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Analysis of Energy Supply Status based on Operating Performance of Integrated Energy Business in Korea

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Abstract

Electricity demand is surging every year in Korea owing to economic growth and a subsequent increase in energy demand. In particular, heavy cooling load during summer and high heating load during winter to fight heat wave and cold wave, respectively, which are allegedly caused by the unpredictable climate change, trigger electricity peak and unstable energy supply as a result. Integrated Energy Business (IEB), which is known as regional heating overseas, draws attention as a distributed energy that can address such structural issues as blackout in the central supply system. Yet, electricity charge lower than production cost, realistic challenges in direct sales of energy production facilities and energy loss incurred from transporting energy from supply facilities to receiving ends keep it from rooting down in Korea. This study compared number of households, number of buildings to which electricity is supplied, capacity of supply facilities, amount of fuel and production and sales volume of energy in order to determine appropriate supply capacity of heat and electricity in regional cooling/heating areas and industrial complexes based on Korea's IEB operation. Also, the study grouped IEB systems according to sizes of energy supply facilities and compared them so as to suggest an appropriate size of IEB and an effective supply system that can be considered for new housing site projects or re-developed regions.

Keywords: Combined Heat Power Plant, District Heating, Energy Supply System, Industrial Estate Heating, Integrated Energy Business

1. Introduction

It has not been long since IEB became active in Korea. The first cogeneration power plant was built in 1985 to supply regional heating for the first time in Korea after the government approved of new urban development plan in the Mok-Dong and Sinjeong-Dong area in Gangseo-Gu (currently Yangcheon-Gu), Seoul in 1983 to boost energy efficiency and create a pleasant residential environment. Regional heating was supplied to industrial complex for the first time in Ulsan Mipo National Industrial Complex in 1972. However, it failed to take off due to high initial investment cost and indirect cost. Ever since, more players have jumped into IEB as the energy business became privatized and more systems were undertaken to supply heat and electricity to small regions. Characterized by its rapid economic growth and a rise in its people's standard of living, Korea has experienced a significant increase in energy consumption each year. The highest point of demand for electricity ("peak") used to occur in summer, whereas in more recent years peak is being observed even in winter owing to the diversifying factors affecting the nation's energy consumption. The aforesaid changes in Korean people's power consumption patterns are making it increasingly more difficult to predict the demand, which is approaching an extent that necessitates alert. With

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the added pressure of restructuring the power industry, power plants have been constructed in the country as KEPCO went public, however the reality is presenting a rather grim picture. Moreover, the increase in CO_2 emissions generated in large power plants as necessitated by massive consumption of fossil fuels, and the air quality restrictions in place to prevent global warming, etc. have made it unavoidable to place limits on the use of energy generated by fossil fuels. A series of such countermeasures for energy environment have sparked an interest in the co-generation power plant system mostly in developed countries, with co-gen power generation technology being spread in recent years as part of IEB. The status on the spread of IEB (or CES, Community Energy Supply System) overseas include Europe, wherein the system has been actively promoted since the oil crisis in the 1970's, with a concentration achieved in district-based heating and air conditioning for areas densely populated with building structures. Particularly in Denmark, tax breaks are offered to CHP production fuels, with policies in place to power-grid certain areas with district-based heating and gas networks. Germany provides their power business owners with stipends to expand their piping networks or construct new facilities provided they generate at least 60% of their calorific supplies in CHP. In Japan, stipends are being offered to high-efficiency natural gas-based co-gen power plants. The UK classification of CHP capacity is clear as it defines it as 50 MW for large CHP, 5 - 50 MW for medium CHP, and 500 KW - 5 MW for small CHP, 5 KW - 500 KW for mini, and no greater than 5 KW for micro.

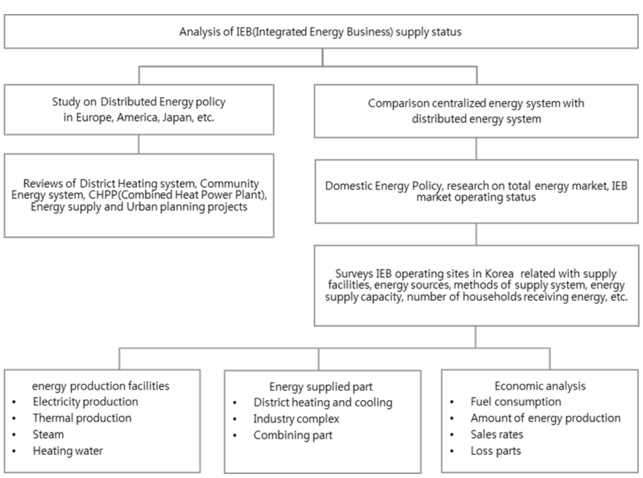

Figure 1. Research flow chart.

This study surveyed performance of integrated energy systems, energy supply size and operation of IEB currently in place and its concept based on IEB system handbook issued by Korea Energy Management Corporation. IEB was divided into two different groups: the regional cooling/heating area and industrial complex area. Energy production relative to fuel amount and the degree of sales were analyzed in accordance with facilities capacity to compare effective energy (heat and electricity) supply capacity. In addition, supply type of thermal and electric energy for number of households receiving energy and type of system introduced were analyzed to suggest penetration ratio of IEB system, limitations of introducing the system, and growth potential. This study will hopefully analyze thermal and electric energy system and suggest optimal solutions for supply infrastructure with the goal to strike a fair balance between IEB's energy supply facilities and energy users. Figure 1 indicates study flow.

2. Description of IEB

2.1 Definition of IEB

IEB is a distributed power type contrary to centralized energy supply. There are other names for IEB depending on size and energy users. In general, integrated energy facilities are defined as ones aimed at comprehensively supplying multiple sources of energy (mainly heat and electricity) produced from at least one energy production facility such as cogeneration power plant, heat-only boiler or resource recovery facilities to multiple users in residential, commercial or industrial complexes. In policy terms, integrated energy is divided into regional cooling/heating systems and industrial complex integrated energy projects. It is also divided based on thermal production capacity and electricity production capacity. Regional cooling/heating refers to supply heat or heat/electricity for heating, hot water supply and cooling purpose at the same time. Thermal production excluding own consumption is greater than 5Gcal/h. Heat or heat/electricity supply systems in industrial complexes require thermal production excluding own consumption to be greater than 30Gcal/h. Community electricity allows the authorized parties to supply or directly sell electricity within the supply zone upon a separate permission from the Ministry of Commerce, Industry and Energy to trade electricity in shortage or in excess with electricity sellers or in the electricity market. Integrated energy supply system (also called as Community energy system) refers to supplying heat or heat/electricity for cooling/heating, hot water supply and processing in industrial complexes in residential, commercial, business, hospital buildings and IT facilities clustered in a certain region. If IEB supplier directly sells electricity with the upper limit of electricity supply capacity of 3.5 KW, the suppliers providing up to 150,000 KW for regional cooling/heating and up to 250,000 KW for industrial complexes are recognized as a community energy service provider. IEB is defined as a new type of power generation business wherein electricity or electricity as well as heat is produced by co-generation facilities or other similar power generation facilities located in certain supply districts and is supplied directly to consumers. In real-world terms, IEB refers to an energy provider empowered to do all of the power generation, distribution and sales operations. Such provider is defined as having a capability of supplying power to meet at least 60% of the district's demand and is required not to compete with other competitors within the same district.

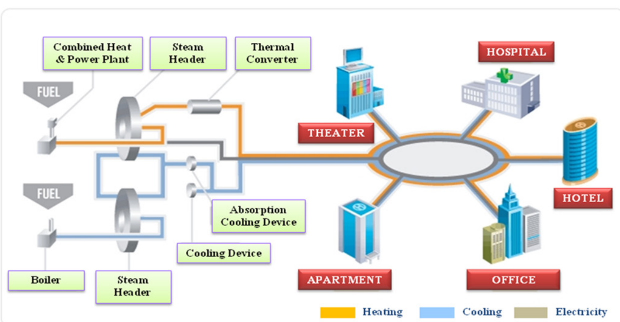

Figure 2. Operational concept map of IEB projects.

2.2 IEB's Energy Supply Method

IEB facilities are divided into energy supplying facilities and energy consuming facilities. The former is intended for producing, transporting and distributing community energy and is classified as those facilities requiring the power seller's management. Energy supplying facilities are divided into heat supplying facilities and heat transporting facilities. Heat supplying facilities refer to those that are related to the production of heat (energy), such as heat generating systems (boilers, turbines/generators, incinerators, etc.), heat pumps, cooling systems, heat exchangers, thermal storage tanks, and other thermal production facilities. Heat transporting facilities include heat transfer pipes, circulation pumps, and other facilities related to thermal transportation or distribution. The heat consuming facilities on the other than are defined as those intended for using community energy, requiring the owner's management. In order to introduce IEB to an area or district, it is imperative that the most economical facility configuration be achieved to accommodate the area or district's load characteristics, and the system-constituting elements (Table 1.) be distinguished as such.

Table 1. System constituting elements of IEB

Energy source	Heat facility	Heat/electricity supplying facility	Applications
electricity, fossil fuels, district heating, LNG, and unutilized energy.	heating facilities, air conditioning facilities, and co-gen facilities.	water heating piping networks, steam piping networks, and cold water piping networks.	heating, air conditioning, and heat-receiving (heat exchangers) facilities.

The basic configuration of IEB is CHP, which is a comprehensive energy system that produces two types (heat, electricity) at the same time from a single fuel. The high-temperature part primarily uses electricity while the low-temperature part uses heat. There are many different ways to generate power depending on fuel used and energy conversion but small-and-medium Combined Heat and Power generation (CHP) type is divided into gas turbine, gas engine, diesel engine and steam turbine. Concept as per capacity is as shown below in Figure 3.

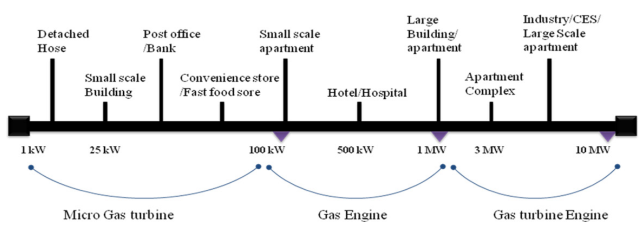

Figure 3. Types of energy supply depending on CHP capacity.

Gas engine cogeneration system can meet 15-2000 KW demand of power generation. Gas turbine cogeneration system can meet demand exceeding 500 KW. The latter is more appropriate for users with higher demand for thermal energy since its heat transfer ratio is higher than that of gas engine.

3. Analysis of IEB Status of Korea

3.1 IEB Status in Korea

The Korean government has steadily advocated a policy to spread IEB. As a result, integrated energy policy has landed as the second heating type following urban gas system, which is individual heating type. Total 84 suppliers in the regional heating and industrial complex sections have earned IEB permission in 111 worksites in late 2013. In the regional cooling/heating area, 31 suppliers are supplying to 55 worksites and 12 new suppliers are building it in 12 worksites. In the industrial complex area, 28 suppliers are supplying to 30 worksites and seven new suppliers are building it in eight worksites. The area practicing regional cooling/heating and industrial complexes have four suppliers supplying to four worksites while two new suppliers are building it in two worksites. All in all, 63 suppliers are supplying integrated energy to 89 worksites (Table 2).

Regional heating is supplied to 2,306,000 apartment houses, which is approximately 14.8% of 15,628,000 houses in Korea. In industrial complexes, steam is supplied to 840 players for processing.

3.2 Thermal and Electricity Production Relative to Fuel Consumption in IEB

As of late 2013, total fuel consumption in 89 integrated energy worksites in service is 11,148,000 toe. This is 4% of 280,165,000 toe in primary energy consumption in Korea. Out of 11,148,000 toe, 4,269,000 toe is for regional heating, 6,559,000 toe is for industrial complexes and 320,000 toe is for both. Thermal production is 63,441,000 Gcal, external heat is 11,211,000 Gcal and heat sales volume is 41,120,000 Gcal. Electricity production is 25,020,000 MWh, which accounts for 4.6% of total power production in Korea (539,174,000 MWh). Electricity received from KEPCO is 6,362,000 MWh and amount of electricity sold is 27,746,000 MWh (Table 3).

Table 3. Amount of fuels consumption by IEB

Category	Amount of Fuels Consumption (TOE)			Total
	CHP	Heat boiler	Others	
District Heating and Air conditioning	3,819,161	433,590	16,002	4,268,753
Industry Complex	4,625,879	1671,151	262,004	6,559,034
Combining part	312,686	7,127	-	319,813
Total	8,757,726	2,111,868	278,006	11,147,600
Rate (%)	78.6	18.9	2.5	100

The following Table 4 indicates operating performance of IEB suppliers based on their thermal and electricity production relative to amount of fuel consumed in 2013.

Amount of own consumption and loss (d) of heat and electricity are shown in the formula below.

- Own consumption and loss (d)
  = production amount (a) + external heat received or electricity from KEPCO (b) – amount of sales (c)

Industrial complexes take the lion's share of d value. Industrial complexes consume a huge amount of energy for their own processes unlike regional heating where most of own consumption is on-site consumption by auxiliary facilities to operate facilities producing energy.

Table 2. Status of ongoing IEB projects

Category	Introduction	Site of businesses	Number of Households/ Buildings	Energy Supply Capacity	
				Thermal (Gcal/h)	Electricity (MW)
District Heating and Air conditioning (Supplied Households)	In Service	55	2,237,635/3,503	14,977	4,144
	Arrangement	12	455,155/	4,439	2,355
	Total	**67**	**2,692,790**	**19,416**	**6,499**
Industry Complex (Supplied buildings)	In Service	30	768	9,835	1,884
	Arrangement	8	106	3,737	950
	Total	**38**	**874**	**13,572**	**2,834**
Combining Part (Households/ buildings)	In Service	4	68,602/72	967	176
	Arrangement	2	11,861/-	1,685	356
	Total	**6**	**80,463/72**	**2,652**	**532**

3.2.1 Thermal Production

Regarding the amount of heat produced, the total amount generated was 69,035 Gcal, of which 85.7% was produced by internal facilities and 14.3% by external supplies. With district heating, of the total amount of heat generated (21,751,000 Gcal), 48.8% was by CHP whereas 17.6% was by heat boilers. In the industrial complex sector, CHP accounts for 69.5% of the total amount of heat produced (45,136,000 Gcal) and heat boilers for 18.6% (Table 5).

In the section combining regional cooling/heating and industrial complex, CHP produces 79.5% and thermal-exclusive boiler produces 2.7% of 2,663,000 Gcal in total thermal production. Regional cooling/heating represents 72.4% of heat received externally. Incinerated heat received when burning waste is 42.1% and production in power plants represents 42.4%.

3.2.2 Electricity Production

Of the total amount of electricity generated (34,394,000 MWh), CHP is responsible for 77.4% of the power generation, while 95.4% of district-based heating is achieved by CHP. As for the industrial complex sector, CHP is handling 58.5% of the total amount of power generated (Table 6).

Table 4. IEB operating performance in 2013

Category		District Heating and Air conditioning	Industry complex	Combining part	Total
Heat (10^3 Gcal)	Amount of production	14,373	46,879	2,189	63,441
	Rate (%)	22.7	73.9	3.4	100
	External heat received	8,112	2,626	473	11,211
	Rate (%)	72.4	23.4	4.2	100
	Amount of sales	20,697	18,199	2,224	41,120
	Rate (%)	50.3	44.3	5.4	100
	Own consumption and loss	1,788	31,306	438	33,532
	Rate (%)	5.5	93.4	1.3	100
Electricity (10^3 MWhl)	Amount of production	17,378	7,177	464	25,020
	Rate (%)	69.4	28.7	1.9	100
	Electricity from KEPCO	1,005	5,345	12	6,362
	Rate (%)	15.8	84.0	0.2	100
	Amount of sales	17,369	10,004	373	27,746
	Rate (%)	62.6	36.1	1.3	100
	Own consumption and loss	1,014	2,518	103	3,635
	Rate (%)	27.9	69.3	2.8	100

Table 5. Amount of heat generated by IEB

Category	Amount of Heat Generated (Gcal)					Total
	Internal Heat Production				External Supplies	
	CHP	Heat boiler	Others	Total		
District Heating and Air conditioning	10,614,403	3,825,831	182,340	14,622,574	7,128,570	21,751,144
Rate (%)	48.8	17.6	0.8	67.2	32.8	100
Industry Complex	31,355,063	8,382,908	3,115,517	42,853,487	2,282,191	45,135,678
Rate (%)	69.5	18.6	6.9	94.9	5.1	100

Table 6. Amount of electricity generated by IEB

Category	Amount of Electricity Generated (MWh)				Total
	Internal Heat Production			Purchased Power	
	CHP	Others	Total		
District Heating and Air conditioning	16,443,931	38,872	16,482,803	744,998	17,227,801
Industry Complex	9,806,809	140,545	9,947,354	6,824,758	16,772,112
Combining part	380,951	-	380,951	12,670	393,621
Total	26,631,691	179,417	26,811,108	7,582,426	34,393,534
Rate (%)	77.4	0.5	78.0	22.0	100

3.3 Classification of IEB Projects depending on Heat and Electricity Supply Capacity

Additionally, analysis was made of the amount of electricity supplied to the households to which IEB supplied power, and of the amount of heat supplied thereto. Of the 55 IEB facilities, those located in non-residential areas were excluded, leaving 54 facilities with which the amount of energy supplied to households was investigated . The amount of electricity being supplied to those households was found to range between 0.2 kW (minimum) and 22 kW (maximum), and the electricity supply (%) against the number of businesses was found to be a mere 30%. As for the heat supply distribution, the analysis found 3 - 70 Mcal/h, of which 20 Mcal/h was the majority case. The investigation also found that in most businesses, the supply of electricity had been abandoned, whereas the supply of heat was being maintained relatively well (Figure 4).

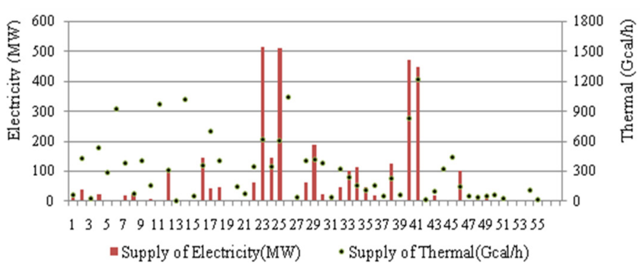

Figure 4. Classification of IEB projects depending on heat and electricity supply capacity.

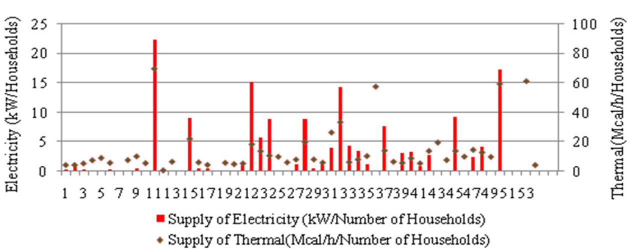

Figure 5. Analysis of amount of heat and electricity supply against number of households

According to the results of investigation of the CHP capacity in each facility that supplies energy, the majority of the facilities were IEB programs supplying energy to massive residential areas. Only 20% of the facilities were using small or medium size CHPs. However, there is still a possibility of such CHP types getting promoted in the country when compared with IEB in terms of the amount of energy supplied to the households (Figure 5).

The results obtained, which had compared the energy supply and demand method hypothesized in this study, offer further possibilities for detailed applications, provided various factors have been taken into consideration.

4. Results and Discussion

4.1 Re-Selection of Integrated-Energy Supply Business Standard

Generally, the standard of such classification is the capacity of heat and electricity supplied. Businesses which received business permission in accordance with Integrated Energy Supply Act are allowed to supply the maximum power load of 150 MW and more than 30 Gcal/h of heat density; industrial complex integrated-energy providers can supply electricity and heat of less than 250 MW and more than 60 Gcal/h in permitted districts; Community energy supply businesses are allowed to supply less than 35 MW of electricity and 5 Gcal/h of heat.

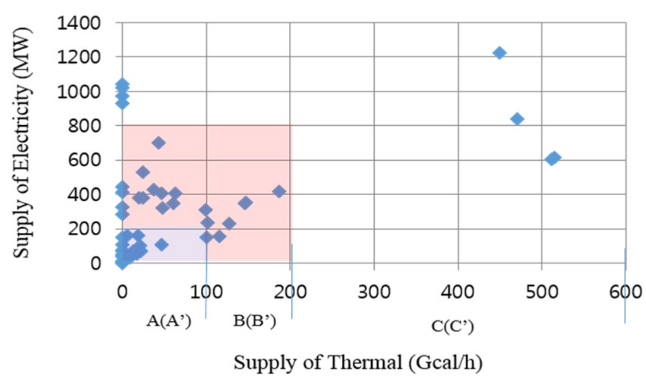

Figure 6. Classification of IEB depending on heat and electricity supply capacity.

Figure 6 shows the distribution of Korea's integrated energy supply based on the capacity of IEB's heat and electric energy supply facilities. It was divided by scale in the scope of businesses implemented in compliance with the Integrated Energy Supply Act excluding small cogeneration system. Largely, the district heating provided for household and commercial use was divided into Group A (200 MW or less, 100 Gcal or less), Group B (800 MW, 200 Gcal), and Group C (1200 MW, 500 Gcal) and that for the industrial complex centering on factories of a certain scale into Group A', Group B', and Group C'. Among current IEB businesses, the facility capacity of Group B to which the district heating belongs took the largest part of the distribution. Industrial complexes were mostly in Group C'. Figure 2 shows the analysis of the record of energy production and sales by group. Group B which takes the largest part of the distribution mostly maintained its energy production and consumption rate at an appropriate level, however, the supply was not fully replenished by the production and the rate of receiving power from KEPCO and heat from other heat sources was high. When the capacity is subdivided in reclassifying IEB, the group with the generation capacity of 100 ~ 150 MW and heat supply of 30 ~ 40 Gcal formed the largest part of the distribution among the ones belonging to Group A, and therefore, the level of electric energy and heat supply shall be divided into sub groups.

4.2 Economic Efficiency based on Own Consumption in Loss in Each IEB Group

Regional cooling/heating and industrial complexes were divided by IEB group. Thermal and electricity production, heat received from outside, amount of electricity received, and ratio on sales and loss in each worksite are indicated in the Figure 7 below.

Own consumption and loss by each group in regional cooling/heating were around 5% for heat and a little higher than 27% for electricity. Heat and electricity were only 2% and 15%, respectively, in industrial complexes because of the high ratio of own consumption, which was excluded in the calculation.

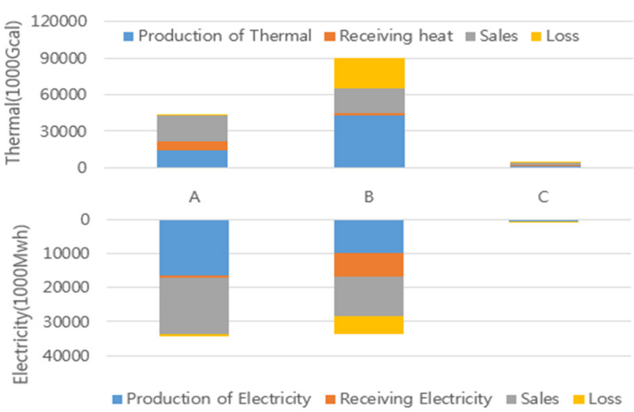

Figure 7. Analysis of the energy production and sale rate by group.

5. Conclusion

This study investigated the current status on the supply of IEB in the Republic of Korea, utilized the results to identify the overriding patterns in its heat and electricity supply, and examined scenarios for introducing optimum IEB for future applications.

The main findings of the study are summarized as follows:

- So far, the percentage of fuels used to operate IEB programs in Korea is 84% for CHP and 14% for PCB. With district-based heating and air conditioning in areas exclusive of industrial complexes, 67% is by internal heat generation and 33% by external sources. The percentage of electricity generated stands at 77%, with the remaining 23% being received from KEPCO. However, a mere 30% of the total applications is being supplied to businesses via power generation.
- Facilities capacity in IEB was 28,532 Gcal/h in thermal capacity and 9,675 MW in electricity capacity for regional cooling/heating. In industrial complexes, thermal and electricity capacities were 16,448 Gcal/h, 3,532 MW, respectively, while in the area that carries both, they are 3,346 Gcal/h (thermal), 965 MW (electricity).
- Thermal and electricity production, sales, own consumption and loss were compared by dividing worksites in industrial complexes and regional cooling/heating into three groups based on installation capacity.
- The amount of power supplied to the recipient households was estimated to be 1 KW on average, whereas the supply of heat was estimated to be 15 Mcal/h on average. Given the fact that each business adopts different supply systems and power/heat receiving and distributing programs, any future studies may establish optimum IEB supply standards based on individual factor analysis.

At present, the amount of power supplied by IEB against Korea's final energy consumption stands at around a mere 5%. However, considering the reality wherein demand for electricity is increasing continuously in Korea, co-generation system holds a large promise for contributing significantly to ensuring of power generation facilities whose construction is constrained by land acquisition and logistics challenges. Particularly considering the fact that co-gen power plants are mostly located in demand-concentrated areas, they are thought to contribute substantially to reducing power distribution loss, mixed costs, and facility construction costs.

6. Acknowledgment

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