8. Integrated Energy Supply Program

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1. General

Background & Overview: Integrated Energy Supply in Seoul

The supply of integrated energy to apartment complexes in Korea began in Seoul. South Korea is highly dependent on other countries for its energy, and the supply of integrated energy is essential as it promotes energy conservation on a large scale to preserve the environment and reduce the burden on citizens.

When the Energy Use Rationalization Act was enacted in 1980, it included stipulations on the supply of integrated energy, but the method was very unfamiliar and required prohibitive investment in the early stages, making it impossible for ordinary entities to participate.

Being an extremely overpopulated city, Seoul was in dire need of residential apartments and needed to disperse its concentrated population. With the development of new residential land, Seoul became the first city in South Korea to adopt an integrated energy supply.

Toward the end of 1982, plans were devised to create a new built-up area in Mok-dong, something which was kept under wraps to prevent real estate speculation, under leadership of the late Kim Jae-ik (killed in the Aung San terror bombing incident), the former Senior Secretary to the President for Economic Affairs.

Provision of energy to La Défense (on the outskirts of Paris, France) was used as the benchmark for an integrated energy supply model.

As Seoul was the first South Korean city to adopt this model, the Ordinance on the Construction & Operation of the Integrated Energy Supply System was passed in 1983, and the Korea Energy Management Corporation (KEMCO), an institution designed to save energy, was commissioned with the task. Construction began in November 1983.

However, KEMCO had no experience to assist it in its new responsibility. For supervision, a reputable engineering company was selected in Europe, and the Design-Build method was used to choose a construction company. Construction finished in 1987.

Supply of Integrated Energy to Existing Apartments in Seoul

In 1984, the City of Seoul benchmarked overseas use of integrated energy in Copenhagen (Denmark), Helsinki (Finland), and Paris (France) for its integrated energy system in Mok-dong, convinced that the program could be applied to existing apartment complexes. Accordingly, the city and the central government jointly participated in the integrated energy project targeting 38,000 apartment units in Yeouido, Dongbu Ichon-dong, and Banpo. For this, a separate legal entity (today's Korea District Heating Corporation) was set up, the city's share of which was 27% (approximately KRW 3 billion).

The KDHC initiated construction in November 1985, with work progressing smoothly until November 1987. Before the Olympics in 1988, all heating piping was complete.

1991 – 1994: Replacement of Fuel with LNG & Concurrent Servicing; Expansion of District Heating to Existing Apartments

From 1991 to 1994, apartment complexes were to shift from bunker C fuel to LNG, depending on their size and age, pursuant to the Environment Minister's decree. Accordingly, apartments in Gangnam, Seocho, and Songpa that adopted the central heating system lodged a request with the City of Seoul and the Ministry of Energy & Resources that district heating be expanded beyond Mok-dong, Yeouido, Ichon, and Banpo.
Furthermore, Seoul decided to supply integrated energy as was being done in the new areas of Mok-dong when it set up a body in charge of new site developments in Gayang, Banghwa, and Deungchon (Gangseo-gu), Daechi and Suseo (Gangnam-gu), and Shinnae (Jungnang-gu), and began to build apartments for lease.
The supply of integrated energy rose substantially as a result of the Environment Minister's decree mandating the switch to LNG and as new development sites expanded in Seoul.
By 1995, integrated energy was supplied to a total of 170,000 households in Mok-dong, Gayang, Deungchon, Banghwa, Nowon, and Jungnang; with the supply of integrated energy to the newly developed cities in the Seoul metropolitan area such as Bundang, Pyeongchon, Ilsan, Bucheon, and Jung-dong, the coverage of district heating was expanded to include 120,000 households in the Bundang-Seoul and the Daechi-Gangnam-Seocho-Banpo-Ichon-Yeouido lines. A decade ago, Seoul was already supplying district heating to some 290,000 households.

Nanjido Landfill Site Rises as a Key Commercial Center

The City of Seoul began a project to transform Nanjido, a landfill for some 30 years, and its environs into an attractive commercial and residential area with a park. The city benchmarked Orange County, Los Angeles (USA) where a landfill became a commercial/residential area that would later be a desired LA location.
In 2000, Seoul extracted the landfill gas and used it to fuel the integrated energy facilities as a way to stabilize the foundation and remove odor. Gradually, integrated energy began to upgrade the quality of life for Seoul residents.
As of the end of December 2013, half a million households used district heating. Following is a history of this move.

2. District Heating Supply by Gu District Office (13 Offices in Seoul) (As of December 31, 2013)

Table 1 - Areas Supplied by the KDHC: 261,591 apartment units and 255 buildings under the jurisdiction of 7 gu district offices

	No. of Households	No. of Complexes	No. of Businesses & Public-use Buildings
Gangnam-gu	85,299	135	65
Mapo-gu	15,373	27	38
Seocho-gu	47,780	77	15
Songpa-gu	75,342	64	28
Yeongdeungpo-gu	10,024	25	97
Yongsan-gu	12,923	35	6
Eunpyeong-gu	14,850	39	6
Subtotal	261,591	402	255

Table 2 - Areas Supplied by SH Corporation: 241,051 apartment units and 258 buildings under the jurisdiction of 6 gu district offices

Category	No. of Households	No. of Complexes	No. of Businesses & Public-use Buildings
Yangcheon-gu	56,869	89	138
Gangseo-gu	52,543	59	73
Guro-gu	2,247	4	-
Nowon-gu	96,705	81	21
Dobong-gu	14,702	11	4
Jungnang-gu	14,985	16	22
Subtotal	241,051	260	258

3. 1983: Construction of a New Town in Mok-dong & the Supply of Integrated Energy

New Town in Mok-dong

In 1983, the City of Seoul selected the Mok-dong area, located 20 km to the west of the city center (City Hall), for a new site development project. The area was prone to flooding in the summer so few people lived there, making it easier to develop the site. Moreover, Mok-dong was fed by a branch of the Han River, and the

adjacent waterfront areas and basins had the potential to accommodate public sports facilities.
The framework of this plan was devised by the City of Seoul and the Office of the President (the late Kim Jae-ik as the Senior Secretary to the President for Economic Affairs).
In order to turn the flood-prone area into a new residential site for 34,500 households, the land needed a massive amount of earth. A hill in Shinwol-dong, Gangseo-gu, approximately 15 km away from the site, was used to source the required earth. On the new site, apartment housing was constructed to accommodate 2,500 households.

Progress in the Development of the Mok-dong Integrated Energy Plan

In 1983, South Korea did not have an 'integrated energy' supply system, but looked at the aforementioned European cities as benchmarks (plus Herning, Denmark). In the new town of Mok-dong, a resource recovery facility (waste incinerator) and a combined heat and power (CHP) plant were installed and a comprehensive energy supply plan established which also embraced renewable energy, such as heat from sewage.
Compared to the existing methods where individual units in apartments and commercial arcades install their own heaters, district heating required a hefty initial investment and was the subject of controversy between the program entities, including the City of Seoul. The conditions upon introducing district heating in Europe were therefore analyzed to compare with those in Mok-dong (see table below), with results showing that Mok-dong was an optimal place to introduce district heating.

Table 3 - Europe vs. Mok-dong: Introducing District Heating

	Unit	Condition	Mokdong Development Dis-trict in Seoul
Heating Degree Days	Heating Degree Days (18-18)	2,000 or higher	2,935
Heat Consumption Density	Gcal/K ㎡ h	20 or higher	38.2
Heat Transport Distance	Km	15 – 20 km	4.5 km
Heating Area	1,000 ㎡	1,200	4,600

Size & Location of Facilities

Incinerators and heat production facilities need to be detached from apartments, commercial arcades, and other residential and living facilities to allow easy access by vehicles carrying fuel or garbage and to minimize noise and odor from heat production. These facilities were therefore set up in the 22,000 pyeong (approx. 72,722 ㎡) area at the northern end of the Mok-dong New Town in order to pre-empt complaints from the community.
The size of the facilities should be adequate to meet the heat demand while minimizing initial investment.

Naturally, projection of demand is one of the most crucial factors. Because apartments were confirmed and sold by lot from the planning stage, it was easier to forecast the heat demand, but the buildings would be completed in different phases, even a decade after the first residents moved in. The range of building floor space ratio was great, from 300% to 900%, making accurate projections more challenging.

Despite such difficulties, the facility size was determined according to the coverage area for apartment/building heating in the Mok-dong New Town (3,367,770 ㎡) with a maximum heat load of 276.6 cal/h.

Since CHP plants require heavy investment, Mok-dong decided to limit heat production at 25% of maximum heat load, producing 20,000 kW/h in electricity and 42 Gcal in heat. Heat-only boilers were installed, taking into account peak demand in the winter months (heat-only boiler capacity: 140 tons/h × 2 units; 80 tons/h × 2 units).

Construction & Operation of Integrated Energy Facilities in Mok-dong

Back in 1983, Seoul had no experience with integrated energy systems. The City commissioned KEMCO with installation and operation of the facilities, a public organization that manages energy demand and energy conservation.

In December 1983, Seoul and KEMCO signed a commissioning agreement that KEMCO would build and operate the facilities for Seoul for the period between December 1985 and 31 December 1998.

Incinerator size was designed to handle 200 tons/day, disposing of all volume to be produced in the Mok-dong New Town. By 1996, the incinerators were changed to handle 550 tons/day.

Features of the Integrated Energy Facilities in Mok-dong

In Mok-dong, 'utility-pipe conduits' were installed for the heat production facilities and at user apartments, commercial arcades, and business buildings, instead of burying heat pipes underground. Heat pipes were then installed within the conduits so as to prevent traffic congestion or interruptions while replacing or repairing pipes in the future.

Furthermore, the insulation requirements were reinforced for the outer walls and foundations of general apartment and multi-household housing in 1983 as a way to promote effective energy conservation. The consumption in this area was therefore relatively lower than in housing built in the 1970s in Yeouido, and residents paid less for heating.

Installation & Operation of User Facilities

District heating came with automatic controllers in the machine rooms, such as plate heat exchangers and devices for external air temperature compensation. However, employees at the apartment management of-

fices had never seen such devices and were unable to operate them properly, creating a source of complaints from residents.

On June 7, 1986, the City of Seoul passed a city ordinance to have KEMCO, the supplier, maintain and manage user facilities, from machine rooms to thermal meters for each household.

From 1986 to 1992, maintenance was carried out in a redundant manner as KEMCO's responsibilities overlapped those of facility employees. Consequently, operating expenses, including labor costs, grew. During the time period under KEMCO management, apartment offices learned to operate the machinery, stabilizing the supply of heating. From April 10, 1995, maintenance and management of the resident-owned heating facilities was no longer carried out by the heat supplier but by the apartment resident representatives' council and the apartment office.

Expanded Heat Supply to Developed Sites in Gayang & Banghwa (Adjacent to Mok-dong)

In 1990, 4 years after integrated heating supply began to Mok-dong in November 1985, the City of Seoul established plans to develop new housing sites in Gayang and Banghwa and adopted Mok-dong's integrated energy model. To minimize investment in production facilities, heat-only boilers were installed, and Mok-dong and Gayang districts were connected by underground heat pipes.

By September 1992, heat was being supplied to 39,000 households in Gayang, Banghwa, and Deungchon; by 1995, this had increased to 73,600 households. As of 2013, district heating was supplied to 114,659 households in the areas under jurisdiction of the Yangcheon, Gangseo, and Guro-gu district offices.

Despite increasing heat demand in Gayang and Banghwa, additional CHP plants were not built; thus the operation rate of the heat only boilers was increased, which came with higher production costs, higher overall costs and higher heating bills.

In 2016, Seoul plans to add a CHP plant to the new development site in Magok-dong to enhance the supply from other CHP plants. GS Power will utilize waste heat from the plant and reduce production costs.

4. 1993: Integrated Energy Supply to Existing Apartments in Nowon, Seoul

Introduction

The positive effects of integrated energy (energy conservation, reduced pollution, lower heating bills, etc.) were confirmed in Mok-dong in 1985 and Yeouido, Ichon, and Banpo in 1987. Based on these outcomes, Nowon, with a concentration of apartment complexes, also adopted the system by way of the CHP plant,

including the use of waste heat from incinerators. District heating supply to Nowon began in conjunction with Shinnae sites in Jungnang-gu.

Pursuant to Seoul Mayoral Policy #456 in June 1992, the construction of integrated energy facilities was initiated, with plans to cover 102,500 households in 10 dongs (administrative zones) under the jurisdiction of 3 gu district offices, with heating supply beginning in December 1994.

Facility Size & Features

The CHP plant produced 37Mw in electricity while the incinerator disposed of 300 tons of waste a day. Learning from experience in Mok-dong, the incinerator site was located far from the housing site to pre-empt complaints from the residents.

Heat pipes measured from 20 mm to 750 mm in internal diameter; 70.5 km of heat pipers were buried (2 lines for a total of 141 km). Main heat pipes for haulage of 300mm or greater came with leak detectors for early detection and prevention of major leaks.

As with Yeouido, Ichon, and Banpo, Nowon also switched from central heating to district heating, with the apartment management offices maintaining and operating the user facilities, again potentially a cause for resident complaints. To avoid this, promotional activities were held and maintenance staffs at the apartment management offices were provided with free training at the early stages in 1995.

Effects of Integrated Energy Supply in Mok-dong & Nowon

As opposed to central heating, district heating significantly reduced energy use and air pollutant emissions (the latter by 25%). In addition to creating a pleasant environment, it allows residents to pay approximately 20% less than with central heating. The general preference for district heating is quite high.

5. 1987: Former Seoul Thermal Power Plant; Central Heating to District Heating; Integrated Energy

Introduction

Between 1982 and 1985, Seoul Thermal Power Plant, located adjacent to the Han River in Dangin-dong, Mapo-gu, Seoul, was refitted as a CHP plant to produce heat and electricity simultaneously, and plans were reviewed to switch the existing apartment heating to district heating.

In 1982, the Ministry of Energy & Resources commissioned a Danish engineering company called Bruun & Sorensen (via KEMCO) to conduct a feasibility test and create basic designs. A project entity was required

to conduct this project, but KEMCO was by its nature not-for-profit and therefore unfit for the district heating
program. A separate legal entity was required.

On July 31, 1984, the South Korean government held an economic ministerial meeting in which the deputy mayor of Seoul also participated. Between 1985 and 1987, the central government planned to invest KRW 2.66 billion and the City of Seoul KRW 3 billion (for a total of KRW 5.66 billion) to create a legal entity; the Korea Electric Power Corporation contributed KRW 4.6 billion in kind for the transformation of the Seoul Thermal Power Plant. With this paid-in capital of KRW 10.26 billion, the KDHC was founded. The central government provided the payment guarantee, and a total of KRW 42.6 billion was procured for construction, with KRW 20.6 billion from the Asia Development Bank and KRW 22 billion from the Special Account Energy Fund.

Today's KDHC was therefore set up on November 1, 1985. On November 15, 1987, the district heating service began, supplying heating to 38,000 apartment households in Yeouido, Dongbu Ichon-dong, and Banpo.

Construction of Heat Production Facilities

Installed in 1968, the Seoul Thermal Power Plant was in operation for 22 years. It was then transformed to produce both heat and power. It was changed to extract steam from cross-over pipes going from central turbine to low-pressure turbine to heat the water in the heat exchanger of the DH pump station. Heated water was then pumped to Yeouido, Dongbu Ichon-dong, and Banpo at a temperature ranging between 75℃ and 115℃; heat was exchanged at the individual user level, after which the temperature would go from 65℃ to 40℃ and be recovered by the DH pump station.

In the beginning, only 375Mw were produced; after transformation of the Seoul Thermal Power Plant into a CHP system, the facility produced 283Mw of electricity and 391Gcal/h of heat.

Unlike some other types of heating, district heating requires an accumulator. An accumulator stores heat when it is not needed during power production, as peak demands for power and for heat do not always correspond. The temperature at which heat is supplied exceeds the boiling point of 100℃ and could potentially vaporize in the pipes. To prevent this, an accumulator was installed to maintain the pressure.

The capacity of the installed accumulators at the time was 20,000 ㎥, and was 36 m in height and 27 m in diameter. Temperature detectors were added at regular intervals to remotely detect temperature distribution from the top to the bottom of such accumulators.

Construction of Heat Pipe Facilities

Two rows of heat pipes were buried (for supply and recovery), each 52.3 km long. The pipes under the Han River between Mapo and Yeouido (1 km) were comprised of 3 rows (for supply, recovery, and backup). Backup pipes were added during the dry season, as the river is 10 m or deeper. The construction work entailed many difficulties as it was the first of its kind in Asia.

Heat pipes were pre-insulated; carrier pipes were steel and casing pipes were high-density polyethylene (HDPE). In between, polyurethane foam was used for insulation.

Should a leak occur in or out of the insulated pipes, it can be detected by the heat pipe monitoring cable, located at the center of the insulating materials. The non-compensated method was selected for the first time in South Korea, burying insulated pipes in the ground that do not compensate for temperature changes in the heating water. The pipes that cross the river were specially made 3-layer insulated pipes so as to prevent additional work.

In Yeouido, utility-pipe conduits had already been installed, and the existing pipes with power cables were used, adopting the compensated method. Yeouido is geographically in a loop, and loop heat pipes were used for better stability of heat supply. In Dongbu Ichon-dong and Banpo, diverging pipes were used to decrease investment costs.

Heat pipes were placed 1.2m from the ground surface; when there was storage, they were buried as close as 0.6m. If a 0.6m depth could not be met, protective measures were taken, such as using concrete pads.

Renovation of Machine Rooms at Existing Apartments & Other Buildings

With the existing central heating systems, heat was turned on intermittently (2 – 3 times/day) during the winter, with the heating circulator pumps needing repair or replacement. With the switch to district heating, new devices were installed such as plate heat exchangers, pressure controllers, and automatic devices for external air temperature compensation.

Main calorimeters were installed at some 200 machine rooms dispersed across Yeouido, Dongbu Ichon-dong, and Banpo to measure heat consumption at user point. The measurements were remotely taken and sent to the central control room at the Seoul Thermal Power Plant, enabling efficient supply of district heating in real time.

Technicians at the apartment management offices were not trained well in operation of the new devices in the machine rooms or with the 24-hour heating switch system. This resulted in excessive heating, with usage soaring by 30% in November 1987 year on year.

Experts were dispatched to 39 management offices to provide technical training on more efficient use of the heating supply, and district heating stabilized as the number of heating/circulator pumps was reduced.

Benefits

As a world first, a thermal power plant was refitted and central heating facilities switched to district heating facilities.

Generally, an integrated energy supply program is an urban infrastructure program that requires that most heat production and pipe facilities are built and installed in the early stages of the program, and the burden

from early investment is prohibitive. However, heat demand increases gradually, depending on when residents move in. As a general rule, there are operational losses for the first 5 or 6 years at least.

With the program mentioned herein however, heat was already being supplied beforehand to the target areas. There were operational losses in November and December of 1987 when the heat supply was first set in motion, but in 1988 and onwards, net profits accrued. The debt ratio was 400%, but there was no issue with the repayment of the ADB/Fund loans.

In terms of energy conservation and air quality improvement, the program was a great success. From 1988 (when the heat supply began in earnest) to 1993, district heating saved 533 TOE in energy over central heating; this translates into KRW 114.4 billion, a savings of nearly 50%. District heating also helped reduce air pollutants by 1,444,946 tons over 6 years – approximately 48% less on average per annum.

This 3-birds-with-1-stone effect was what helped 4 new cities in the capital area – Bundang, Ilsan, Pyeongchon, and Bucheon Jung-dong – to adopt the integrated energy system from the 1990s.

6. 1992 & 1996: Integrated Energy in Gangnam, Seocho, Songpa

In Gangnam and Seocho in Seoul, apartments were built mostly between 1975 and 1980 and were centrally heated. Particularly from 1990 to 1993 when the switch from bunker C to LNG became mandatory pursuant to the Environment Minister's decree, these apartments did not switch to LNG but to district heating.

In 1991, the City of Seoul reviewed district heating in its plans to develop Suseo and Daechi. As a result, a 90,000 kW CHP plant began construction in the new city of Bundang, 16 km away from Suseo. Two rows of heat pipes were installed between Bundang and Suseo, and contingency heat-only boilers installed in Suseo. This project embraced new development sites in Gangnam, Seocho, and Daechi, and supply of district heating was approved by the Minister of Energy & Resources.

As a result of this approval, district heating was supplied to the existing 85,000 households in Apgujeong and Seocho, as well as 15,000 households in the new apartments in Suseo and Daechi – about 100,000 households in total.

By 1996, Songpa faced collective complaints from the residents of the existing centrally-heated apartments in Jamsil Jugong Complex 1 – 4, waiting for reconstruction, and in Munjeong-dong, who were demanding district heating.

Korea City Gas (currently Cowon Energy) strongly objected, fearing that the demand for heating LNG would drop, but centrally-heated apartments that used LNG ultimately opted for district heating, as residents were well aware of the advantages of the new system.

Accordingly, the KDHC installed heat-only boilers at the heat sources in Suseo and Irwon. Waste heat from the incinerator covering the Gangnam area was used to supply district heating to some 120,000 households.

7. 2001: Use of Nanjido Landfill Gas & Integrated Energy Supply to Sangam, Mapo-gu, Seoul

Introduction

Seoul had plans to turn the Nanjido landfill into a park. It also planned to use the gas collected from the landfill for district heating; as for the waste heat from the incinerator (resource recovery facility) in Nanjido, Seoul reviewed plans to use it for district heating at the Sangam site in Mapo-gu (facilities related to the World Cup Stadium), and multi-household housing in Seongsan.

In line with these plans, the KDHC proposed to bury heat pipes in Seoul, connecting Ilsan (Goyang) to the Seoul Thermal Power Plant in Mapo (Seoul) and further ensuring connection to Nanjido and Sangam, ultimately winning approval and beginning construction of heat production facilities in Sangam in March 2000. These were completed by the end of November 2001, and were the first to supply district heating through the use of landfill gas.

It is worth noting that at Digital Media City (DMC) in Sangam-dong, Nanjido heat production facilities used district heating to produce cold water (4C°) which was supplied via 2 rows of pipes to the corresponding buildings, creating a new type of heating and cooling system.

To produce this cold water, an ice storage system, district cooling circulator pumps, turbo chillers, and absorption refrigerators were put in place on July 31, 2006. Heat pipes were completed between March 2000 and the end of June 2003.

8. Connecting 11 Heat Production Facilities in Metropolitan Seoul to Maximize Energy Efficiency

In 2008 and 2009, the KDHC launched commercial operation of the 530 mW CHP plants in Paju and Hwaseong, thereby completing the 99 km long main heat pipes for haulage that connect Paju - Goyang – Sangam (Seoul) – Seoul Thermal Plant - Yeouido - Dongbu Ichon-dong - Banpo - Seocho - Gangnam - Songpa - Bundang - Pangyo - Gwanggyo – Suwon Yeongtong – Hwaseong. An integrated operation center was founded to provide integrated supply of heat.

This system enables 11 facilities to maintain their heat production as economically as possible, based on data such as yearly external air temperatures, power demand in Korea, and the heat demand in corresponding areas. Some 1.01 million households in Seoul and the capital area benefit from this stable, affordable source of district heating.

As of 2013, energy savings totaled 704,643 Gcal, with residents paying 4.9% less for heating, tantamount to KRW 46.6 billion saved. The financial burden lessened, as did the burdens on air quality and the environment.

Plans for the future include wider connection of the metropolitan Seoul area, such as the 4 km segment between Yeouido and Mok-dong, or Mapo and Nowon.

9. Implications & Evaluation

Of the 10 million people in Seoul, 2 million use district heating, supplied by 2 public organizations, one of which is the City of Seoul.

So far, integrated energy has helped decrease energy use by 30% per annum and reduced carbon dioxide emissions by 40% and pollutants (e.g., nitrogen oxide) by 25%.

Compared with individual heating where separate heaters are installed for each household, district heating users pay 20% less in heating per year.

Those apartments adopting district heating since 1989 have thermal meters and temperature controllers at home, allowing residents to save more energy as they see fit. More households are able to control their home environment, as is often the case in advanced nations.

In the meantime, Mok-dong and Nowon have a small CHP plant (less than 100 MW), and pay approximately 8% more (in winter) than those homes that are connected to a large CHP plant (100MW or greater). Compar- atively, this results in a chronic operational loss.

The City of Seoul therefore plans to address these issues by securing heat from larger adjacent plants via heat pipes as soon as possible.

10. Overseas Applicability

For the 32 years between 1983 and February 2015, South Korea has had a wealth of experience with integrat- ed energy. This can be invaluable in applying the system in major central and western Asian cities.

As a first step, Seoul would do well to invite civil servants from cities in Uzbekistan, Kyrgyzstan, Sri Lanka, India, and Bangladesh and share its experience of the last 3 decades.

In the meantime, Seoul may also consider new land site development projects in overseas cities and invest in their integrated energy infrastructure. These projects can be funded by payments in minerals and other resources in kind, or through loans procured from the IBRD or the ADB.