District Heating and Cooling in the Pacific Rim: A Growth Industry

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Pacific Rim Countries Seeing Exponential District Heating and Cooling Growth

It's been just a few short years since the International District Heating and Cooling Association first held its annual conference on the west coast of the United States. This year, the IDHCA returns to the west coast — Seattle — but with a view not limited to the borders of North America. This year, we look even beyond the Pacific Ocean to China, Japan and Korea. These countries of the Pacific Rim, with cultures dating back thousands of years, have developed district energy cultures as well. As international energy business continues to grow, District Heating and Cooling offers a look at the progress and needs of the district heating and cooling industries operating and growing thousands of miles west of the North American shores.

In recent years, more contact and correspondence has been occurring between the district heating and cooling industry in North America and representatives of the Chinese, Japanese and Korean district energy organizations. Except for an article about district heating in Japan published in the second quarter 1989 issue of District Heating and Cooling, however, not much has been published about district heating and cooling in these three prominent Asian countries. While heating is several decades old in China and Japan, it is not even one decade old in Korea. Systems in China and Japan serve a diverse consumer base, each with a rather strong residential load. Korea's focus is mainly residential, as new cities are being built.

Energy conservation and environmental improvements are goals of all three, and in all three countries, the goals are already being realized. But the contribution district heating and cooling can make to new or improved infrastructure is a major driving force. As in North America, district heating has been in place the longest, with district cooling being developed more aggressively in recent years. Unlike North America, however, a district cooling technology based on hot water absorption is gaining widespread acceptance in Korea.

IDHCA received considerable cooperation from the Chinese, the Japanese and the Koreans in the preparation of these articles, and we thank them for their high-quality assistance. The opportunities evident for significant technical collaboration in the future are extensive and exciting. We hope these pages will provide information that will make visits and technical information exchange among the international delegates to the 1994 IDHCA Conference in Seattle even more meaningful.
Residential Focus Key to Korea Growth

Korea plans to supply district heating to 1.5 million households in and around the capital city of Seoul by the year 2001, with an additional 300,000 households to be supplied in the provinces. At that time, 15 percent of Korea's heat will come from district heating, up from the current 4 percent nationwide. The saturated heat load is expected to be 9,000 Gcal per hour (35,716 MMBtu per hour). That's an impressive goal considering that the Korean district heating industry is barely a decade old. The industry's rapid growth is closely linked to government policies on urban development and redevelopment, pollution, and energy conservation.

Korea District Heating Corporation (KDHC), which is the largest utility in Korea, was established in 1985 and restructured as a public corporation based on the Integrated Energy Supply Act in order to contribute to the efficient implementation of energy savings and environmental improvements in Korea as well as to expand the district heating systems throughout the country.

A Look at the Total Picture

District heating is seen as an integral part of the solution to one of Korea's major problems: the overpopulation of Seoul. One-fourth of Korea's population lives in the capital city. To cope with the burgeoning problem of the capital's overpopulation, the government has a long-term plan to disperse the population to provincial areas and newly built cities by relocating economic activities and development.

Presently, Korea has seven district heating systems, all built within the past 10 years, which will serve a total of 617,000 households.

Presently, Korea has seven district heating systems, all built within the past 10 years, which will serve a total of 617,000 households when saturated. (Currently 268,000 households use the service. In comparison, there are 237,000 total households in Seattle proper and 1 million in Chicago.) The systems are located in Pundang, Anyang, Koyang, Puchon, Kangnam, Chungang, and Mokdong. KDHC owns the first six of the seven systems; the last is owned by the Seoul government. The three networks of Kangnam, Chungang and Pundang are interconnected with each other for more reliable and stable heat supply.

The seven systems have a total heat load of 4,430 Gcal per hour (17,580 MMBtu per hour) when saturated, 1,547 Gcal per hour (6,139 MMBtu per hour) currently, and a total current heat production capacity (both combined heat and power units and heat-only boilers) of 3,728 Gcal per hour (14,794 MMBtu per hour).

KDHC works in close cooperation with the Korea Electric Power Corporation (KEPCO) which owns the country's existing six combined heat and power plants for district heating. In fact in several cases, KDHC has installed and separately owns heat-only boilers to serve as back-up to KEPCO's cogeneration units. KDHC, however, is constructing and will own the combined heat and power plants in two new district heating system locations, Talseo and Tongsuwon, strengthening its leading role in Korean district heating and cooling development.

As of 1992, the total fuel use for the seven systems was allocated as
follows: oil, 71 percent; liquefied natural gas (LNG), 26 percent; and refuse, 3 percent. All combined heat and power plants in the Seoul area are now required to use LNG as fuel, so its use has increased dramatically since 1993. The forecasted reduction of pollutant emissions by the year 2001 is said to be 17,200 tons, comprised primarily of 11,200 tons of SOx, 5,100 tons of NOx, and 900 tons of dust.

Hot water is the main medium used in Korea’s district heating systems. With a highest supply temperature of 115 degrees C (239 degrees F) in the winter and a lowest return temperature of 65 degrees C (149 degrees F) in the summer, the hot water is used for both space heating and domestic tap water through the indirect connection with consumer installations. The systems use preinsulated steel pipes that are encased in polyurethane insulation surrounded by polyethylene coating.

New Systems for Cities Old and New

The first to use district heating for residential areas in Korea was Mokdong, west of Seoul. A combined heat and power plant equipped with an incinerator began supplying hot water district heating to 26,000 house-
Korea: A Travel Temptation

The Republic of Korea has something to tempt every type of traveler. The tourist map legend lists symbols not only for the usual rest areas, camping sites, hospitals, museums and expressways, but for ancient fortresses, royal tombs, hot springs, waterfalls, golf courses and ski resorts. Korea has a wealth of history, an abundance of breathtaking scenery, and an endless offering of things to see and do in addition to conducting international business.

But first, the basics. The Korean peninsula extends southward from the northeastern edge of the Asian continent. Over 70 percent of the Korean peninsula is mountainous. The Republic of Korea, or South Korea, population 44 million, is about the size of England and Scotland combined. To its north lies communist North Korea.

Korea has four distinct seasons, with hot, humid summers, and long, cold, dry winters. Average January temperatures range from minus 2 degrees to 7 degrees C (28 - 45 degree F). The heating season starts in September and lasts until March. In summer, it's usually in the mid-20s degrees C (70s F).

Seoul is the center of Korea in almost every way. Pusan is Korea's principal port and second largest city, located on the southeastern tip of the peninsula. Taejon, located in the central region about halfway between Seoul and the southern coast, has been designated by the government for redevelopment as a sort of "second" capital to help reduce the population pressure on Seoul.

The beginning of the end of Korea's isolation came in 1910, when Japan, an enemy for centuries, annexed Korea and instituted colonial rule, requiring the use of the Japanese language and other aspects of Japanese culture. Korea was liberated from Japanese rule after World War II, but suffered another blow when the nation was divided into North and South in 1948. The Korean War of 1950-53 brought further devastation, but South Korea has had a near-miraculous recovery.

Today, South Korea is a democracy with three branches of government, based on the separation of powers. It has been diligently seeking reunification with North Korea (population 22 million). In 1985, families separated by the division of the country were allowed to visit across the border for first time since 1953.

Heavily influenced by neighboring China, a unique Korean culture has thrived for millennia. As late as the 19th Century, however, Korea remained adamantly closed to Western overtures for diplomatic and trade relations. Considering the nation's history, the modernization of Korea has happened at lightning speed.

Before World War II, Korea was economically antiquated, with few significant industries. With a limited domestic market, Korea developed an export-based industrialization strategy, making a shift from subsistence agriculture to modern manufacturing and export trade in textiles, chemicals, steel, footwear, ceramics, glass, electronics and automobiles. In less than 30 years, Korea's Gross Domestic Product increased from US$2.3 billion to US$210.1 billion. Now the economy is moving toward more science and technology, away from labor-intensive industries in which it now competes with developing nations. Intensive research is being done in computers, robotics, semiconductors, telecommunications, biotechnology, alternative energy resources, and oceanographic and aeronautic technologies.

A lower-tech industry but one that is — dare we say it? — making a splash is the hot springs business, which is based on Korea's abundant geothermal fields. Health spas have been developed in beautiful landscapes so people can bathe in the relaxing and — according to some — curative waters of natural, mineral hot springs. The largest public bath in the world, the Jumbo Jungle Bath at Pugok Hot Spring in the southeastern region, can accommodate 3,000 people at a time. Customers can choose from herbal baths, hot baths, supersonic wave baths, low temperature baths, outdoor baths, massage pools, a regular sized swimming pool a diving pool, a children's pool and a babies' pool.

Nestled in the middle of a lotus pond, the Hyangwonjong Pavilion is located in Kyongbokkung Palace, which was built in 1394.

Courtesy of Korea National Tourism Corporation.
holds and the Mokdong business area in 1986. The system has been operated by the Korea Energy Management Corporation on behalf of the Seoul government which owns the system in Mokdong. Refuse presently is used as a fuel in the Mokdong system, and in the near future its use is expected to increase rapidly to help improve the environment and conserve other precious energy resources.

In 1987 these district heating pipelines were installed across the Han-River.
 Courtesy of Korea District Heating Corporation.

In 1992 Korea's Integrated Energy Supply Act called for the expansion of district heating nationwide.

On the other hand, the Southern Seoul, now called Chungang, hot water district heating project became operational in 1987, three years after government approval. The project was assisted by government funding of 56.2 billion Won (US$70 million). Constructed, owned and operated by the KDHC, the district heating system in Chungang supplies 43,000 households in 89 apartment complexes and 118 office buildings as of January 1994. During the month of January 1994, 157 Teal of heat was supplied by the Seoul Combined Heat and Power Plant, which has 387 Gcal per hour (1,536 MMBtu per hour) of heat capacity.

The interior of one of Korea's newer district heating pumping stations.
 Courtesy of Korea District Heating Corporation.

According to Chang, Ha Gyoon, technical division manager of KDHC's Technical Department, the largest new district heating project to date is associated with the construction of five new satellite cities 20 km to 25 km (12 to 16 miles) from Seoul. District heating was mandated by the government for this massive undertaking. Currently KDHC owns the 714 Gcal per hour (2,833 MMBtu per hour) heat-only boilers, a quarter-million tons of hot water accumulators, and 650 km (404 miles) of heat supply pipes. Approximately 2,630 Gcal per hour (10,437 MMBtu per hour) of heat energy from five combined heat and power plants owned by KEPCO is supplied to the KDHC networks. Completed in 1993, all five district heating systems were constructed and are owned and operated by KDHC. Together the systems supply heat to 264,000 households and 500 buildings as of 1993. The highest peak demand in 1993 was 354 Gcal per hour (1,405 MMBtu per hour) at the Chungang combined heat and power plant. The peak demand will be increasing gradually as the households move into the newly developed cities.

“Our role is the construction, operation and expansion of district heating,” says Chang. “We are trying to expand our customer base in the existing district heating systems until saturated. We are also about to begin two new projects, near Suwon City and Taegu City.”

In addition, KDHC recently began providing consulting and training to China’s district heating industry. “We’ve come a long way rather quickly,” observes Lee, Sang Man, executive director of the Korea District Heating Corporation. “In the beginning we lacked the technology to be self-reliant. In 1991 KDHC established a joint-venture company, Korea District Heating Engineering Company (KDHEC), with Ekono Limited of Finland to develop more advanced technology. The results have been favorable. In 1993 we completed all five new district heating systems in the satellite cities. Much has been done and we look forward to additional growth.”

Making Growth Happen

After phenomenal growth in just 10 years, Korea’s district heating industry is about to increase further. In 1992 Korea’s Integrated Energy Supply Act called for the expansion of district heating nationwide. The government designates a district heating area for any newly developed area that is more than 3.3 square kilometers (1.3 square miles) and has a forecasted saturated heat load of more than 150 Gcal per hour (595 MMBtu per hour), based on the Act.

Why is Korea investing so much in district heating? The nation relies heavily on imported energy and is confronting an air pollution problem. District heating, with fewer stacks and more efficient central controls, reduces harmful emissions. Its efficiency means energy conservation and energy savings, and its reliability means a comfortable environment, around-the-clock.

But it’s not just district heating that’s garnering all of the attention. The first commercial district cooling system, operated by KDHC, began operation in 1992. KDHC is developing the district cooling industry to eliminate the use of chlorofluorocar-
Happy 600th, Seoul

The Korean government and the tourism industry have designated 1994 as "Visit Korea Year" in commemoration of the 600th anniversary of Seoul's designation as the nation's capital. The festivities planned are expected to be the second largest tourist attraction in Korea's history after the 24th Seoul Olympiad of 1988. Festivals and international sports events are scheduled for the entire year, throughout the country.

Date of Seoul goes by the lunar calendar, the official celebration date will be November 29, 1994.) Two years later, a wall was built around the city in only 49 days.

With Korea's aggressive economic redevelopment beginning in the early 1960s, Seoul began to take on the sheen of the international center it is today. Since the 1970s, new town development in the Seoul region has been important to help relieve overpopulation of the city, and in 1982, a

The Korea World Trade Center, a 50-acre site located in the south of the Han-gang River in Seoul, contains businesses, the Korea Exhibition Center, a deluxe hotel, a plush department store, a duty-free shop and a shopping mall plus the City Air Terminal.

With a population of 11 million, Seoul, which means "capital," is the financial, political, commercial, recreational, educational and cultural center of the Republic of Korea. Nearly one in four Koreans lives in the capital, which is located on the Han-gang River in the northwest area of the country. Although Seoul was a seat of government more than 1,500 years ago, its role as a modern capital truly began in 1394 — October 28 to be exact — when it was selected as the capital of the Choson Dynasty. (Because the foundation

rejuvenation of the Han-gang River began, addressing pollution and transforming over 20 miles of riverfront into paths, gardens and recreational facilities. Five of the original gates of Seoul and parts of the 10-mile city wall have been restored. Remains of old fortifications, pottery kilns, and royal burial sites can still be seen in Seoul, alongside 5-star hotels, fashionable retail centers, entertainment and performing arts complexes, universities, medical centers and stunning corporate headquarters, befitting the cosmopolitan center it has become.

The absorption refrigeration machines installed in the Korea District Heating Corporation's head office building use hot water to produce air conditioning.

The authors sincerely thank Lee, Sang-Man and Chang, Ha Gyoon of the Korea District Heating Corporation for their extensive cooperation and assistance during the preparation of this article.
Energy is a growing industry in Japan, the most densely populated country in the world and a nation almost totally dependent on imported energy resources.

Japan is second only to the United States as a world market economy and is struggling, consequently, with the downside effects of industrialization — primarily air pollution from our common addiction to petrochemicals. As it happened, the same forces that propelled Japan's extraordinary postwar recovery have created an economic and political climate highly favorable to district heating and cooling (DHC).

DHC Debuts with World's Fair and Winter Olympics

In its relatively brief history, the district heating and cooling industry of Japan has grown aggressively. The first system was built in 1970 by the Osaka Gas Company to supply hot and chilled water to the Sennri New Town central district, next to the site of Expo 1970. That was closely followed by a Tokyo Gas Company system, a direct response to a request by the Tokyo Metropolitan Government to promote district heating and cooling instead of heavy oil for heating.

The Hokkaido Heating Company was the third to be established, supplying the community’s new government buildings with hot water beginning in October 1971, just in time for the opening of the 1972 Winter Olympic Games in Sapporo.

“Heat Service Law” Confers Legitimacy on DHC

That same year, the Japanese government passed a measure legally defining district heating and cooling plants with capacities greater than 5 giga-calories (Gcal) per hour as “heat service utilities.” This decree was a watermark in the development of district heating and cooling for two important reasons: It immediately placed all the country’s then 11 district systems under the jurisdiction of the Ministry of International Trade and Industry (MITI), and it put district systems on a par with all other public utilities.

While the 1972 law gave district utilities equal legal status with gas and electric, the government has thrown its considerable weight behind district heating and cooling in other ways.

From that point on, district heating and cooling system operators would be entitled to low-interest funding from the Japan Development Bank and could apply a special depreciation deduction to their investment in equipment, just like gas and electric utilities. In 1972, the Japan Heat Service Utilities Association and the Japan District Heating and Cooling Association were established by general contractors, equipment manufacturers, utility companies and other...
promoters of district heating and cooling.

Although the government has been consistently supportive, most of the development in the Japanese district heating and cooling industry has been through private enterprise.

While the 1972 law gave district utilities equal legal status with gas and electric, the government has thrown its considerable weight behind district heating and cooling in other ways. The energy evolution in Japan began with the switch from coal to oil. By the late 1960s consumption was up, but so was air pollution caused by the usual suspects: sulfur oxides, soot and smoke. A nationwide grassroots movement soon forced the enactment of environmental protection standards to establish acceptable emission levels, and district heating and cooling was recognized as a viable solution. In some parts of Japan, energy policy has been used to literally mandate the use of district heating and cooling.

The process of integrating district heating and cooling into Japan’s energy picture hasn’t been easy, in spite of its obvious benefits and government encouragement. The two oil crises of the 1970s and the recession that followed caused unexpected increases in plant construction costs, delays in major housing and building projects and great reductions in general energy consumption. As many as 80 new district heating and cooling projects fell by the wayside during this period: only two per year were built between 1976 and 1985.

A strong national economy and a boom in metropolitan development in the 1980s helped breathe new life into the district heating and cooling industry. Between 1986 and 1989, new heat supply projects for 20 districts were approved and another 30 were on the horizon.

**District Heating and Cooling Development Primarily a Private Matter**

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**Massive Natural Gas Project Planned**

Japan’s Ministry of International Trade and Industry (MITI) announced plans in 1992 to construct a trunk pipeline connecting Tokyo, Nagoya and Osaka, a distance of over 400 km. The pipeline would eventually circulate natural gas throughout the country. Natural gas accounts for only 11 percent of total energy consumption in Japan, and has been supplied to only 5 percent of the country, mostly in the port areas of these three cities. (According to U.S. Department of Energy statistics for 1991, the rest of Japan’s energy use is divided as follows: petroleum, 57 percent; coal, 16 percent; hydroelectric, 5 percent; and net nuclear power, 11 percent.) The plan is not without its critics. Some say the project is too expensive, and the gas industry lacks experience in such large-scale energy transmission. The Tokyo-Osaka link is expected to cost between 600 billion and 1 trillion yen (US $4.5 to 7.5 billion).
Currently, 75 individual enterprises are operating a total of 93 district heating and cooling systems, with another 19 under construction. Because about 50 percent of the fuel used in Japanese district heating and cooling systems is gas, it's no surprise that natural gas companies are major promoters and purveyors of district heating and cooling. Electric power utilities have been looking into the market, too; so far, the Tokyo Electric Power Company has obtained approval to operate in eleven districts. The petroleum oil industry had also made tentative moves toward district heating and cooling.

The vast majority are both heating and cooling systems, with natural gas being the most often-used fuel, followed by heat pumps. A growing number are being designed to use waste heat from garbage incineration, such as the Tokyo Heat Supply Company's system for the Hikarigaoka Housing Estate District, which serves 12,000 homes and 15 schools in addition to commercial facilities.

The largest heating-only system in the country began supplying the city of Sapporo in 1971. It uses both oil and solid trash fuel, high-temperature water as the heat medium, and has a capacity of 197 Gcal per hour (782 MMBtu per hour). The most extensive heating/air conditioning system also came on line in 1971 to serve the Shinjuku district of Tokyo. This is a combined heat and power system using natural gas and gas turbines, steam and chilled water as media, with a heating capacity of 142 Gcal per hour (564 MMBtu per hour) and cooling capacity of 157 Gcal per hour (623 MMBtu per hour).

Business and commercial applications account for more than 75 percent of district heating and cooling custom-

er in Japan. Office buildings are the primary users, followed by hotels, department stores, hospitals and others. Residential customers account for the remaining 25 percent. Metropolitan Tokyo has about 45 percent of the systems, influenced by stringent anti-pollution laws. Nearly all the systems supply both heating and cooling. With the growing demand for air conditioning huge office-commercial buildings in metro areas, cooling is expected to take on an even more prominent role in the near future.

Roadblocks and Opportunities

Japan's current economic problems have caused slowdowns and changes in the Japanese economy. Japan is an archipelago consisting of four main islands, a number of island chains, and nearly 4,000 smaller islands. The total land mass is only one twenty-fifth the size of the United States. This small area supports the seventh largest population in the world, 123 million people, one-quarter of whom live in the Tokyo metropolitan area.

Japan is in the temperate zone, at the northeastern end of the monsoon area that reaches from Japan to India. The climate is generally mild, although the weather can be variable, with a rainy season, heavy snow in some areas, and occasional typhoons with torrential rains and violent winds. That's not to mention 77 active volcanoes and occasional earthquakes.

After 250 years of isolation, Japan opened the doors of its ancient civilization in the mid-1800s, and hastened to catch up on centuries worth of advances in just decades. By the end of the first World War, which it entered through an Anglo-Japanese alliance, Japan had become one of the world's major powers. The nation was soon rocked, however, by the worldwide depression, internal political scandals and war with China. And then came World War II.

Under the post-World War II Occupation by the Allied forces, Japan underwent major social changes. Continued on page 28
Japanese Eyeing Change in Economic Structure
Continued from page 26

and political reforms, among them a new constitution, the right to organize trade unions, agricultural reform, and freedom of assembly, speech, press and religion. Women were granted the right to vote and equal legal status with men. Democratization and economic growth led to a change in family structure, away from the traditional extended family, toward a nuclear family. Economic rehabilitation supported by aid from the United States ultimately led to Japan’s recovery and rise to prominence in the world economy. An abundant, well-educated labor force and the availability of plentiful, low-cost, energy from abroad facilitated this growth. In 1951, Japan regained the right to conduct foreign affairs, and gradually returned to full participation in international diplomacy and trade.

By 1968, Japan ranked second only to the United States among the market economies in terms of national economic scale, and experienced double-digit growth rates into the 1970s. Steel, aluminum, petrochemicals and cement were major industries. The oil crises of the 1970s brought changes to Japan’s industrial revolution, including a greater focus on diversification and energy conservation. Even with typical annual growth rates of less than 4 percent since 1980, Japan remains the world’s second largest economy today.

In the 1980s, Japan made plans to improve its infrastructure, economy and trade relations. These plans included higher-quality housing; the stabilization of land prices and an increased supply of land for housing; the creation of new jobs; the promotion of investment to develop advanced technology and new industries; increased direct investment in overseas manufacturing facilities; expansion of consumption; shortening of work hours; steps to ensure fair competition between Japanese and foreign corporations; and increased imports and access to the Japanese market. Such changes would amount to a transformation of Japan to a domestic demand-led economic structure with less dependence on exports.

In the not too distant past, Japan’s primary industries were agriculture, forestry and fishing. Now, the two largest are the automotive industry and electronics, with 42 trillion yen (US $378 billion) and 54 trillion yen (US $486 billion) in production in 1990, respectively. Televisions, audio equipment and other consumer goods formerly made up the bulk of the electronics industry’s production, but have been surpassed by computers, semiconductors and other electronic components and industrial equipment.

Currently, 40 percent of Japan’s gross domestic product (GDP) is in what it calls the “goods-producing” sector (mining, manufacturing, construction and agriculture). The goal is for that to decline to one-third, with the rest of the GDP divided equally between the “networking” sector (transportation, communications, commerce, finance, insurance, real estate and utilities) and the “knowledge and service” sector: management, software design, information banks, health care, education, leisure services and public services — industries anticipated to provide the most new jobs.

Japan’s government, private industry and university research institutes are involved in a number of large-scale technological development projects. In the energy arena these include research on nuclear fusion, coal liquefaction and gasification, thermal power generation, solar batteries and energy-saving technology. Other projects are in space development (Japan hopes to launch its own space shuttle in the next decade), aviation, marine development, genetic engineering and superconductivity. In 1992 Japan launched a 10-year research program into four-dimensional computers that would function more like the human brain. They would be used for automatic driving systems for cars and devices capable of recognizing and identifying people.

Japanese workers are among the best paid in the world, although they lag behind in vacations and work hours. Until 1987 the statutory workweek was 48 hours, later reduced to 46. Plans call for a further reduction, to 40 hours. Like many other nations, the workforce is demanding more flexibility in careers and better working conditions.
even halted development in some outlying regions. The lack of systematic urban planning has also been a factor. Outside of urban areas, the expense of creating district energy systems, especially for air conditioning, is often much higher than the cost of on-site cooling systems for individual buildings. The challenge, then, becomes one of overcoming economic objections by convincing potential customers of the environmental and social advantages.

District heating and cooling developers in Japan point to the same list of benefits used by their American counterparts when arguing their case: more efficient use of energy; prevention of air pollution; more favorable urban environments; effective use of building space (a major concern in Japan, where land is at a premium); reduced costs for labor, equipment and maintenance; lower fuel costs through use of exhaust heat; reduced need for fuel transportation and storage (i.e., fewer urban disasters); and the elimination of dangerous combustion-type heat sources.

Obvious benefits aside, the future of district heating and cooling in Japan will be determined by how well its promoters can address critical issues. Foremost, the economic ones: systems require huge capital investments, take about four years to plan and build, and then must break even within five. Then there are the regulatory hurdles: the large number of licenses and approvals required makes full government cooperation a necessity, especially where questions of pipe routing and potential conflicts with power and gas companies must be resolved. Finally, the challenges of technology remain, particularly how to make more effective use of exhaust heat and other untapped energy sources.

Not surprisingly, the Japanese are highly interested in combined heat and power systems, and are implementing it in many combinations: natural gas, electricity, liquid natural gas, oil, coal and natural and synthetic exhaust heat (river water, exhaust heat from plants, substations, subways, underground power transmission lines, sewage process water and heat from waste incineration plants).

**Challenges Aside, Industry Growth is Forecast**

In 1992, MITI announced aggressive long-term plans for alternative energy projects throughout Japan. One calls for futuristic developments called “eco-cities” that will involve the collection and use of waste heat. These cities would feature “eco-factories” that maintain high standards of conservation and recycling. MITI estimates that the new energy and antipollution technologies involved would cut energy consumption by 6 percent and carbon dioxide emissions by 9 percent by the year 2020. The plan calls for an international joint research program to develop technologies to produce energy through electrolysis of water, using surplus hydroelectric and solar power by the year 2020. If such technologies were adapted worldwide, MITI estimates, global emissions could be reduced 20 percent by the year 2050.

Even without new technologies, typically five to ten new district heating and cooling systems are planned each year in Japan, with heat sales possibly increasing by as much as 15 percent annually.

That’s not all MITI has in store. Last year, MITI was to begin massive energy saving projects in Japanese cities to cut energy use by 50 percent and reduce carbon dioxide emissions. Choosing 10 to 20 urban reconstruction projects, MITI would pay half the cost of introducing energy-saving equipment, with an emphasis on com-
bined heat and power systems and heat supply networks.

There is no question that district heating and cooling will play an active role in these futuristic scenarios. Even without new technologies, typically five to ten new district heating and cooling systems are planned each year in Japan, with heat sales possibly increasing by as much as 15 percent annually.

From huge apartment monoliths to arts and cultural centers, from parking facilities to hot springs spa hotels, from greenhouses to people’s houses, a wide variety of buildings in Japan are already heated and cooled by a district energy system. The relative youth of the industry is definitely an advantage, as Japanese district heating and cooling systems are modern, structurally sound elements of the country’s infrastructure.

In developing their industry, the Japanese appear to have learned much by studying American and European systems, importing knowledge from abroad and applying it effectively. With their fabled dedication to quality, and a clear vision of their industry’s role in society, the people bringing district heating and cooling to Japan should be able to look forward to a most auspicious future.

The authors sincerely thank the Japan District Heating & Cooling Association for its extensive cooperation and assistance during the preparation of this article.
China: District Heating Seen as

The People's Republic of China has announced plans for major improvements to its infrastructure over the next ten years, including 40 new airports, 14 new metro subways and light rail systems, and many roads, bridges and power plants. Building and equipping the power plants alone could cost more than $100 billion, according to The Wall Street Journal. Even before these ambitious plans get under way, energy is already the ninth largest industry in the nation.

District heating and cogeneration (combined heat and power) will figure significantly in the improvements. Air pollution is a serious problem in many Chinese cities because coal is widely used for residential heating and in industrial applications. The price of coal has soared recently, and electricity and natural gas are in short supply. (Natural gas comprises only 2.1 percent of total fuel consumption in China). District heating helps reduce coal use because it is so efficient, and with fewer stacks, emissions are easier to control. For those reasons, it makes sense that China's energy policy supports and encourages the development of district heating. The policy currently requires that all large buildings within new residential and commercial quarters in large and medium-sized cities in North China must be connected to the district heating system. The Ministry of Urban and Rural Construction is in charge of the development and management of district heating.

The total building space supplied by district heating systems in China is 328.32 million square meters (3.5 billion square feet), a 19 percent increase over 1991.

Heating supplied was 92,667,797 T per an (185,336,000 MMBtu per year) for steam and 266,702,609 x 10^6 kj/an (252,847,000 MMBtu per year) for hot water. The total building space supplied by district heating systems in China is 328.32 million square meters (3.5 billion square feet), a 19 percent increase over 1991. Based on statistics compiled for 506 cities in 1992 and extrapolated for the remaining systems, the total district heating pipeline network in China is 362 km (226 miles) for steam and 4,230 km (2,644 miles) for hot water.

Not surprisingly, China's district heating industry is flourishing. One estimate places the number of district heating systems at 1,600, mostly in China's north, northeast and northwest regions. About 250 systems are in the planning stages. Presently, 83 cities have combined heat and power (CHP) systems; 13 percent of the urban buildings in Northern China are heated by CHP systems.

At the end of 1992, China's total district heating supply capacity was 25,491 T per hour (50,982 MMBtu per hour) of steam and 45,386 MW (154,857 MMBtu per hour) of hot water. (T = 2,000 lbs). The total district heating capacity in China is now 85,667 T per hour (171,280 MMBtu per hour) for steam and 160,877 MW (568,207 MMBtu per hour) for hot water.

More Combined Heat and Power on Horizon

The trend is to build more CHP systems, replace heat-only systems,
Energy Solutions

and expand the service to more buildings. Although district heating systems do not, for the most part, supply domestic hot water service, the technology is being researched, as is district cooling. Present air-conditioning load density may not be high enough, however, to make district cooling pipeline installation cost-effective.

Large projects are funded and owned by the municipal governments, while universities, institutes and some enterprises own and fund their own systems. Coal is used in 95 percent of systems, while geothermal supplies 3 percent and waste heat recovered from industry supplies 2 percent. Some reports have indicated that oil is used in isolated cases. Nearly 70 to 80 percent of the systems use hot water as the medium, with steam accounting for the rest. Most of the piping is steel, with only a few cast-iron applications.

The majority of buildings that use district heating in China are commercial, office and residential buildings made of brick and reinforced concrete. A typical building connected to a district heating system ranges from 3,000 square meters (10,000 square feet) to 86,000 square meters (860,00 square feet). Most buildings have a single-pipe hot water heating systems, according to Ouyang Kunze, senior research engineer and head of section, Institute of Air Conditioning at the China Academy of Building Research in Beijing. The institute specializes in research in heating, ventilation, air conditioning and refrigeration, and is part of the Ministry of Urban and Rural Construction. Ouyang has worked in the research and design of district heating and energy conservation for 15 years and is currently researching the dynamic simulation of hydraulic and thermal conditions in hot water network for district heating systems.

Chinese district heating experts believe the primary reason for the growth of combined heat and power systems and district heating systems is that they are good for the environment. In addition, they cite reduced energy consumption, efficiency and reliability as influencing factors.

"People think it is the best way for heating. If a building in North China is not heated by a district heating system, it will bring a much lower price when sold."

"People think it is the best way for heating," says Professor Yo Jiang of Tsinghua University in Beijing. "If a building in North China is not heated by a district heating system, it will bring a much lower price when sold. In China, we don't have universal use of on-site heating in homes as in Europe and the United States. We don't know what system can be better than district heating. "Jiang is head of the heating, ventilation and air-conditioning (HVAC) division of the university’s Department of Thermal Energy, and general technical director of the first company in China that deals with the computer control and management of district heating systems.

Energy companies cooperate closely with universities, which act as..."
design institutes for the district heating industry. The District Heating Association of China publishes a journal, *District Heating*, but the industry has divided responsibility. For example, marketing and planning may be handled by one company or association member and technical development by another. Management of the heat source may be handled by one company, and management of the district heating network by another.

**Beijing and Beyond**

The first district heating system in China was constructed in the capital city of Beijing in 1958. Overall, district heating and cogeneration experienced steady growth for the next several years, but the industry was dormant between 1976 and 1978. Since 1981, however, it has been a top priority of the government, and has grown rapidly.

With a population of 10.5 million, Beijing has the largest district heating system in China. Winter often brings temperatures of minus 15 degrees C (below 5 degrees F), while summer heat can reach 33 C (the high 80s F) or more.

"When the Beijing system was constructed, it had 13.55 kilometers of pipeline, and heat supply for about 30,000 square meters (323,000 square feet) of building space," Jiang says. "Now the city has 237 km of steel pipeline, and heats about 21 million square meters (226 million square feet). One square meter of space needs 40 to 60 W of heat at peak load."

According to Ouyang Kunze, 18 percent of Beijing's buildings are supplied with heating from three combined heat and power systems and three heat-only boilers. Peak demand is 700 T per hour (1,400 MMBtu per hour) of steam for industrial use and 2,140 MW for heating. Hot water is the primary medium, while steam is used for industrial applications.

A new system is now being built in Beijing, called the Shijingshan Heat and Power Plant project, which includes a cogeneration plant and four central boilerhouses as heat sources. The cogeneration plant has three steam-extraction heat and power generators with single-unit power capacity of 200 MW. Peak heating demand is 700 MW and the installed pipeline length is 95 km. The system will have 205 heat-exchange stations. Total investment for this system is 1.27 billion yuan (US$145 million), including the loan of US$5.4 million from the World Bank. Part of the system is already in operation.

China's second largest system is in Shenyang, population 5.7 million, located 900 km northeast of Beijing, heating 9 million square meters (96 million square feet) plus some industrial use. Now an industrial center, Shenyang was a trading center for the nomads beyond the Great Wall a thousand years ago and was controlled by the Russians after World War II. The city of Harbin, 385 km northeast of Beijing, also has a large district heating system.

Tianjin, with 9.2 million inhabitants, is China's third most populous city. Located 130 km southeast of Beijing, it is a highly industrialized city that serves as Beijing's seaport. Winter in Tianjin is frigid and long, with strong winds sweeping in from Siberia. The city of Tianjin, with considerable low-temperature geothermal resources, is a focal point for the geo-
uprising, they agreed to end China’s partitioning.

Some Chinese believed the only way to overcome foreign intrusion was to modernize on their own. The emperor disagreed but was ultimately overthrown by followers of the reformer Sun Yat-sen. In 1911, Sun became president of a provisional government, and China had its first taste of democracy. Sun was succeeded, however, by a repressive regime and more unrest.

Early in World War I, Japan seized the Shandong province and attempted to make China a Japanese protectorate. Although China entered the war on the Allied side in 1917, the Versailles peace conference awarded the Shandong territory to Japan.

Japan eventually signed a treaty guaranteeing China’s sovereignty and the Open Door Policy, proposed much earlier by the United States, in which all nations would have equal commercial and industrial rights in China.

But this did not mean peace. Sun’s new revolutionaries, the Kuomintang, engaged in civil war with the national government in Beijing, which was supported by warlords in the north. Failing to get support from the West, Sun aligned with the Chinese Communist Party and sought aid from the Soviet Union. In 1926, Chiang Kai-shek led the Kuomintang to victory. Chiang then reversed Sun’s policy of cooperation with the Communists and killed many of their leaders. Yet he failed to stop Japan from expanding its northern occupation. So began yet another civil war — this time between the Kuomintang and the Communists.

Japan took advantage of China’s internal unrest, occupying Manchuria in 1931 and invading China proper six years later. The Communists effectively conducted guerrilla warfare against the Japanese, and Mao Zedong emerged as a new leader.

During World War II, China received aid from the United States and Great Britain as it continued battling Japan. After the war, China’s internal hostilities continued, leading to a full-scale war, with each side trying to get the territories formerly held by Japan. The United States sent arms to Chiang Kai-shek’s forces, now called the Nationalists, but the Communists got the upper hand in 1947. Beijing fell in 1949 without a fight, and was soon followed by other cities, as the Nationalists retreated to the island of Taiwan, and the People’s Republic of China was born.

The Communists reunited China and banished foreign influence. They brought inflation under control, managed to distribute food more effectively, collectivized agriculture and nationalized industry.

China actively engaged in the Korean War in the early 1950s. Toward the end of the decade the nation suffered from poor economic policy and devastating weather, which led to crop failures and famine. Millions died. An ideological rift developed between the Soviet Union and China, and in 1960, the Soviets withdrew their support.

For decades, Mao was regarded as supreme leader, and his ideas on active revolutionary struggle and guerrilla warfare were extremely influential. In the 1960s, a power struggle emerged due to the growing power of moderates within the hierarchy who, unlike Mao, believed China could not modernize on its own. This led to the Cultural Revolution and more trying times. Progress on a variety of fronts slowed significantly.

China then turned to more diplomatic measures with renewed efforts to establish good relations with other countries. It was seated at the United Nations in 1971, and the following year U.S. President Richard Nixon made his historic visit to China, the first significant contact between the two nations since 1949.

Presently, China is home to 1.2 billion people, one quarter of the world’s population. The country spans 10 million square meters (2.8 million square miles), including Tibet. The climate ranges from frigid temperatures with permafrost in the north to temperate, sub-tropical and tropical areas in the south. In summer, the national average temperature is 25 degrees C (77 degrees F). In winter, temperatures can dive to well below 0 degrees C (32 degrees F). The terrain includes vast mountain ranges, deserts, prairies, plateau, highlands and plains.
A New Business Horizon

The opening of the China market is a business dream come true. With 1.2 billion people and a market virtually untapped, China beckons with seemingly endless international business opportunities. The past 15 years have been a period of rapid transformation for the Chinese economy, and the statistics are enticing. China's rate of economic growth is 13 percent annually, factory output is up 23 percent and retail sales are way up, according to a recent Wall Street Journal special report. Investment in China's infrastructure in the next decade is expected to exceed $500 billion, the New York Times reports. Corporations and entrepreneurs around the world are eager to get in on the investment boom.

China's goals are to repair and develop its infrastructure, strengthen its national defense and excel in the sciences, agriculture industry and technology. In short, it seeks to be a world leader in all these areas by the year 2000. Under the leadership of Deng Xiaoping, China has lessened its emphasis on revolutionary socialism and moved toward a greater acceptance of free enterprise, expanded international trade and joint ventures with foreign interests.

Economic liberalization began in 1978, when the Communist Party's Central Committee granted permission to two coastal provinces, Guangdong and Fujian, to develop foreign trade. The following year, relations between China and the United States were normalized, and in 1980, China authorized joint ventures with foreign companies. In the mid-1980s, financial reform began, and the foreign trade system was decentralized, giving decision-making authority to corporations and provincial governments. In a major policy reversal, Beijing divided most rural land among peasant households, allowing farmers to keep or sell what they grow beyond government quotas. The United Kingdom agreed to return Hong Kong to China in 1997.

By 1989, double-digit inflation was causing serious problems. Hundreds of thousands of citizens crowded into Tiananmen Square calling for democratic reform. The tragic end of the demonstrations brought condemnation from around the world. Japan and the West cut off aid. Although the penalties were short-lived, a delicate dialogue continues between China and other nations, linking trade with human rights issues.

In 1990, a stock exchange opened in Shanghai, the first since 1949, and the government opened land development to foreigners.

Based on 1992 statistics, the leading industries in China are (in billions of U.S. dollars):

- Textiles $33.3
- Machinery $30.7
- Smelting and rolling of ferrous metals $23.9
- Chemicals $21.9
- Food $19.2
- Communications and transportation equipment $17.7
- Building materials and other nonmetal minerals $16.3
- Electronic machinery and equipment $14.2
- Electric power, steam and hot water $11.7
- Electronics and telecommunications equipment $10.6

The most common type of foreign investment in China is a joint-venture factory. The top joint venture is Shanghai Volkswagen Corp./Volkswagen AG, Germany. The chief investors, in order, are Hong Kong, with over US$21 billion invested between 1985 and 1992; Japan, with US$3.7 billion; the United States, with US$2.7 billion; and Taiwan, Germany, Singapore, the United Kingdom, France, Italy and Canada.

Doing business in China presents some challenges, of course. The communications and distribution systems, for example, are in need of modernization. But China, and its people, are changing. Just weeks ago, China's finance minister agreed to allow foreign banks to expand into some cities where they had been prohibited. Yet with reform come the problems inherent in a market economy.
Geothermal use is increasing as it becomes clear alternative energy resources are needed. According to the Chinese National Bureau of Statistics, the price of coal recently rose more than 27 percent, the highest increase of all commodities in China. Since China has a large geothermal capacity, many areas are starting to tap into that natural energy supply to save fossil fuels and reduce air pollution.

**The Challenges Posed by Growth**

"As we develop alternative energy sources and technologies, we're faced with new challenges," says Jiang. "With district heating, right now we're working on the detection of leaks and blockages of the network by pressure measures, control and adjustment of the network, and the dynamic simulation of flow dynamics and thermal state of the network."

Heat imbalance due to poor network design is one of the most common problems. To achieve the lowest possible usable level for customers farthest from the central source, the entire system temperature or pressure has to be boosted, significantly raising the temperature of the hot water or steam throughout the system, which greatly reduces efficiency. Another problem is that buildings don't have individual meters.

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Construction of an actual district heating network in Tianjin began in 1985. Marshy terrain and a river bisecting the city provided special challenges. Three plants provide heating for about 50 percent of Tianjin's residences. Industrial heating is met through steam generation. Between 1985 and 1990, the total floor space supplied by geothermal district heating increased from 150,000 square meters to 850,000 square meters.

In March 1990, possibly the deepest well ever drilled for the purpose of low-temperature geothermal heating was drilled in Tianjin at a depth of 3100 meters. The public and the government are so concerned about air pollution that they support the development of such wells regardless of the engineering costs.

The heating bill is determined by how many square meters of the building are heated, not by actual use. In addition, Jiang reports, there is no thermal control within each building.

Chinese energy experts have indicated they are interested in an exchange of scientific and technical information with their colleagues around the world on a number of topics including the use of hot water meters, variable-speed pumps, district heating and cooling, domestic hot water supply, and combined heat and power. Information on advanced techniques and new products is also welcome as the district heating industry continues to plan for rapid energy growth.

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