin emission standard strengthened: 0.5→0.1ng/N m ³ (Jul. 2003)					
※ Dust emission standard strengthened: 30→20 mg/S m ³ (Jan. 2010)					
※ Nitrogen oxide emission standard strengthened: 80→70 ppm (Jan. 2010)					

Second, disposed waste is examined so that the facility does not incinerate toxic materials. Keeping such pollutants out of the incinerators is as important as having excellent pollutant restriction devices in operation.

Mercury and other heavy metals are included in the waste and are emitted as gas into the atmosphere during the incineration process. Dioxin is known to form when aromatic material and chlorine are combined during incineration. Types of waste capable of generating dioxin include food, waste with high water content and PVC products. Therefore, households and businesses are required to keep such materials separate when disposing.

Despite strict management and guidelines, the possibility that such substances might be mixed in the waste cannot be ruled out. Therefore, the incineration facilities search the waste loads brought in by trucks at random for heavy metals and have them return if such materials are found, and the company bringing the contaminated waste in is penalized. It is meaningful that such investigation and monitoring is done by people recommended by the resident consultative group. They work whenever waste is brought into the facility. Right after food waste began being recycled, it made up 10–20% of garbage brought into the facilities. Now it is lower than 5%, mainly because of this monitoring of waste content.

Third, air pollutants are measured in real time and statistics are displayed, representative of the methods used in waste management, along with thorough purification facilities and examining waste brought into the facilities. The system measures pollutants in emitted gas in real time, and then displays these figures to the public. The figures include those from the tele-monitoring system, auto dioxin collection and electronic displays of gas density. To ensure the objectivity of these figures, facility operators are not permitted to be near the measurement devices. The tele-monitoring system automatically measures dust, SO_2 , HCl , NO_x , CO and O_2 , flow amount and temperatures with devices installed in the middle of the incinerator chimneys, and then sends the results to the central control room and the government's control center in real time.

At the same time, results are shown on electronic displays so that local residents can see the numbers. Three electronic displays have been installed in Gangnam, and 1 each in Yangcheon, Nowon and Mapo. Dioxin is the most-feared pollutant among residents: it cannot be measured in real time as other pollutants can. Therefore, analysis needs to be done at labs once every 6 months (within 1 day). This delay, and the possibility for manipulation, caused many to distrust the results. To resolve these issues, the SMG has installed auto dioxin collectors in all chimneys of the 4 facilities. The kit absorbs and stores 3–6 months of dioxin from emitted gas, from which the amount can be calculated. The kit is utilized in analysis of dioxin density, and a new kit is installed to collect dioxin in the following period.

Figure 6. Electronic Display Board of Gas Emissions & Auto Dioxin Collector

Electronic Gas Emission Display Near Incineration Facility



Auto Dioxin Collector Kit



Fourth, the time for pick up is limited, as is the number of garbage trucks. Waste transportation brings odors throughout the city, emits exhaust and increases traffic on the roads. To resolve these issues, the waste is brought in only at night and early morning so that the public is exposed less and the roads not busy. Moreover, waste coming from districts outside the district in which the facility is located should be transported in trucks of at least 11 tons' capacity. This fundamentally limits the number of waste management vehicles.

Policy Effects

1) Reducing Use of Landfills

Seoul does not have a landfill site within city limits, and there is a very low chance that there will be one in the future. Therefore, reducing the amount of waste going into landfill is the core task of MSW management. Sharing the 4 facilities in Seoul contributes significantly to this task.

The amount of waste put in landfill in 2012 was only 10% of the amount in 1997, which was right after Yangcheon and Nowon facilities began operation. The overall waste amount (incineration + landfill) decreased to 1/3. The amount incinerated was up to 3–4 times that in 1997. The landfill rate was thus significantly reduced from 93.6% in 1997 to 25.4% in 2012.

If facilities were not shared and the incinerators only processed local districts' waste (Yangcheon-gu, Nowon-gu, Gangnam-gu, Mapo-gu, Jung-gu, Yongsan-gu), the landfill rate would have remained the same as it was in 2006 – about 76.3%. The statistics explained above are also reflected in Seoul City's waste management record. After facility sharing commenced, the landfill rate of domestic waste recorded about 7.8% in 2012 (it was 61.9% in 1997).

Table 6. Change in Waste Going to Landfill after Facility-Sharing Agreements Signed

	Prior to Agreements			After Agreements Signed	
	1997	2003	2006	2010	2012
Incineration Facilities	Yangcheon Facility Nowon Facility	Yangcheon Facility Nowon Facility Gangnam	Yangcheon Facility Nowon Facility Gangnam	Yangcheon Facility Nowon Facility Gangnam	Yangcheon Facility Nowon Facility Gangnam

		Facility	Facility Mapo Facility	Facility Mapo Facility	Facility Mapo Facility
Amount Incinerated by 4 Facilities (Tons)	187,096	162,795	320,562	740,287	771,110
Landfilled Amount (Tons)	2,730,200	1,866,096	1,033,738	527,790	262,435
Incineration + Landfill (Tons)	2,917,296	2,028,891	1,354,300	1,268,077	1,033,545
Landfill Rate (%)	93.6	92.0	76.3	41.6	25.4
Landfill Rate (%) of Domestic Waste	61.9	42.4	24.8	14.4	7.8

2) Energy Reduction

The low-heat value of MSW brought into the incineration facilities in Seoul is 2,762 kcal per kg. The facilities can recover about 74% of the heat generated from incineration. Part of this heat is used in operations, and most of the remaining is sold to neighboring district heating facilities. Energy sales recorded before facility-sharing was 561,411 Gcal in 2006, increasing to 1,269,336 Gcal in 2012, after the facilities began shared operations.

Before facility-sharing, about 52,000 households got their heat and hot water from recovered energy. Once sharing began, recovered energy was provided to more than 50,000 additional households for heat.

Utilizing heat from incineration also has significant meaning in terms of the environment. The heat from incineration can be used for water and homes, leading to a reduction in LNG consumption. CO₂ emissions are also reduced, leading to a reduced greenhouse effect. The amount of greenhouse gas emissions was recorded as 27,000 tons less in 2006 and 60,000 tons less in 2012. This is equivalent to the annual emissions from 540 buses in Seoul.

Table 7. Comparison of Energy Substitution Effect of District Heating, Before & After Facility-Sharing Agreements

	Before Sharing (2006)	During Sharing (2012)	Note
Amount of Incineration Heat Sold (Gcal)	561,411 (1.0)	1,269,336 (2.3)	▸ Yearly heat and hot water use per home: 10.9 Gcal
Amount of Gas Substituted (LNG m ³) (Homes)	59,597,770 m ³ 51,506 homes	134,749,045 m ³ 116,453	▸ LNG 1 N m ³ = 9,420 Kcal ▸ Yearly heat and hot water use per home: 10.9 Gcal
Reduction in GHG Emissions (Tons CO ₂) (City Buses)	26,725 Tons 239	60,426 Tons 540	▸ LNG 1 N m ³ = 2.23 kg CO ₂ ▸ GHG emissions by Seoul city buses: 112 Tons of CO ₂

Major Challenges & Solutions

1) Local Resident Opposition to Incineration Facilities

From the planning stage, opposition to the incineration facilities had been stubborn from the majority of people, as they were understood to create pollutants including dioxin. During construction, residents living nearby complained that their property values were decreasing and the environment was being contaminated. Due to the strength of the opposition, questions were also raised as to why the SMG was building the facilities, rather than having the 25 *gu*-districts build their own.

Much time was spent resolving the disputes with residents. During this time, public attention shifted to recycling. A total of 14 years (1992 ~ 2005) was spent building the 4 facilities, and there have been 396 instances of opposition from nearby residents. This opposition was usually in the form of group demonstrations (67%), while the rest was through documents. The main complaints varied from fundamental disagreement with the construction itself or changes to plans such as relocation, capacity reductions, and related to installation of strict pollution control facilities.

Solutions

Residents have enjoyed long-term and regular medical checkups. Seoul began monitoring health in 2000 to track any connection between resident exposure and health issues. The city has also run pollution-controlling facilities, limited traffic and monitored the material coming in as waste. While these efforts are to track the health of nearby residents potentially affected by dioxin and other toxins from the incineration facilities, they also help with objective evaluation of the environmental impact. This enables the SMG to confirm the safety of such facilities, resolve resident concerns, and find solutions when negative impact does occur. Investigations are in 3 areas: air quality assessment (environmental impact), assessment of dioxin and heavy metal in blood stream (impact on human body) and assessment of the overall physical and mental health of residents (health impact). Fixed research groups, volunteers and facility employees undergo body and health examinations. Recently, examinations have been only on the fixed research group, while additional pollutants such as dioxin in the atmosphere or black carbon density were added to monitoring. Assessed items, methods and targets are decided upon agreement with the resident consultative group. The 10th examination was conducted in 2014, and none have shown any negative impact on the environment, the body or health.

Table 8. Assessment of Health of Residents Near Seoul's Incineration Facilities

Assessment Period	2000 ~ 2004	2005 ~ 2008	2009 ~ 2012	2013 ~ 2015
Number of Assessments	3	3	3	3
Target Areas	Residential areas around Yangcheon Facility, Nowon Facility, Gangnam Facility			
Assessed Items	<ul style="list-style-type: none"> ▸ Environmental Impact Assessment: dust, heavy metal, odor ▸ Impact Assessment on Human Body: dioxin and heavy metal in blood, etc. ▸ Impact Assessment on Health: medical checkups, recognition and evaluation of quality of life 	<ul style="list-style-type: none"> ▸ Same as the first and second assessments ▸ Added evaluation of dioxin in atmosphere ▸ Added autumn season to environmental impact assessment 	<ul style="list-style-type: none"> ▸ Same as step 3 ▸ Traffic impact assessment as part of environment impact assessment (black carbon, etc.) 	
Assessed Group	Separate assessments of residents and workers in affected and control areas	Separate assessment of residents in affected areas	Separate assessment of residents in affected areas	Assessment of local residents in affected areas
Assessment Method	Separate follow-up study on control group	Separate follow-up studies on control and affected groups	Follow-up study on affected group	Follow-up study on affected group
No. of people assessed	<ul style="list-style-type: none"> ▸ Heavy metals: 270 ▸ Dioxin: 53 	<ul style="list-style-type: none"> ▸ Heavy metals: 270 ▸ Dioxin: 75 	<ul style="list-style-type: none"> ▸ Heavy metals: 270 ▸ Dioxin: 100 	<ul style="list-style-type: none"> ▸ Heavy metals: 360 ▸ Dioxin, tumor marker: 100
Notes		<ul style="list-style-type: none"> ▸ Number of residents targeted for dioxin examinations increased 	<ul style="list-style-type: none"> ▸ Number of residents targeted for dioxin examinations increased 	<ul style="list-style-type: none"> ▸ Tumor marker examination added ▸ Traffic impact added ▸ Comparison of diseases with district-based statistics from National Health Insurance Corporation

Program to Enhance Local Resident Convenience

Subsidies are provided for heating in public housing, monthly maintenance fees or rent, the cost of housing improvements (waterproofing or painting), and facility fees or medical costs for residents in affected areas. The main targets of these subsidies are residents within a 300m radius of an incineration facility boundary. This includes a total of 12,367 households (3,413 households near Yangcheon Facility, 6,190 near Nowon Facility and 2,934 households near Gangnam Facility). The subsidy fund is called the Resident Support Fund, and was created in accordance with an SMG ordinance. The fund is supplied through grants from the SMG and from districts sharing the facility, and income from management of the grants. The SMG grants include money for constructing the incineration facilities and subsidies for heating in affected areas (up to 70%) and is paid to the *gu*-district when the waste is brought in. The subsidy given on bringing in the waste includes 10% for total waste, and an additional 10% paid by neighboring *gu*-districts that share the facility. Funds from these *gu*-districts are decided in the facility-sharing agreement. For Yangcheon Facility, sharing districts pay KRW 21,000 per ton into the fund, separate from the waste fee. The fund's income is mainly from interest earned on the bank account. The total Resident Support Fund was valued at KRW 169.9 billion from 1996 (when Yangcheon Facility began operations) to 2013. The money paid for waste brought into the 4 facilities is KRW 25,260 per ton. Affected areas will receive about KRW 13.56 million per household.

Table 9. Statistics on the Resident Support Fund (1996~2013)

	Total	Yangcheon Facility	Nowon Facility	Gangnam Facility	Mapo Facility
Resident Support Fund (KRW mil.)	169,945	45,230	63,765	60,275	675

Affected Population (No. of households)	12,537	3,413	6,190	2,934	0
Amount Incinerated (tons) (1997~2013)	6,727,728	1,389,705	1,767,559	2,023,626	1,546,838
Resident Support Fund (KRW/ton)	25,260	32,547	36,075	29,785	436
Resident Support Fund (KRW 1,000/household)	13,556	13,252	10,301	20,544	-

Continuous Effort to Earn the Trust of Local Residents

There can exist a variety of reasons for residents to oppose construction of an incineration facility. The most significant ones include a drop in property values, pollution and environmental impact, and impact on health and the human body. The traffic inconvenience due to an increased number of garbage trucks is another one.

Property values do, in fact, drop. However, this effect is exacerbated when the dispute includes demonstrations or other more severe methods of opposition. Where there is no dispute, the impact on real estate disappears. However, Seoul has offered subsidies for heating costs, maintenance fees, rent, facility fees, medical checkup costs and more, based on the decision that potential impact and concern can also be counted as damage to neighboring areas. The Resident Support Fund established in 1996 has offered about KRW 1,356 million per household.

Seoul has taken a few measures to restrict damages to neighboring areas from air pollutants. Resident representatives can observe the facilities to help ensure there is no water, food waste or toxic substances in the waste. When found, the truck carrying it is temporarily suspended from bringing further garbage into the facility, and the waste rejected. Air pollution is measured in real time and displayed on electronic display boards. Items that cannot be tracked in real time are collected for at least 3 months in a tracking analysis. Resident health has been monitored since 2000 to help better understand the

impact on the environment, the human body and health.

These measures are not in place because problems have arisen. They are in place to build trust in the communities around the facilities. The same methods can be used for other waste disposal facilities, such as those for food waste or landfill sites.

Presentations to Hear Residents, Reception of Complaints

Seoul held 121 public discussions and presentations to collect community opinions on construction of the incineration facilities. Neighboring residents objected strongly to the construction, and the result was a planned reduced capacity for both the Nowon and Gangnam facilities (800 tons/day from 1,000 tons/day for Nowon and 900 tons from 1,900 tons for Gangnam). In addition, the Gangnam Facility was at first designed to be shared with Songpa-gu, but the scope was reduced to only Gangnam-gu.

The discussions and negotiations took place over a period of 3 to 13 years. Since the project periods were extended, there have been difficulties in pursuing the plans as the land has been used for other purposes in some cases, or the budgets changed.

A lot more time was also required to obtain agreement from the residents, to use the facilities as regional facilities. For the Gangnam Facility, the SMG and the resident consultative group had about 160 meetings over 5 years, before an agreement on sharing the facility was finalized on May 7th, 2007. As many as 100 meetings took place for the Nowon Facility, and an agreement was concluded on June 30th, 2007. Mapo had 40 meetings over 1 year, and agreed to share use on February 10th, 2009.

Yangcheon Facility took much longer: 9 years. There were 150 meetings, and the agreement was finalized on May 10th,

2010.

Subsidiary Facilities for Residents

These regional incineration facilities have a variety of subsidiary facilities such as swimming pools, fitness centers, golf courses, cultural lecture halls, study rooms and auditoriums. These facilities are available to local residents for low cost.

Table 10. Subsidiary Facilities to the Incineration Facilities in Seoul

	Yangcheon Facility	Nowon Facility	Gangnam Facility	Mapo Facility
Construction Period	Dec. 1992~Feb. 1996	Dec. 1992~Jan. 1997	Dec. 1994~Dec. 2001	Dec. 2001~May 2005
Area	14,627 m ²	46,307 m ²	63,813 m ²	58,435 m ²
Construction Cost (Subsidiary Facilities)	KRW 32.1 Billion (KRW 8.1 Billion)	KRW 74.3 Billion (KRW 9.4 Billion)	KRW 115.5 Billion (KRW 9.4 Billion)	KRW 171.2 Billion (KRW 9.5 Billion)
Subsidiary Facilities	Swimming pool Fitness center Study room Auditorium	Swimming pool Fitness center Cultural lecture hall Study room	Swimming pool Fitness center Cultural lecture hall Study room	Sauna Fitness center Driving range Study room

2) Incineration Facility Installation & Management – Duties & Costs

Seoul has been divided into 25 local *gu*-districts for administrative convenience. Composing physical boundaries for this reason is done all over the world. However, the boundaries act against securing sites for disliked facilities such as waste landfills or incinerators. It might be easier for each district to have its own facilities, but disputes will arise, as the size will

be reduced, along with efficiency. Reduced size also hinders operational stability and the effectiveness of pollution prevention devices.

This is why metropolitan governments, rather than regional districts, install and operate large-scale waste disposal facilities such as incinerators or landfills. Tokyo (Japan), London (England), and Paris (France) operate the same way. Another common factor is that local districts take care of waste collection, transportation and recycling in many metropolises including Seoul. This is because local districts may have more direct contact with residents so it is easier for them to ask for cooperation than it is for the metropolitan government, meaning they can be more effective in collecting waste.

Although the governments of local districts and metropolises have clearly different roles, the demands and location need to be flexible enough to include the views of the local districts. In particular, it is desirable for local districts to determine the facility location and capacity and the districts that will share the facility. This is because the local district governments, rather than the metropolitan government, can better understand its own residents and specific needs for waste management. For example, it took 7 years for the Gangnam Facility to be designed and completed because disputes continued over both capacity and location even after construction started. On the other hand, the Mapo Facility took only 3.5 years, because the districts had all decided the capacity, location and who would share the facility before construction started.

Figure 7. Bottom-Up Construction Process for an Incineration Facility

Local districts request facility installation	<ul style="list-style-type: none"> - Facility capacity (at least 400 tons per day considering heat recovery efficiency) - Agreement from districts that will share the facility - Multiple candidate locations within the sharing districts
Basic design	<ul style="list-style-type: none"> - Regions that will share the facility - Quality and quantity of waste - Division of responsibilities between sharing districts

Determination and announcement of location criteria, selection of candidate locations	<ul style="list-style-type: none"> - Foundation of location selection council – Check accessibility and resident status - Safety in land size, stability of the ground, and vulnerability to water disasters, landslides, and cracks in the land - Identification of restrictions such as cultural artifacts, schools, military facilities, height limitations and the need to protect water supply
Candidate location search	<ul style="list-style-type: none"> - Suggestion of support measures to local communities and affected regions - Results of environmental impact assessment once the facility is installed
Selection and announcement of location	<ul style="list-style-type: none"> - Agreement from residents of affected areas (for a facility in Hanam, consent from 2/3 of residents) - If there is no affected area, agreement from residents of <i>dong</i> and <i>ri</i> (for a facility in Hanam, consent from 2/3 of residents)
Selection of construction company (preliminary design, impact assessment)	<ul style="list-style-type: none"> - Examination of preliminary designs - Evaluation of technological capability and past construction records - Construction cost evaluation
Presentations for residents	<ul style="list-style-type: none"> - Preliminary designs and environmental impact assessment – Collect resident opinions
Commencement of detailed design and construction	<ul style="list-style-type: none"> - Reflect resident opinions - Selection of affected areas selected within 2 years of establishing plans for installation of waste disposal facility, foundation of resident consultative group, and environmental impact assessment
Operational and pre-performance testing	<ul style="list-style-type: none"> - Witnessed by resident representative, or designated organization - Additional construction for final adjustments
Commencement of operations	<ul style="list-style-type: none"> - Various examinations on facility performance - Dioxin density measured - Environmental impact assessment conducted

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