MARKET ASSESSMENT
OF COGENERATION IN CHINA

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I. Preface

Cogeneration in China experienced relatively slow development from its start in the 1950s to the latter part of 1970s. During the latter of 1970s, the energy-saving consciousness in China was awakened by the experience and lessons drawn from the international oil crisis. In the 1980s, an energy policy was pronounced by the Central government that placed equal importance upon saving and development, with saving given highest priority. This energy policy encouraged cogeneration and centralized heating. Cogeneration was listed as a major energy-saving project by the State Development & Planning Commission.

These policies and pronouncements of the 1980's resulted in rapid development of cogeneration in the late 1980's and throughout the 1990's in China. By the end of 1999, 1,402 sets of heating units of 6MW and above had been installed, with a total capacity of 28,153MW. This represented 12.6% of the installed thermal power capacity in the country. By 1999, use of cogeneration had saved about 27 million tons of standard coal per year and avoided about 70 million tons of carbon dioxide and 500,000 tons of sulfur dioxide .

Although significant progress has been made in addressing pollution problems in China, serious issues remain. Despite strengthened environmental laws and management practices, increased environmental investments, and other measures, only one-third of China's largest 338 cities have met the second grade of its national air quality standard; 137 of these cities exceed the third grade standard. Coal combustion continues to be the primary source of much of this pollution.

In 1999, 18.57 million tons of sulfur dioxide was emitted. Of this, industrial sources emitted 14.6 million tons and the residential sector emitted 3.97 million tons. In addition, 11.59 million tons of smoke dust was emitted, 9.53 million tons from industrial sources and 2.06 million tons from the residential sector.

China is a developing country with a huge population. Its economy is rapidly developing. Carbon dioxide discharges amount to only 2.51 tons per person per year, much lower than that of the developed countries in Europe and North America. However, because of its large population, China now discharges over 3 billion tons of CO2, or 13.6% of the world total, second behind the USA. Many project that China will be the leading emitter of CO2 in the next 15-20 years.

Currently there are approximately 430,000 industrial coal boilers and furnaces in China. Besides industrial kilns and heat-treating furnaces, there are about 390,000 industrial boilers and hot water boilers. The average capacity of these small boilers is around 4 tons per hour (t/h), their operating efficiency ranges from 30 to 60 percent, and they consume over 300 million tons of raw coal every year. If the majority of the small boilers were replaced by large cogeneration plants with a thermal efficiency of 85 to 90 percent, potential savings of tens of millions of tons of standard coal and nearly 100 million tons of carbon dioxide would be achieved.

The expanded use of cogeneration in China is a high national priority. Government policies and market conditions are such that cogeneration will continue to grow in importance as a desired energy option. As described in this report, it is projected that the installed capacity of cogeneration in China will increase at least 3,000 MW per year beginning in the year 2001. In addition China is projected to increase heating capability by 4,500 MW per year and heating load of 20×10^6 MWh per year. The investment required to achieve this growth will be 15 to 18 billion Yuan per year (excluding heating network investment). Using cogeneration will save about 2.88 million tons of standard coal per year for each 3,000 MW added, reducing carbon dioxide emissions by 7.55 million tons and sulfur dioxide by 57,600 tons per year.

Since Sept. 2000, the China Energy Conservation Investment Corporation has led an investigation of the cogeneration market in China. The investigation included gathering statistics and other materials, and meeting with many government officials, cogeneration experts, local officials, experts of the heating industry, and cogeneration operators. In addition, recent national and regional energy plans, policies and analyses of energy efficiency and cogeneration in China were completed to fully assess the markets for cogeneration. This report summarizes the results of this work. It is supplemented by an assessment of the United States' and European cogeneration markets, which is provided as Appendix A.

II. Energy planning in China

The energy development strategy of China has been pronounced as follows: to ensure maintenance of China's energy security, the energy structure should be optimized as the highest priority, and energy efficiency improvements and protection of the environment should be advanced and the development of the West should be accelerated.

The production and consumption projections in the energy planning of China for 2005 are based upon two principles. The first is that the energy supply should be based on domestic resources with appropriate imports. The second is that clean energy should be produced and used as priority options.

In 2000, the total production of primary energy was about 1.09 billion tons of standard coal, among which, coal represented 65.46%, oil was 20.94%, natural gas was 3.3%, and 10.3% for hydroelectricity and nuclear electricity. Energy plans of China for 2005 call for total production of primary energy of about 1.23 billion tons of standard coal. This includes: 63.45% from coal, 17.55% from oil, 5.07% from natural gas, and 13.93% from hydroelectricity and nuclear energy.

In 2000, the total consumption of primary energy was about 1.17 billion tons of standard coal, among which, coal represented 61.03%, oil was 26.69%, natural gas was 3.06% and 9.22% were hydroelectricity and nuclear electricity. China's energy plans for 2005 project total consumption of primary energy to be about 1.37 billion tons of standard coal, of which, coal will represent 57.15%, oil 24.97%, natural gas 4.85% and hydroelectricity and nuclear energy 13.03%.

By 2005, the annual rate of increase of energy consumption in China will be about 3.26%. By 2005, the percentage of coal consumed for primary energy will decrease 3.88 percentage points and the generating capacity will increase 5%. Energy policies and priorities will drive cogeneration markets in the next 5-years. The key drivers that will effect cogeneration include:

- National focus on the promotion of clean coal technology, vigorous development of coal-bed methane, oil and natural gas.
- Electricity initiatives that will focus on the construction and reconstruction of distribution networks in towns and cities, construction and reconstruction of the national transmission network, and construction of the electricity transmission lines from the West to the East.
- Energy efficiency initiatives that will focus on implementation of the program of energy savings in the electric machinery system, implementation of energy-saving demonstration projects in the major energy-consuming industries, promotion of cogeneration for combined heat and power, combined heat, power and cooling, and combined heat, power and coal gas production.

III. Current status of power and cogeneration in China

1. Overall status of the power industry of China in 1999

Table 3-1 summarizes the electric power capacity in China by capacity type. As can be seen, thermal systems represent nearly 75% of the installed capacity. Figure 3-1 shows this pictorially.

Table 3-1 Quantity of different parts in the total installed capacity of power in 1999—MW

Total installed capacity	298,767.9
Among which—Hydropower	72,970.8
Thermal electricity	223,434
Nuclear electricity	2,100
Others	263.1

Figure 3-1 1999 Electric Capacity in China by Energy Source

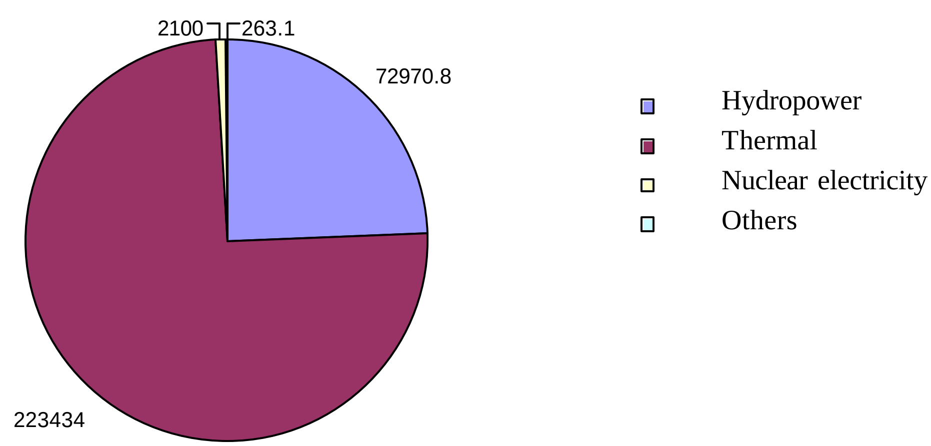


Table 3-2 summarizes China's power generation by energy sources for 1999. Over 80% of the generation comes from thermal units. Figure 3-2 shows this pictorially.

Table 3-2 Quantity of different parts in the total power generation of China in 1999—100 million kWh

Power generation	12,331.41
Among which—Hydropower	2,129.27
Thermal electricity	10,047.37
Nuclear electricity	148.33
Others	6.44

Figure 3-2 1999 Electric Power Generation in China by energy source

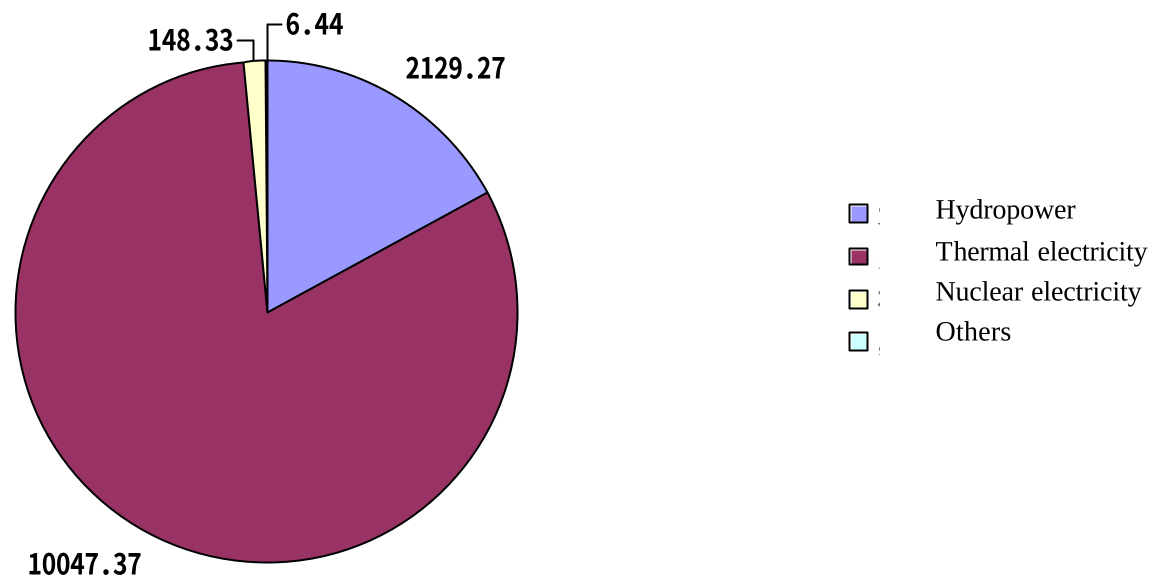


Table 3-3 summarizes the amount of fossil fuels that were consumed in the electric power plants in China in 1999.

Table 3-3 Energy consumption for power generation in 1999

Energy for power generation	365.39 million tons of standard coal
Among—Raw coal	481.87 million tons
Oil	11.59 million tons
Gas	12.90668 billion cubic meters

2. Status of Cogeneration—1999

In 1999, 1,402 heating units with 6,000kW or over per unit were operating in China. In total, their capacity was 28,153MW. This represents 12.6% of the total installed capacity of thermal power, and $108{,}907\times10^{4}$ GJ of heat.

The classification of these heating units by size is shown in Figure 3-3. Figure 3-4 depicts the capacity of these units by unit size. Table 3-4 further classifies the units for 1998 and 1999.

Figure 3-3. The Number of Sets by Unit Capacity (1999)

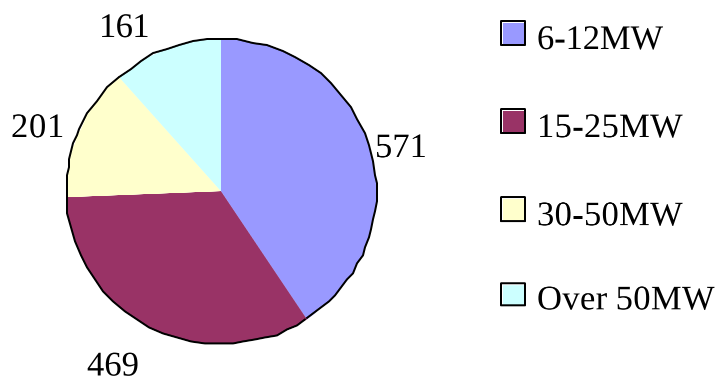


Figure 3-4. Total Capacity by Unit Size (1999)

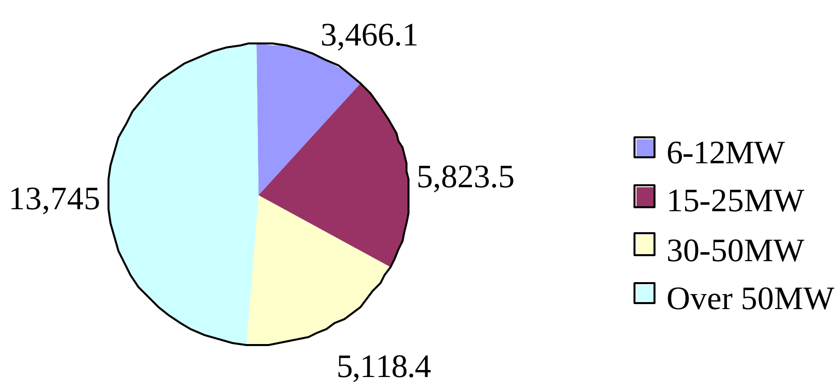


Table 3-4 Classification of heating units of different capacities in 1998 and 1999

Capacity	Parameter	1999		1998		Increment	
		Set	MW	Set	MW	Set	MW
6MW~12MW (not including 12 MW)	High-pressure sets	1	10	1	10		
	Medium pressure sets	570	3,456.1	541	3,278.5	29	177.6
12MW~25MW (not including 25 MW)	High-pressure sets	14	181.6	14	181.6		
	Medium pressure sets	455	5,641.9	426	5,252	29	390
25MW~50MW (not including 50 MW)	High-pressure sets	120	3,015	120	3,010		
	Medium pressure sets	81	2,103.4	70	1,823	11	280.4
Over 50MW	High-pressure and super-high pressure	161	13,745	140	11,372	21	2,373

IV. State policy and legislation and its impact on development of cogeneration

At the beginning of 1980s, after cogeneration was listed as a major energy-saving program by the State Development & Planning Commission, one-third of the capital needed to support the project was provided by the government. Since the 1980s, cogeneration has undergone rapid development in China. Meanwhile, the State emphasized the principle of "defining electricity with heating", which required the type and construction scale of cogeneration units to be decided according to the heating requirements of the heat users. Therefore, a group of thermal power plants with backpressure turbine units of 3-12MW per unit were built in that period. A disadvantage of the backpressure turbine unit is that it cannot accommodate big changes in the thermal load. As a result, steam-extraction condensing units or post-posed units were retrofitted onto these cogeneration plants.

The construction of a cogeneration project must obtain the approval of the State or the local government. Projects with unit capacity of 25MW and above must be approved by the State; those less than 25MW must be approved by the provincial government.

The State required that heat supply planning be undertaken by cities to encourage district heating. Therefore, the majority of the cogeneration plants in China either provide heating for many enterprises at the same time or for on-site cogeneration plants servicing a factory and providing excess heat for other users in the district. These options require relatively expensive, long pipelines for the heating network.

The rapid development period of cogeneration in China was from the end of 1980s to the beginning of 1990s. During this period, the State still provided huge capital support for its use. Meanwhile, a series of taxation policies with transfer of profits to energy-saving projects were set up to provide incentives for building cogeneration projects. The tax policies included specific provisions such as: repayment of loans before taxation, zero tax rate for the heating circulating tax, and loan rates of 30% of the prime interest rate. Additionally, as the power supply was rather tight around the country at that time, it was easy for cogenerators to sell their electricity to the grid. During this period, local small-scale cogeneration projects underwent their fastest development.

In the middle and latter parts of 1990s, policies to reform the national economy by creating a market-based system were accelerated. As a result, the national financial and accounting system also underwent major reform including eliminating many of the incentives provided for using cogeneration. In addition, at this time, China had excess power supply and monopoly ownership of the power market, leading to difficulties in obtaining local investment for cogeneration. As a result of this combined lowering of loan repayment capability and the increasing difficulty for obtaining project financing, the number of new, small and medium-scale cogeneration projects was greatly reduced.

In order to standardize the construction and operation of the cogeneration projects, the *Provisions on the Development of Cogeneration* (Jijichu, No.1268, 2000) was issued jointly by the State Development & Planning Commission, the State Economic & Trade Commission, the Mnistry of Construction, and the State Bureau of

Environmental Protection. This policy document reiterated the principle of defining electricity based upon heating needs and the process for review and approval of cogeneration plants. In addition, it specified the minimum thermal efficiency of cogeneration plants to be greater than 45% for coal-fired units, and greater than 55% for gas-fired units. Meanwhile, requirements for the thermoelectricity ratio of units with different capacities were also specified. The issuance of the document standardized the construction and operation management of the cogeneration plants and was helpful for the healthy development of the cogeneration market.

After the execution of the policy specified in the *Official Reply to Issues Concerning the Acid Rain Control Zone and the Sulfur Dioxide Pollution Control Zone by the State Council* (State letter, No.5, 1998), only cogeneration plants were allowed to be constructed near cities within the two control zones. In addition, at about the same time, policies were announced to accelerate development of the western areas of China. Central to China's western development plan was the proposal to transmit electricity from the West to the East. New projects to develop pure condensed steam generation were limited in the eastern regions and have begun to be dismantled while larger cogeneration plants have begun to be expanded or constructed. In recent years, dual-purpose units for power and heat at size ranges of 200 to 300MW per unit have undergone rapid development in the large cities in the cold Three North Regions.

V. Features of cogeneration in China

Several characteristics of cogeneration plants in China distinguish them from other countries. For example:

1. Among the current cogeneration plants, medium-pressure and sub- high-pressure parameter units of 6-12 MW (not including 12 MW) per unit represent 40.7% of the total amount of the cogeneration units and 12.3% of the total cogeneration capacity. These small-scale units represent a large percentage of China's cogeneration units.

2. Unlike the practice in other countries, construction of cogeneration plants in China emphasizes the principle of defining electricity output based upon heating demand, making heating the main commercial target. As a result, the selection of the type and capacity of the cogeneration units in China is driven by the actual current thermal load of the users. Therefore, units with smaller capacities are usually selected. In the future, as the thermal load increases, units with the same capacity will be duplicated and constructed in the same cogeneration plant, resulting in a large number of small units.

3. In order to meet environmental protection requirements, a majority of the coal-fired boilers for the small and medium-scale cogeneration projects usually choose circulating fluid bed boilers that release relatively low levels of nitrogen oxides and which can simultaneously remove sulfur dioxide within the boiler. In most cases, the capacities of the circulating fluid bed boilers are 35t/h or 75t/h, with a few as large as 130t/h or 220t/h. The industrial policy of the State is that circulating fluid bed should be selected for coal fired boilers below 410t/h. Recently, a small batch of circulating fluid bed boilers of 410t/h have also started to be installed.

4. Both industrial steam and residential heating are supplied by cogeneration plants in the small and medium-scale cities in the Three North Regions. In addition, there are both steam heating networks and hot water pipeline networks for space heating in the heating network of the cities. The heating network is very complicated and the investment is huge. The typical reasonable heating range of a cogeneration plant is within a radius of 5km for steam supply and 10km for hot water.

5. Cogeneration of heat, power and cold air is encouraged by the State. Such systems are mainly used for technical process refrigeration in textile and chemical enterprises, as well as refrigeration of large-scale public works projects. As issues concerning the metering of cold air for residents are still unsolved, it is still difficult for such systems to be used for residential applications. Use of cogeneration for absorption refrigeration in the summer can balance the thermal loads in winter and summer, resulting in energy-savings and improved economic efficiencies.

6. Use of cogeneration to produce coal gas, heat and power with circulating fluid bed boilers in combination with retort furnaces is also encouraged by the State. At present, this technology is undergoing industrial experimentation,

and it is encouraged by small and medium-scale cities. It is one of clean coal burning technologies encouraged and supported by the State, which is expected to become the mainstream technology for small and medium-scale cogeneration plants.

7. Cogeneration plants are constructed for enterprises with large requirements for steam and power consumption in the fields of petroleum refining, non-ferrous smelting, paper making and chemical industry, to meet their own requirements for heating and power. These cogeneration plants usually produce electricity that is totally consumed by the large enterprises; often no excess electricity is available to supply to the transmission network.

8. Cogeneration plants planned and constructed in large cities in the North are mainly for supplying heat with a heating area over 10 million square meters. These cogeneration plants are designed with large dual-purpose steam extraction and condensing units of over 100MW per unit. In the heating power plans of small cities, typically one or two district cogeneration plants are built as contrasted with the three or four that are typically built in medium-scale cities. In cities of medium scale and above in the South, one cogeneration plant is planned and constructed in the development zone of each city.

9. Over 95% of fuel consumed by the cogeneration plants of China is coal. A number of oil-fired cogeneration units were built in the petrochemical industry before the 1980s. However, because of the rising price of oil and a relative long operational life, they are all in a state of off-production or half shutdown and are being replaced with large-scale coal-fired cogeneration plants. Bark, branches and black liquor are used for fuel for cogeneration in the wood pulp and paper making plants. There are few combined cycle cogeneration projects in China because the availability of natural gas is low and the price is high.

VI. Opportunities and challenges faced by cogeneration

1. Market forces

According to the specifications of the 39th clause of *the Energy-Saving Law of the People's Republic of China* that came into effect on Jan. 1st, 1998, the development of the following cogeneration related universal energy-saving technologies are encouraged by the State:

- centralized heating to improve the utilization rate of the cogeneration units,
- development of step utilization technology of thermal energy,
- cogeneration technology to produce heat, power and cold air
- cogeneration technology to produce heat, power and coal gas, and
- improvement of the comprehensive utilization rate of thermal energy.

Furthermore, several departments of the government have attached great importance to the development of cogeneration. For example, on Aug. 22, 2000, the *Provisions on the Development of Cogeneration* (Jijichu, No.1268, 2000) was issued jointly by the State Development & Planning Commission, the State Economic & Trade Commission, the Ministry of Construction and the State Bureau of Environmental Protection. This document provides legal and policy guarantees for the development of cogeneration. In addition, the Ministry of Construction has proposed that centralized heating in cities rely mainly on cogeneration

Government policies related to the overall urban planning of China call for industrial development and high-tech development zones to which new and old city industries will be gradually gathered or migrated. In addition, residential districts developed by city real estate developers will be mainly focused on multi-storied and high-rise buildings, which are more conducive to the use of centralized heating. All of these policies will help the expansion of cogeneration in China.

Industrial energy users in China are also supportive of cogeneration because, compared with industrial boiler heating, cogeneration heating can guarantee heat stability and reliability that can improve the quality and increase the output of the industrial product.

2. Reform of national power system

The state has decided to reform the power system. In the first stage, generation will be separated from the network. The National Power Grid Corporation is responsible for the transmission, distribution, dispatching and transaction of electricity. Power generation companies will bid to sell power to the network. The National Electricity Supervision and Management Committee will be responsible for the development of regulations as well as the supervision of execution and settlement of disputes.

Electric power reform will end the exclusive monopoly of the electricity sector that has existed for many years. As a result, the issue of network entry of electricity generated by the local cogeneration plants and the self-sufficient cogeneration plants of enterprises, which had been lingering for many years, has been resolved. However, cogeneration plants are faced with new challenges. These include: price competition for the entry of networks with the large-scale condensed steam power plants, and the need to improve the technical and management levels and institute modern enterprise system reform to reduce staff and improve efficiency and reduce the production cost at cogeneration plants to make them cost competitive. Currently, some cogeneration plants have begun considering building new or expanding medium and large-scale cogeneration units and to dismantle those small units that are near the end of their operational life, aiming to further reduce the coal consumption and personnel required for generation.

3. Heating price

The heating network investments for the district cogeneration plants are huge and the heating cost is high. Over 50% of sales income of the cogeneration plants comes from the heating charges. Currently, the prices for heating and power supply are all decided by the government. In addition, apportionment and calculation of heat and electricity from the cogeneration plants are different according to the methods adopted by various regional governments. Also, the actual heating prices that are paid often are different than those that are charged.

In some regions, the policy of supporting heat with electricity is taken. This increases the electricity price and lowers the heating price, transferring the financial benefits to the consumers. In some regions, the heating price is lower than the cost of producing the heat, while in most of the regions, the heating price of cogeneration plants is only about 70% of the heating cost of the small coal fired boilers with a heating profit margin of lower than 5%. Readjustment of the unreasonable heating price is an important job for the cogeneration industry after the reform of the power system.

4. Capital funds

Generally speaking, the capacities of cogeneration units in large cities are large. Typically the large cogeneration plants are owned by large enterprises, such as the National Power Corporation, that are very active in the financial markets. As a result, they are easily able to obtain funds for the construction of cogeneration plants. However, because of the huge capital requirements for the heating networks of large diameter, long pipelines that require underground tunnels for construction in big cities, municipal authorities are usually responsible for their construction investment and operation. Since only a small part of registered capital will be provided by the local budget and the rest will depend on financing, often the heating networks can’t be completed simultaneously with the cogeneration plant.

In small and medium-scale cities, the cogeneration units and heating systems are small. As a result, ownership of the power plant and the heating network usually belongs to the same organization. However, big companies are typically not willing to make the investment required for the entire system and small companies have neither the financial ability to raise the money needed nor the capability to take on such a difficult construction project. As a result, financing of the small systems is even more difficult.

VII. Cogeneration market assessment

Based upon the trends in development of cogeneration in China in recent years, efforts to reform the power system, and changes that are occurring in China brought about by market reform, it is estimated that the cogeneration market will grow by over 3,000 MW per year in the foreseeable future. This growth is projected to occur in the following sectors:

- 620MW per year in industrial enterprises,
- 2000 MW per year for centralized heating (residential heating and industrial heating) in cities in the Three Northern Regions
- 500 MW per year in industrial development zones in the South

Each of these markets is discussed in detail in the following sections.

1. Self-sufficient cogeneration plants

Self-sufficient cogeneration plants of enterprises with large requirements for steam and power consumption have been built to ensure that their heat supply needs would be met. As a result, they often elected to install small units with relatively poor performance parameters to ensure the lowest cost. However, in today's market, the heat and power balance has been taken into consideration in the selection of units for the self-sufficient cogeneration plants resulting in more appropriately sized and efficient systems.

1) Petroleum industry

The one-step crude oil refining capability of China is 270 million tons a year. In 1998, the total refining output of China was 150 million tons, 90% of which was undertaken by China Petro-Chemical Corporation (SINOPEC) and China National Oil and Gas Corporation (CNOGC).

A. Self-sufficient power plants/stations of SINOPEC

SINOPEC produces oil and gas, refines crude oil and produces petrochemical products. In the process of oil and gas development, petroleum refining and production of petrochemical products, a huge quantity of electricity is consumed. In recent years, the power consumption of SINOPEC remained constant at around 30 billion kWh per year. As the majority of the subordinate enterprises of SINOPEC are large-scale joint enterprises, most enterprises have their own self-sufficient power plants or stations. By the end of 1999, 22 enterprises had their own self-sufficient power plants/stations, with a total installed capacity of 3,740.7MW. The enterprise with the largest installed capacity is the Central Plains Petroleum Prospecting Bureau with a scale of 523MW.

The size classification of units of SINOPEC is shown in Table 7-1.

Table 7-1 Classification of installed cogeneration units of the SINOPEC enterprises

Installed capacity	Number of enterprises
Below 10MW	2
Below 50MW	8
50MW—100MW	4
100MW—200MW	5
Over 200MW—500MW	3

Initially, SINOPEC built mostly small-scale oil-fired cogeneration units. Many of these units are now near the end of their operational lives. With rising oil prices, the enterprises have found it to be in their best interests to replace these units with large coal-fired cogeneration units. Two sets of 50MW coal-fired cogeneration units have been constructed at Tianjin Petrochemical Factory, replacing six sets of small oil fuel units. In addition, a 50MW coal fuel cogeneration units is planned to be built at the Dushanzi Petrochemical Factory of Xinjiang.

By 2005, the planned total installed capacity of cogeneration of SINOPEC will be 4,300—4,500MW, an increase of 560—760MW compared with current installed capacity.

B. Self-sufficient power plants/stations of CNOGC

China National Oil and Gas Corporation (Oil Group) includes enterprises for oil exploration and development, refining, chemicals production, petroleum engineering and construction, petroleum mining, machinery manufacture, and pipeline transportation of petroleum, among other things. The Oil Group owns 13 major oil and gas fields including: Daqing, Liaohe, Dagong and Tuha. It owns 14 major refining/petrochemical enterprises including: Daqing Petrochemical, Dalian West Pacific Petrochemical and Ningxia Petrochemical.

In 1998, the overall power consumption of the Oil Group reached 32.7 billion kWh, of which, 20.6 billion kWh was for oil and gas fields and 1 billion kWh for long distant oil pipelines.

As the majority of the petrochemical enterprises of the Oil Group are super-sized joint enterprises, most enterprises have their own self-sufficient power plants. Their first priority is to ensure the availability of ample supplies of electric power for production security. Second priority is for production process heating and building heating. In 1998, the self-generation capacity of the Oil Group provided 38.5% of its total power consumption.

The installed capacity of the self-sufficient power plants of the oil fields and petrochemical enterprises subordinate to the Oil Group is about 2,900MW, which are mostly small and medium-scale units of 50MW or below. In 1998, the coal consumption was 7.95 million tons, the oil consumption was 1.64 million tons while its generating capacity was

12.6 billion kWh, among which, 6.68 billion kWh was generated by the oil and gas fields and 5.97 billion kWh was by the petrochemical enterprises (cogeneration).

The objective of the Oil Group's plans to build self-sufficient power plants is to reduce the fuel oil consumption by reconstructing the existing cogeneration plants with coal in the East and gas in the West. In addition, their plan is to expand the scale of the cogeneration plants and realize centralized heating to replace fuel oil boilers.

By 2005, China National Oil and Gas Corporation plans to increase its installed cogeneration capacity by 650MW.

2) Chemical industry

A. Overview

In the chemical industry, there are many self-sufficient power plants with a wide range of applications. Except for generation with waste heat from the production of sulfuric acid, 198 chemical enterprises with self-sufficient cogeneration plants are spread over 25 provinces and municipalities. According to incomplete statistics, up to 1998, the total number of installed cogeneration units in the chemical industry was 346 with a capacity of 1,885MW. According to elementary statistics, within one or two years, 25 enterprises are planning to expand or construct new self-sufficient power plants with a total capacity increase of around 200MW.

Table 7-2 provides statistics on the number of cogeneration units currently installed in each segment of the chemical industry by unit size. Two segments of the chemical industry – fertilizer production and soda ash/chlorine soda production dominate regarding the number of cogeneration units they employ.

Table 7-2 Distribution of current installed cogeneration units in the chemical industry

Unit capacity MW Sets / Industry	0.75	1.0	1.5	2.0	3.0	6.0	12.0	25.0	50.0	Total
Fertilizer	16	9	37	2	43	49	11	10		177
Soda ash, chlorine soda	3	1	5	1	18	27	22	1		78
Oil paint, dyestuff	1		1		2	2				6
Rubber		3	1			3				7
Pesticide	1		1		6	1				9
Mine		1	4	2			2			9
Carbon black			10		3					13

Others		14	8		16	7	6	3	2	47
Total	22	18	67	5	88	89	41	14	2	346

B. Development potential

The consumption of power and steam is huge in the chemical industry. The industry is learning that its economic efficiency will be improved by using cogeneration. For example, in Jiangsu province, a synthetic ammonia factory with a yield of 35,000 tons replaced its six old, small boilers with one 35t/h medium temperature and medium pressure boiler together with steam extraction backpressure steam-turbo generator. The result was, besides provide heating for the factory, it could also provide heating for a papermaking factory and a grease factory nearby. In addition, it resulted in a reduction in coal consumption per of ton ammonia produced by an average of 80 kg of standard coal.

C. Projection of development of self-sufficient power stations/plants in the chemical industry

In recent years, cogeneration developed rapidly in the synthetic ammonia, chlorine soda and soda ash enterprises. About 50% of the small synthetic ammonia enterprises have cogeneration stations or provide heating with district cogeneration plants. Among the 40 chlorine soda enterprises, 80% have set up cogeneration stations. Without exception, all ten big soda ash enterprises have set up cogeneration stations and are ready to expand. It is estimated that, by 2005, the total installed capacity of self-sufficient power plants in the chemical industry will reach 3,000MW, and by 2015, the installed capacity will reach 4,000MW. This represents an increase of over 1,100 MW of cogeneration capacity by 2005 and 2,100MW by 2015.

3) Light industry

A. Current status of cogeneration in the light industry

Among the 44 sectors that are in the light industry category, the largest are wood pulp and papermaking, well salt, wine making, fermented goods and refined sugar. Among these, the sugar-refining industry is a seasonal production business. Some enterprises have installed small-scale extraction and condensing units, which extract steam for heating in the sugar-refining season and condense steam for power in the non-sugar-refining season. Regarding the well salt, wine making, and fermented goods industries, because the enterprise scale is small, few have cogeneration stations. Therefore, cogeneration stations in the light industry mainly exist in the wood pulp and paper making industries.

In 2000, paper and cardboard production output reached 30 million tons. Energy consumption in these industries was about 20 million tons of standard coal per year, among which, 70% was raw coal, and the rest were bark, branches and black liquor. Usually all wood-pulp papermaking factories have cogeneration plants, while the majority of straw-pulp papermaking factories do not. Parts of straw-pulp papermaking factories with a yield of 30,000 tons per year have installed boilers that burn black liquor for recovering alkali. But, only a few have set up self-sufficient cogeneration plants. Instead, most have self-sufficient boilers. A few straw-pulp papermaking factories get heat from district cogeneration plants. According to incomplete statistics, the existing installed capacity of self-sufficient cogeneration plants in the papermaking industry is 1,500MW with 180 units in total as shown in Table 7-3.

Table 7-3 Classification of current installed cogeneration units in the papermaking industry

Unit capacity	Units	Capacity in total
3MW and below	96	200MW
6MW	36	220MW
12MW	32	380MW
20-50MW	10	320MW
50MW and above	6	380MW
Total	180	1,500MW

B. Development projection

It is estimated that, by 2005, the paper and cardboard output of China will reach 40 million tons. As a result, it is estimated that the installed capacity of self-sufficient cogeneration units will increase about 600MW to help meet to increased demand for paper and cardboard.

Table 7-4 Newly increased installed capacity of cogeneration units of part of the papermaking enterprises

Name of enterprise	Installed capacity	Units
Ningbo Zhonghua Paper Industry Co., Ltd.	50MW	2
Hainan Paper-pulp Factory	37MW	3
Shandong Huatai Paper Industry Co., Ltd.	27MW	2
Jiamusi Paper Industry (Group) Corp.	25MW	1
Yueyang Paper Industry Co., Ltd.	25MW	1
Rizhao Paper-pulp Factory	25MW	2

4) Non-ferrous metallurgical industry

A. Current status of the non-ferrous metallurgical industry

By 1999, the non-ferrous metal production capacity of China was: mine materials, 5.41 million tons; smelting, 7.61 million tons; processed copper and aluminum, 5.91 million tons. The production output of non-ferrous metal for the year was 6.947 million tons, among which, copper was 1.17 million, aluminum was 2.8 million, lead was 910,000 and zinc was 1.7 million. China's production output of ten non-ferrous metals has been second in the world behind the U.S. for 6 consecutive years.

B. Current status of energy consumption in the non-ferrous metallurgical industry

In 1999, the output of non-ferrous metals in China was 6.947 million tons. The energy consumption of the industry in 1999 was 33.66 million tons of standard coal, representing 2.76% of China's total energy consumption for the year. Electricity represented 65.1% of the consumption, coal represented 25.3%, coke represented 4.6%; heavy oil 1.8%, and gasoline, diesel oil and natural gas represented about 1.13%. A variety of other energy sources represented the remaining 2.07%.

C. Current status of self-sufficient cogeneration plants of the non-ferrous metallurgical industry

The non-ferrous metal smelting process requires a large quantity of heat and electricity. During the 1960s and 1970s, there were few self-sufficient cogeneration stations, and the majority of enterprises provided heating directly from boilers. In the 1980s, the national power supply was very tight and could not guarantee the electricity and heating for production. As a result, in the middle and latter part of 1980s, self-sufficient power plants were built as part of new aluminum oxide factories and in response to the technical reforms aimed at old factories. High-temperature flue gas from the industrial furnaces and kilns in the production enterprises of copper, nickel, lead, zinc and tin plants was recovered to build power stations with remaining heat or boilers for heating. By the end of 2000, among the large-scale production enterprises of non-ferrous metals such as copper, aluminum, lead, zinc and nickel, 17 self-sufficient cogeneration plants/stations had been built with 61 boilers. The total capacity was 5,710t/h. The installed capacity of 61 sets of generating units was 517.5MW with a generating capacity of 2.63046 billion kWh. These units are summarized by industry by unit capacity in Table 7-5.

Table 7-5 Current status of self-sufficient cogeneration stations in the non-ferrous metallurgical industry

Unit capacity MW / Sets / Industry	**1**	**3**	**6**	**12**	**15**	**25**	**Total**
Aluminum			18	5	3	7	33
Copper, nickel	1	4	9	3			17
Lead, zinc and tin		3	3	3	2		11
Total	1	7	30	11	5	7	61

D. Development projections of self-sufficient cogeneration stations in the non-ferrous metallurgical industry

It is estimated by experts that, by 2005, the output of non-ferrous metal industry will reach 9 million tons with an annual growth rate of 3.7%. By 2005, the output of copper will reach 1.55 million tons with an annual increase of 3.26%; aluminum will be 3.55 million tons with an annual increase of 4.65%; lead will be 1.2 million tons with an annual increase of 4.33%; zinc will be 2.2 million tons with an annual increase of 2.77% and the remaining 6 kinds of metal will reach 500,000 tons.

According to projections, ten additional cogeneration stations are preliminarily planned to be expanded with 11 units. This will increase the industry's cogeneration generating capacity by 309MW, saving 352,720 tons of standard coal. Details of this projection are shown in Table 7-6.

Table 7-6 Development prediction of self-sufficient cogeneration stations in the non-ferrous metallurgical industry

Unit capacity MW / Sets / Industry	1	3	6	12	15	25	50	125		Total
Aluminum							2	1		3
Copper, nickel			1	5						6
Lead, zinc and tin		1			1					2
Total		1	1	5	1		2	1		11

5) Projections of expected capacity additions of self-sufficient cogeneration stations in major industries of China

Table 7-7 summarizes the projected cogeneration plant increases in the industrial sector through 2005 by industry. As can be seen, capacity additions of over 620MW per year are expected.

Table 7-7 Prediction of newly increased capacity of self-sufficient cogeneration stations in major industries of China in 2005

Unit: MW

	Newly increased capacity	Capacity increased per year
Chemical industry	1,000	200
Petroleum industry	1,240	240
Light industry	600	120

Non-ferrous metallurgical industry	309	61.8
Total	3,149	621.8

2. Market for centralized heating in cities in the Three North Regions

1) Development of civic architecture in China

In recent years, residential building in cities has undergone rapid development. From 1996 to 2000, the building area has increased 1.2 billion square meters in towns and cities around the country, with an average increase of 240 million square meters per year. Compared with that in 1998, building area increased 310 million square meters in 1999. Experts estimate that, during the ten years from 2000 to 2010, building area will further increase by about 3.35 billion square meters, 335 million per year in average. Of this, the building area of the Three North Regions will increase about 150 million square meters per year.

Table 7-8 Current building area in towns and cities

Unit: 100 million square meters

	1985	1990	1995	1998	1999
Actual building area of premises at the end of year	23.9	39.8	57.3	70.9	73.5
Actual building area of dwelling houses at the end of year	11.3	19.6	31.0	39.7	41.7
Actual living space of dwelling houses at the end of year	5.8	9.8	15.5	19.8	21.0

2) Current status of centralized heating in cities in the Three North Regions

As shown in Table 7-9, Among the 15 provinces, municipalities and autonomous regions in the Three North Regions (North China, Northwest and Northeast China), urban centralized heating has rapidly developed in about one-half, where the urban heating ratio is near or above 25%. However, the development is unbalanced. Centralized heating in Qinghai in the West is just at the starting stage. And Shaanxi and Henan have reached levels of only 10%. By the end of 1999, the centralized heating area reached 923 million square meters in the Three North Regions. In total, the centralized heating area of China was 967 million square meters in 1999.

Though the statistics of the urban heating ratio are very high in the Three North Regions, based upon on-site investigation, it was found that quite a few centralized heating boiler houses were designed with several hot water boilers of less than 10 tons. Their efficiency is very low. Currently the building area of planned district heating of the western suburb cogeneration plant at Tangshan, Hebei is 9 million square meters, among which 3 million square meters is directly provided by the cogeneration plant. The rest of the boiler houses centralized heating, such as dormitory areas for the railway employees, are all in dormitory areas of over 300,000 square meters. Through on-site investigation, it was learned that the centralized heating boiler houses are designed with 6 to 7 hot water boilers, among which, the largest is no more than 10 tons.

Table 7-9 Statistics of urban houses and centralized heating in the Three North Regions—1999

Unit: 10,000 square meters

Region	Actual building area of premises at the end of year	Actual building area of dwelling houses at the end of year	Actual living space of dwelling houses at the end of year	Area with centralized heating	Heating percentage
Beijing	27,430	14,211	6,670	6,976	25.4
Tianjin	15,042	7,831	4,035.15	5,011	33.3
Hebei	29,536	15,914	8,593.84	8,751	29.6
Shanxi	20,036	11,106	5,951.44	4,645	23.2
Inner Mongolia	14,241	8,013	4,194.15	4,335	30.44
Liaoning	49,631	28,965	14,538.66	17,653	35.57
Jilin	22,061	13,364	6,922.81	8,430	38.2
Heilongjiang	34,025	20,443	10,545.18	12,945	38
Shandong	54,162	29,596	14,873.82	10,737	19.8
Henan	33,147	18,013	8,892.84	3,222	9.72
Shaanxi	14,328	7,624	4,003.08	1,465	10.2
Gansu	9,647	5,151	2,699.38	3,067	31.8
Qinghai	2,256	1,122	633.9	60	2.66
Ningxia	3,364	1,714	946.34	1,520	45.2
Xinjiang	11,971	6,727	3,385.87	3,511	29.3
Total	340,877	189,794	96,886.46	92,328	

The building area of Ürümqi is 40 million square meters, among which 11 million square meters is from centralized heating with 4.5 million through large-scale hot water boilers of over 35 tons and 4.8 million through boilers of less than 10 tons. Currently, almost all boilers for centralized heating in small and middle scale cities are small boilers of less than 10 tons.

3) Projection of increase of urban centralized heating area in the Three North Regions

Table 7-10 provides statistics on the initiated and completed building areas developed by centralized real estate development enterprises in the Three North Regions in 1999. These buildings generally were developed according to the urban centralized heating plans.

The urban stock building area in the Three North Regions is 3.4 billion square meters, among which, 70% to 80% still takes heating from dispersed boilers; 2.5 billion square meters of which are expected to be changed to centralized heating.

Table 7-10 Statistics of building area that is completed or started by real estate development enterprises in towns and cities—1999

Unit: 10,000 square meters

Region	Construction area	Completed area	Started area	
		Civic architecture	Civic architecture	Urban house
Beijing	3,784	1,208.5	1,061.8	850
Tianjin	1,596.7	454.8	497.3	446
Hebei	1,489.4	693	725.7	649.4
Shanxi	762.5	259.4	412.5	389.5
Inner Mongolia	473.5	268.6	315.9	235.8
Liaoning	2,614.5	1,277.9	1,328.	1,056.8
Jilin	751.4	368.6	403.5	329.2
Heilongjiang	1,118.7	547.4	727.4	566.9
Shandong	2,824.4	1,401.9	1,406	1,158
Henan	1,339.6	444.9	574.4	487.9
Shaanxi	1,313.54	580.8	414.7	345.3
Gansu	431.2	172.1	135.2	115.1
Qinghai	174.3	78.1	60.6	47.1
Ningxia	209.6	124.2	135.3	105.6
Xinjiang	343.4	160	212.7	194.8
Total		8,040	8,411	

Based upon analysis of the centralized heating area of China in 1999 versus that in 1998, it was determined that centralized heating in the three northern regions increased by 100 million square meters in 1999. Taking this analysis one step further indicates that the centralized heating area of the regions will increase by about 150 million square meters per year over the next several years.

3. Projection of cogeneration market in Three North Regions

1) Current status and changes of cogeneration in large cities

As a super-sized city in the Three North Regions, Beijing currently has a building area of 274.3 million square meters, among which 228.5 million is in the urban districts. It is planned that the building area in the urban districts will reach 268.5 million square meters by 2005. In 1999, the centralized heating area in the urban districts was 69.78 million square meters. There were eight heating sources with a total heating capacity of 17,980 GJ of heat for residential use and 1,320 ton/h of steam. The length of urban heating pipeline was 328km. There were 1,002 heat power stations. As shown in Table 7-11, cogeneration plants in Beijing have a capacity of 2230MW and provide heating for 30.98 million square meters.

Table 7-11 Status of heating supply from cogeneration plants in the urban districts of Beijing (SEEMS TO BE DISCREPENCY IN THE NUMBERS – 2 COLUMNS HAVE SAME NUMBERS)

Project	Installed scale (MW)	**Heating capacity (10,000 square meters)**	Actual heating supply (10,000 square meters)	**Heating in 2005 (10,000 square meters)**
First Cogeneration Plant	580	1,452	881	1,452
Second Cogeneration Plant	200	1,089	803	1,089
Shijingshan Cogeneration Plant	800	1,089	1,000	1,089
Gaobeidian Cogeneration Plant	650	2,106	414	2,106
Total	2,230	5,736	3,098	5,736

Table 7-12 Heating supply and prediction of urban districts in Beijing

Project		Unit	2000Year	2002Year	2005Year
Civil architecture area in the urban districts		10,000 square meters	22,850	24,450	26,850
Gas	Gas heating area	10,000 square meters	2,400	5,000	9,900
	Converted into natural gas	100 million cubic meters	3.6	10.	16.5
Electricity	Electricity heating area	10,000 square meters	300	1,000	1,750
	Converted into power	100 million kWh	3.14	10.465	18.314
Fuel oil	Fuel oil heating area	10,000 square meters	200	800	1,250
	Converted into oil	10,000 ton	2.4	9.6	15
Heating area by City Heating Power Company		10,000 square meters	5,099	6,399	8,359
Heating area by other coal fuel boilers		10,000 square meters	14,851	11,251	5,591

Note: cogeneration heating area is included in the heating area by City Heating Power Company

As shown in Table 7-12, coal consumption for heating in Beijing will be gradually reduced as it is replaced by natural gas. Consideration is being given to installing a natural gas combined cycle cogeneration plant project. The 170MW of combined cycle heating units together with four sets of 75t/h hot water boilers using natural gas, will provide heating for 5 million square meters. In addition, Beijing has planned to build five more combined cycle cogeneration plants at Chaoqiao, Zhengchangzhuang Village, Shangdi Industrial Development Zone and Tsinghua University and Sun Palace. In some super sized cities such as Beijing and Tianjin, in order to meet the environmental requirements, natural gas is expected to substitute for coal and natural gas combined cycle systems are expected to be used more.

Based upon information gathered on the construction of cogeneration plants in big cities in the North and information on projects approved by the government in recent two years, it is concluded that urban cogeneration units are likely to be large systems of higher performance than in the past. This is in part to meet stringent environmental requirements and in part to improve system economics.

The population in the urban districts of Shenyang, Liaoning province is 5 million. In 2000, the energy consumption was 12 million tons of standard coal, among which, coal was 11 million tons, electricity was 11 billion kWh, oil fuel was 400,000 tons and product oil was 750,000 tons. Currently, the installed capacity of cogeneration units of the City is 638MW, among which, the installed capacity of Shenhai Cogeneration Plant is 400MW, Shenyang Cogeneration Plant is 100MW, Jinshan Cogeneration Co., Ltd. is 24MW, Huanggu Cogeneration Co., Ltd. is 24MW, Xinbei Cogeneration Co., Ltd. is 24MW and the self-sufficient cogeneration plant of Shenyang Antibiotics Plant is 24MW.

The heating area of Shenyang is 80 million square meters, among which the centralized heating area is 45 million square meters and the heating area served by the cogeneration plants is 17.5 million square meters. The guiding principle for the urban heat source construction of Shenyang is emphasizing cogeneration with large-scale district boiler houses as a supplement. It is planned that the Jinshan Cogeneration Plant will increase its capacity by 50MW, Huanggu Cogeneration Plant will increase its capacity by 12MW and the Third Shenyang Cogeneration Plant will increase its capacity by 100MW. By 2005, the installed capacity of cogeneration units in Shenyang will increase by 200MW, and the heating area by the cogeneration plants will increase by 7 million square meters.

The population of the urban districts of Shijiazhuang, Hebei province is 1.6 million. The current building area is 35.67 million square meters, and the thermal load for space heating is 2,279MW. The thermal load for industrial production is 1,238 ton/hour. The heating ratio of area of buildings that use space heating to the total amount of building area is 44% and the industrial heating ratio is 66%. According to the urban planning of Shijiazhuang, by 2010, the building area will increase 37 million square meters. The targets created in *Urban Centralized Heating Planning of Shijiazhuang* are for 2010, the city heating ratio will reach 70% and the industrial heating ratio will be 80%. In order to reach the above targets, the City has developed a construction plan to add two sets of 200MW heating units at Shijiazhuang Cogeneration Plant and add two sets of 50MW units at the Second Cogeneration Plant of Shijiazhuang Oriental Cogeneration Stock Company. Right now the two projects are in the approval process. Meanwhile, two additional sets of 125MW heating units are planned at the Shijiazhuang South Suburb Cogeneration Plant.

Ürümqi has a population of 1.6 million with a building area of over 40 million square meters. However, the centralized heating area is only 11 million square meters with an urban heating ratio of only 25%. The City has only one cogeneration plant at Weihuliang, which has two sets of 125MW heating units installed with a heating capacity of 3.5 million square meters. As the heating system is still in the process of construction, it can only provide heating for 1 million square meters. Ürümqi is one of the cities with serious air pollution problems. Currently, it has 2,958 heating or industrial boilers with a coal consumption of 7 million tons per year, including 1,224 small boilers of less than 4t/h. The indexes of sulfur dioxide and dust in the air all exceed the national standards. In order to solve the air pollution issue, the City has planned to install four sets of 200MW heating units in the south district and get an increase of heating area of 10.5 million square meters. Meanwhile, it also plans to use natural gas in the urban districts.

Tangshan is a local level city of Hebei province. Currently, it has a population of 1.57 million with a building area of 43.48 million square meters. Tangshan's centralized heating area is 18 million square meters with a heating ratio of 41%, including:

- Tangshan Power Plant that has four sets of 12MW and one set of 50MW heating units that can provide heating for 4.38 million square meters, and
- Tangshan West Suburb Cogeneration Plant which has two sets of 50MW heating units that can provide heating for 3 million square meters.

According to the urban planning of Tangshan, by 2010, it will get an increase of building area of 20 million square meters, and increase the urban heating ratio to 60%. It has planned to add by 2005 two sets of 300MW heating units at Tangshan Power Plant to get an increase of heating area of 10 million square meters. Right now, the project is in the approval process. In addition, Tangshan plans to add one set of 200MW heating units at Tangshan West Suburb Cogeneration Plant to get an increase of heating area of 5 million square meters.

There are 21 cities with more than 1 million population in Three North regions, the planned cogeneration capacity growth of each city in the next five years is around 200-600MW.

2) Cogeneration market change in medium-scale cities

The amount of cogeneration units in medium-scale cities of the Three North Regions is also expanding. Currently, Dezhou Cogeneration Plant of Shandong province has one set of 50MW and one set of 25MW units in the approval process. In addition, Shihezi of Xinjiang has started the construction of two sets of 50MW heating units. One of the two sets of 25MW heating units at Kuitun already has begun installation. Also, Cangzhou of Hebei province has two sets of 25MW heating units approved for construction.

There are 117 middle size cities in Three North regions, most of these cities have already had cogeneration plants. Those cities with rapid economic development will newly build and expand cogeneration plants in the future.

3) Cogeneration market in small cities

Local industries in small cities with population less than 200,000 mainly include fertilizer, winemaking, papermaking, food and small chemicals. Factories above a defined scale are primarily located near the towns. Based upon actual operating results of small cogeneration projects that have been completed, the industrial thermal load and heating capacities are mostly over 300,000 tons per year. The industrial scale of small cities is small. And, there are few self-sufficient cogeneration plants. District cogeneration plants are primarily used to supply heat.

Small cities with heating periods of over 4,000 hours in the cold region of the North, have a typical heating area of about 1 million square meters. Currently, they mostly use small boilers for heating. Even if these cities have no industrial thermal load, they can build backpressure cogeneration plants, which operate for heating in winter and are examined and repaired in summer. Their economic efficiency will be much better than hot water boilers. There are about 50 small cities that can meet these conditions in this region. If the issue of tying into the electricity network can be solved, the number of this type of cogeneration plant will soon become more popular in this region.

In some small cities with a large industrial thermal load, owing to the shortage of construction funds, even if the projects get approved, cogeneration plants are still unable to be built. Therefore, most small cities in the Three North Regions have no cogeneration plants or very small plants.

There are 15 cities with a population of 50,000 to 100,000 in Xinjiang as well as in Inner Mongolia (Figure 7-13). None of these cities have cogeneration plants. Among cities with a population of 100,000 to 200,000, 50% have no cogeneration plants. And, as to cities with a population of over 200,000, 30% have no cogeneration plants. However, most cities with a population of over 300,000 have built cogeneration plants, which, since they are small scale, cannot meet the requirements for centralized heating.

There are 168 cities with a population below 200,000 in the Three North Regions (Figure 7-14), which form a large cogeneration market. As to those cities with a relatively large industrial thermal load, if the issue of construction funds can be solved and a reasonable heating price can be achieved, many cogeneration plants would be built. However, as to those small cities with a short heating period in winter and a small industrial thermal load, it will be difficult to justify cogeneration plants.

4) Analysis of cogeneration market capacity in Three North Regions

As of the end of 2000, 60 cogeneration projects have been completed in Hebei province with an installed capacity of 2,300MW. However, the average urban heating ratio of the province is very low. In many medium-scale cities, such as Langfang, Zhangjiakou and Hengshui, have no cogeneration plants. As shown in Table 7-14, there are 23 cities with a population of less than 200,000 in Hebei province. The majority of these cities have no cogeneration plants or centralized heating. However, the requirements for cogeneration plants are huge in other regions. According to the energy planning of the province, by 2010, Hebei will get an increase of installed capacity of power units of 10,000MW, and the overall installed capacity will reach 25,000MW. Among these, cogeneration plants with a capacity of over 50MW per unit will be the focus for future development. In addition, 15 to 20-20MW gangue cogeneration plants will be built. Based upon energy planning of Hebei province, it is estimated that 300 to 400MW of cogeneration capacity will be built annually through 2010.

Shandong province has a land area of 156,700 square kilometers with a population of 87.85 million. Among 142 counties and cities of the province, 95 have built cogeneration plants. Currently, there are 161 cogeneration plants in Shandong, with 277 sets of cogeneration units and an installed capacity of 1.8 million kilowatts, which represents 11% of the total installed capacity of generating equipment. In 1997, it had 8,642 industrial boilers with a capacity of 97,100 tons of steam. The centralized heating area was small in Shandong's towns and cities, and the heating ratio was only 19%. However, Shandong has imposed a standard requiring that the urban heating ratio should be higher than 35%. According to planning, cities at the county level and above will all require the construction of cogeneration for centralized heating. And cities at the county level are required to achieve a heating ratio of higher than 20% in the next several years. In recent years, in Shandong province, the overall construction scales for the cogeneration projects submitted by the local organizations have been around 300MW per year. This level of growth is expected to continue into the future.

The total construction scale of cogeneration plants that are under construction in Xinjiang, including those at Shihezi, Yili and Kuitun, is 200MW. Over 1,000MW of cogeneration is planned for the whole Region over the next few years.

It is estimated by experts that, provinces with a faster economic development in the Three North Regions can be expected to increase their installed cogeneration capacity by over 300MW every year. Provinces with a relatively slow development in the Three North Regions are expected to increase their cogeneration capacity by 100 to 200MW per year.

Table 7-13 Urban heating and cogeneration status of Inner Mongolian Autonomous Region

Population	City	Cogeneration scale	Heating method
over 300,000	Hohhot	Two sets of 200MW under construction	
	Baotou	750MW	
	Wuhai	Two sets of 12MW under construction	
	Chifeng	36MW	
over 200,000	Hohhot	24MW	
	Tongliao	30MW	
	Jining		Small boiler heating
	Linhe		Small boiler heating
	Hailar	24MW	
	Dongshen	30MW	
over 100,000	Xilin Hot	24MW	
	Manzhouli		Small boiler heating
	Yakeshi	12MW	
	Zalantun	6MW	
over 50,000	Tumd Left Banner, Hohhot		Small boiler heating
	Ongniud Banner		Small boiler heating
	Ningcheng County		Small boiler heating
	Kailu County, Tongliao City		Small boiler heating
	Jarud Banner, Tongliao City		Small boiler heating
	Jalaid Banner, Hinggan League		Small boiler heating
	Tuquan County, Hinggan League		Small boiler heating
	Horqin Right Wing Middle Banner, Hinggan League		Small boiler heating
	Dalad Banner, Ih Ju League		Small boiler heating
	Hanggin Banner, Ih Ju League		Small boiler heating
	Jungar Banner, Ih Ju League	Power Plant of Jungar Coal Company	Circulating water heating
	Urad Front Banner, Bayannur League		Small boiler heating
	Wuyuan County, Bayannur League		Small boiler heating
	Alxa Left Banner, Alxa League		Small boiler heating

	Oroqen Autonomous Banner, Hulun Buir League		Small boiler heating

Table 7-14 Statistics of city population in Three North Regions

Unit: 10,000 person

Region	Total	Grouping according to nonagricultural population in urban districts				
		Above 200	100-200	50-100	20-50	Below 20
Beijing	1	1				
Tianjin	1	1				
Hebei	34		3	2	6	23
Shanxi	22		1	1	4	16
Inner Mongolia	20		1	1	6	12
Liaoning	31	2	2	6	7	14
Jilin	28	1	1		11	15
Heilongjiang	31	1	1	6	10	13
Shandong	48		3	5	20	20
Henan	38		2	5	10	21
Shaanxi	13	1			5	7
Gansu	14		1		2	11
Qinghai	3			1		2
Ningxia	5				2	3
Xinjiang	19		1		7	11
Total	308	7	16	27	90	168

4. Cogeneration market in industrial development zones in non-heating regions in the South

Centralized heating and cogeneration are mainly for industrial customers in the southern cities of China. Industry-based development zones have been planned and constructed in nearly all small, middle and large-scale cities in the South. In addition, the economic and technological development zones in the Yangtze Delta at the southeast coast have achieved a rapid development and reached a large scale. Cogeneration plants have become one of the essential elements in the development zones and have played an important role in the introduction of industrial projects. One typical example is Taicang Economic Development Zone of Jiangsu province.

Taicang City is located in the southeast region of Jiangsu province with Yangtze River on the east, Shanghai on the south and Suzhou on the west. The population of Taicang is 447,500, and its overall land area is 815 square kilometers. Taicang Economic Development Zone is a provincial-level development zone approved by the Provincial Government with a total planned area of 25 square kilometers. By the end of 1998, the construction of first phase of 5.2 square kilometers was nearly completed including the auxiliary infrastructure construction (roads, water supply, power supply, communications and heat supply). Businesses from over ten countries and regions (Japan, America, Great Britain, Germany, South Korea, Singapore as well as Taiwan and Hong Kong) have invested in the development zone. Several industrial projects, mainly in the fields of electronics, machinery, food, light industries, textile and metallurgy, have been completed. From the beginning of construction, it was determined that cogeneration would be needed to provide centralized heating and environmental protection

The Taicang Cogeneration Plant is 2×75t/h coal powder boilers and 2×15MW steam extraction condensing units, which were put into operation respectively at the end of 1998 and the beginning of 1999. Currently, another 75t/h coal powder boiler is under construction at the plant. The generating capacity of the plant has reached 188.4126 million kWh per year with a annual heating capacity of 315,600 tons. The average thermal load of the plant has reached 50 ton/hour with a peak value of near 90 ton/hour. Currently, over 20 kilometers of heating network have been constructed and has begun to provide heat for 58 customers. The construction of the cogeneration plant makes the heating network of the urban districts of Taicang achieve a coverage of 80% and its centralized heating ratio has reached 68.03%. This has created the proper conditions for the next step -- providing hot water for residents.

Upon the construction of the cogeneration plant, over 60 coal/oil fuel boilers were eliminated with a total capacity of over 260 ton/hour. It has achieved a reduction in emissions of flue gas and dust of 560 ton/year. This has resulted in a decline of the daily average concentration of TSP from 0.276mg/m^3 in 1997 to 0.164mg/m^3 today.

As shown by this example, construction of the development zones facilitates construction of cogeneration plants. On the other hand, construction of the cogeneration plant provided good protection for corporate production and attracted more investment projects into the development zone. The Taicang Cogeneration Plant is representative of economic and technological development zones throughout China.

Currently, cogeneration plants have been constructed in most of the eastern development zones, especially those in the Yangtze Delta such as Jiangsu, Shanghai and Zhejiang. However, few cogeneration plants have been constructed in the development zones in the mid-west region and the south. Currently, the State is implementing a strategy of Great Western Development. With the increase of investment to the west, the number of cogeneration plants will increase in the western development zones.

There are 162 cities with a population of over 200,000 in the South (Table 7-15), among which, 70% have no cogeneration plants. Furthermore, the existing cogeneration plants are mainly based on industrial thermal load with a typical construction scale of 50MW or below. According to the development projections, in the next several years, it is quite possible to expect about 500MW of new heating units per year constructed in the southern economic and technological development zones.

Table 7-15 Statistics of urban population in the South

(unit: 10,000)

Region	Total	Grouping according to nonagricultural population in urban districts				
		Over 200	100-200	50-100	20-50	Below 20
Shanghai	1	1				
Jiangsu	44	1	1	4	19	19
Zhejiang	35		1	2	7	25
Anhui	22		1	4	9	8
Fujian	23		1	1	5	16
Jiangxi	21		1		8	12
Hubei	36	1		3	14	18
Hunan	29		1	3	8	17
Guangdong	54	1		3	30	20
Guangxi	19			2	4	13
Hainan	9				2	7
Chongqing	5	1			2	2
Sichuan	31	1			13	17
Guizhou	13		1		3	9
Yunnan	15		1		2	12
Total	348	6	8	22	126	195

5. Natural gas combined cycling cogeneration market

1) Development planning for natural gas in China

According to primary estimates, the natural gas resources of China are 38 trillion cubic meters, of which 29.9 trillion cubic meters exist on land. The resources are mainly concentrated in the mid-western regions and offshore oil and gas fields, of the Tarim and Sichuan in the West being the largest. Other important fields include: Erdos, Zhunger, Bohai Bay, Zhujiang River estuary, East Sea, the southeast of Hainan Island and Yingge Sea,. In 1998, the output of natural gas was 21.5 billion cubic meters, among which, besides self-use by the natural gas extraction enterprises, the actual supply provided to consumers was 14.9 billion cubic meters. It is estimated that, by 2005, the output of natural gas will reach 37 billion cubic meters and 8.5 billion cubic meters will be transported from the West to the East; by 2010, the output of natural gas will reach 45 billion cubic meters and 21 billion cubic meters will be transported from the West to the East.

2) Status of natural gas consumption (1998)

Currently, the chemical industry is the largest consumer of natural gas in China, consuming 41.5%. The fertilizer industry, within the chemical industry sector, is the largest user, consuming about 37% of the country's gas.

Approximately 28% of China's gas is consumed by the oil and gas extraction industries, 12.5% is used to produce electricity and 3% is used in other markets.

3) Natural gas requirements prediction

Table 7-16 provides projections of natural gas consumption by market sector. These projections indicate that the largest growth in gas demand will be for electric power generation. In addition, by 2010, urban gas use will increase dramatically.

Table 7-16 Natural gas requirements predicted by experts

Unit: 100 million cubic meters

Section	2005	2010
Power generation	174	484
Chemical industry	120	180
Industrial raw materials	168	257
City fuel	106	230
Total	568	1,151

By 2010, there will be a gap of 70 billion cubic meters between the predicted demand and the supply of gas in China. Therefore it is planned to import 20 billion cubic meters from Siberia in Russia and 30 billion from three countries in Central Asia -- 10 to 15 billion cubic meters from Kazakhstan, 5 billion from Uzbekistan and 10 to 15 billion from Turkmenistan. In the eastern coastal area, the problem will be solved through the import of LNG. The construction of the first phase project with a capacity of 3 million tons of imported LNG has started in Guangdong province.

4) Natural gas combined cycle cogeneration market

It is expected that natural gas combined cycle generation will not be competitive at this time with coal power in the Three North Regions because coal prices are low and flue gas desulfurization systems are not required (IS THIS RIGHT?). However, in southern regions such as THE Yangtze Delta and Guangdong, it can compete with the 600MW coal-fired plants that must install flue gas desulfurization units. It should also compete favorably with nuclear power stations. After the completion of transportation systems for gas from the west of China to the east and by increasing imports of LNG, the natural gas supply will increase significantly. As a result, cogeneration plants constructed in the development zones of the large and medium-scale cities in regions such as Yangtze Delta and Guangdong will be mainly based on gas combined cycle units. Shanghai is already planning to build 200MW combined cycle cogeneration units at two industrial development zones (Jinqiao and Songjiang). In addition, energy experts in Jiangsu are calling for clean energy to be used. However, considering the limitation of gas supply sources, no large-scale development will be achieved before 2005.

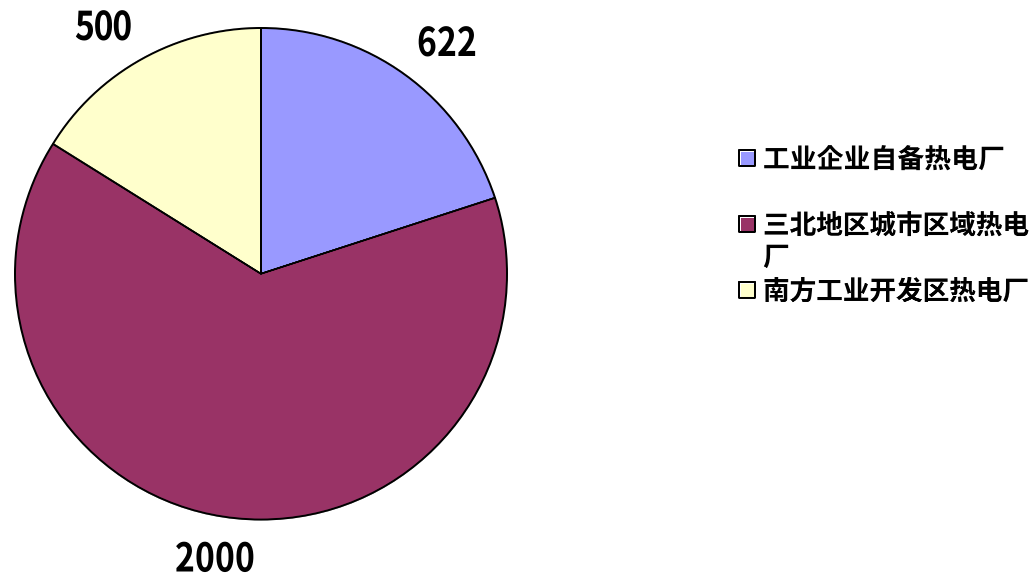
Although in the Three North Regions, the generation cost of natural gas combined cycle power plants is higher than that of coal fuel power plants, in order to meet the environmental protection requirements for cities like Beijing, Tianjin and other provincial capitals, the fuel structure must be adjusted, and increasing the percentage of natural gas is a priority option. Cogeneration using a gas-combined cycle may be the choice to achieve better energy and economic efficiencies than using natural gas directly in boilers for heating. Already in 1999, one small cogeneration plant with one set of 50MW natural gas combined cycle units was built in Tianjin Economic and Technological Development Zone. Currently, discussions are underway regarding using cogeneration combined cycle heating project in the urban districts. For example, Beijing is discussing demonstrating a natural gas combined cycle cogeneration plant project in the Electronic Town. According to the feasibility study reports, its construction scale will be 170MW combined cycle units and four 75t/h natural gas fuel hot water boilers with a heating area of 5 million square meters. In addition, five other combined cycle cogeneration plants are planned to be constructed in Beijing.

Table 7-17 Assumed consumption of natural gas in Beijing

Unit: 10,000 cubic meters

	2000	2001	2002	2005
Used by residents and public	44,533	50,225	55,918	80,491
Heating	50,553	66,635	94,885	145,759
Refrigeration	3,000	4,400	4,400	5,842
Direct combustion engine	659	758	842	
Car fuel	2,847	5,694	8,760	19,710
Cogeneration				100,000
Industry	7,428	9,382	13,952	53,548
Total	109,020	137,094	178,757	405,350

The relatively highly developed regions of southeast China are located in energy import regions. The thermal efficiency of natural gas combined cycle cogeneration plants is higher than coal units and they are much cleaner. As a result, gas-based power systems in this region may be the most acceptable option and may be the main market for natural gas combined cycles. Though combined cycle cogeneration plants cannot compete with coal power in super sized cities such as Beijing or in large cities in the natural gas producing areas, in order to meet the environmental requirements, the fuel structure must be changed. As a result, it is projected that, by 2005, over 1,000MW combined cycle cogeneration units will be put into production (Table 7-17). Use of combined-cycle units is expected to accelerate even more after 2005.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工业企业自备热电厂
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南方工业开发区热电厂

VIII. Conclusion

Worsening air pollution, which is in part caused by hundreds of thousands small, inefficient coal-fired boilers, is one of the main obstacles in achieving Chinese's sustainable development objectives. To solve this problem, it has been recognized that replacing these boilers with central heating and heat-power cogeneration is a viable option.

Based upon projections made in this report, the installed capacity of cogeneration in China will increase at least 3,000MW per year in addition to increases of heating capability of 4,500MW, and heating load of 20×10^6MWh per year. The investment required to achieve this growth will be 15 to 18 billion Yuan per year (excluding heating network investment). The expansion in use of cogeneration will also improve air pollution caused by thousands of small coal fired boilers. Centralized heating and cogeneration may be the most effective methods to address this problem by replacing these small, very inefficient boilers with larger, much more efficient cogeneration systems. Using cogeneration will save about 2.88 million tons of standard coal per year for each 3,000 MW added, reducing carbon dioxide emissions by 7.55 million tons and sulfur dioxide by 57,600 tons per year.

In 1999, the installed capacity of cogeneration was 12.6% of the total installed thermal power. If cogeneration increases 3,000MW per year and the installed thermal power increases 5% per year, the total installed capacity of cogeneration will reach 43,100MW or 14%-15% of the installed thermal power. Although this is an impressive increase, it still does not approach the level at which cogeneration is used in Europe. If cogeneration use in China reaches the 30%-45% range currently used in Europe, the installed capacity of cogeneration would be 85,000MW. This achievable goal implies that the cogeneration market in China still has a lot of growth potential.

Power system reform is currently underway in China. It is expected that the reform will facilitate settlement several of the issues concerning the acceptance by the grid of electricity from cogeneration plants, which has been an impediment to cogeneration for many years. Thus, deregulation will bring new development opportunities for cogeneration. However, faced with competition in the power market, cogeneration enterprises must carry out modern enterprise system reform and improve their technical, financial and management levels. Meanwhile, the heating market needs to be further expanded and the urban hot water and air conditioning markets, which are still in their infancy, need to be developed. In addition, the implementation of coal gas cogeneration technology should be pushed to create large new markets for cogeneration.

In the 1980s, cogeneration began to develop rapidly in large part because of preferential policies of the government, which was aimed at energy savings. In the 1990s, energy saving was connected with environmental benefits such as reduction of greenhouse gases, and cogeneration again was regarded as an acceptable environmental protection option, resulting in it receiving significant attention. China's recently enacted *Energy-Saving Law* has given cogeneration even higher priority. With continued preferential government policies and improving market conditions expected to be brought about by power system reform, cogeneration will continue to develop rapidly in China.

APPENDIX A. COGENERATION IN THE UNITED STATES AND THE EUROPEAN UNION

Cogeneration in the US

In 1998, cogenerators in the United States produced 306 billion kilowatt-hours (kWh) of electricity, 54% of which was consumed by the cogenerators, the rest was sold to electric utilities.[i] Cogenerated electricity in the U.S. represents approximately 9% of all electricity generated in the United States.

Natural gas is the primary fuel used for cogeneration in the U.S. In 1998, 195 billion kWh of gas-based electricity was used by cogenerators. This represents 64% of all electricity produced by cogenerators. Coal (17%) and renewable energy (13%) are the other primary fuels used.

A large portion of cogeneration in the U.S. is owned by large industrial manufacturers. In 1994, manufacturers generated 142.5 billion kilowatt-hours of electricity, on site--90 percent of that was cogenerated. They generated more electricity than they could use, so they sold or transferred offsite 28 million kilowatt-hours. Approximately 40 percent of all cogenerated electricity took place in establishments within the paper industry. The chemical industry was the next largest cogenerator (35%).

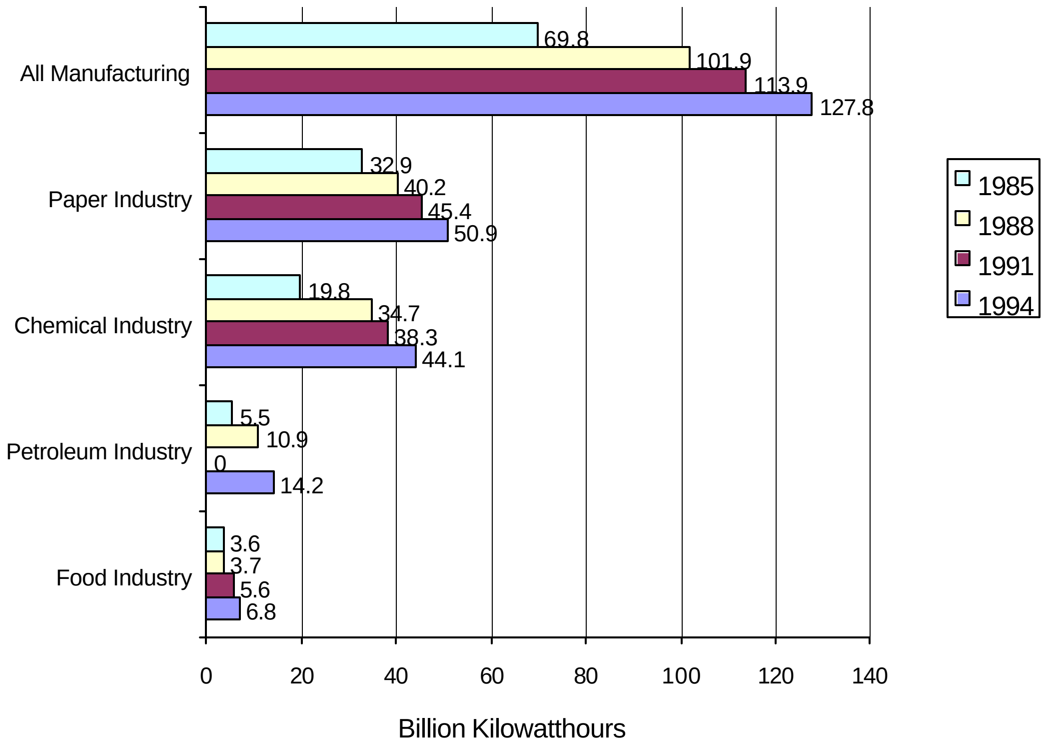
Industrial cogeneration is highly concentrated in the U.S. This is because the needs and characteristics of specific industries have historically been a primary driver for the development of industrial cogeneration. High steam demand, high capacity utilization, and free byproduct fuels, all-important ingredients for economically viable cogeneration projects, are common characteristics of the major cogenerators. As a result, 85% of industrial cogeneration (56% of national total) is found in the chemicals, refining, and paper industries. The food industry also is a major cogenerator. The iron and steel industry, once a major cogenerator when integrated steel-making operations were popular, now cogenerates very little because the industry has declined in size and electric arc furnaces replaced blast furnaces, which were the major fuel source for cogeneration plants.

Over 27% of all industrial cogeneration is located in Texas, Louisiana, and Oklahoma due to the high concentration of chemicals, refining and paper industries.

Growth in industrial cogeneration was very dramatic between 1985 and 1994. Figure 1 shows the growth in electricity cogeneration in the major industries and for all of manufacturing during that time period. Growth was driven by passage of the Public Utility Regulations Policy Act of 1978 (PURPA), a Federal law. One section of PURPA required utilities to buy electricity from independent power suppliers who generated electricity using renewable energy or used cogenerators to produce the electricity. These new electricity suppliers had to meet certain qualifying criteria set by the Federal Energy Regulatory Commission--some of the suppliers came from the manufacturing sector.

Figure 1

Electricity Cogeneration in the Manufacturing Sector, 1985, 1988, 1991, and 1994



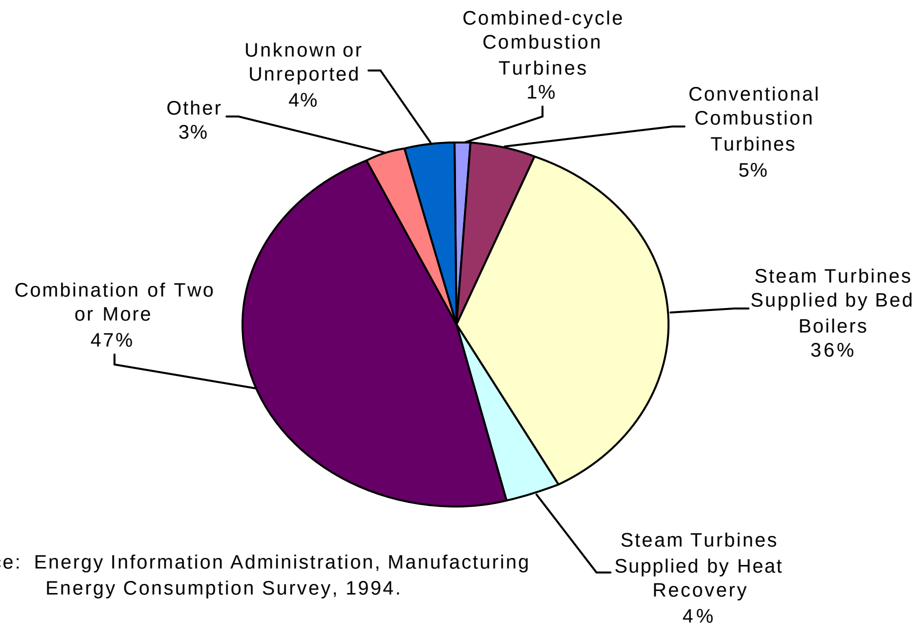
Source: Electricity Generation with Manufacturing Sector: An Historical Perspective,

However, manufacturers generate electricity onsite for many reasons. Cogeneration is found mainly in those industries that have large steam requirements for process heating--using energy twice, mainly as a source of both thermal heat and electricity -- is efficient. Additionally, many of the establishments that use cogeneration technologies have a large supply of byproducts such as bark, wood chips, black liquor, or different forms of gas. Industries that cogenerate also are some of the largest users of electricity. For example, in 1994, the paper and chemical industries used 35 percent of the electricity and accounted for 74 percent of total onsite generation. Onsite generation also has the benefit of reliability and manufacturers, such as those in the paper industry, have energy sources such as biomass that can be used to produce electricity onsite very cheaply.

For cogeneration in the U.S., a mix of technologies is used: boiler/steam turbine – standard design but reconfigured to produce high electrical output; combustion turbines – lower cost natural gas or distillate systems that are higher efficiency and provide more electricity per unit of steam at peak efficiencies. Figure 2 shows the percent of cogenerated electricity in the manufacturing sector by generation technology.

Figure 2

Percent of Cogenerated Electricity in the Manufacturing Sector by Generation Technology, 1994



Source: Energy Information Administration, Manufacturing Energy Consumption Survey, 1994.

Technology choice can be very regional. For example, 67% of cogeneration in Texas, Louisiana and Oklahoma uses combustion turbines because of availability of gas and by-product fuels and because of the high electricity demand in the region. Similarly, 76% of cogeneration capacity in the South Atlantic is conventional boiler/steam turbine because of its proximity to coal (for paper and chemicals industries) and biomass and byproducts fuels in paper mills.

Traditional cogeneration, like in China, provides steam to industrial users as its primary function, with electricity generated as a by-product. However, in the U.S., electricity production dominates at cogeneration facilities. Non-traditional facilities were leveraged to produce the maximum possible electric output within the constraints of the PURPA power-to-heat requirement of about 18. PURPA required a minimum of 5% of the cogeneration output be heat. The non-traditional plants receive minor income from steam sales; their efficiency was also lower.

Electricity Generation in the Paper Industry in the U.S.: 1988 to 1994

Approximately 41 percent of all electricity generated by industry took place in the paper industry—59 billion kWh. Of this amount, 87 percent was cogenerated. In 1994, as in other years, the paper industry had large amounts of usable wood and wood related byproducts, including mostly black liquor (882 trillion Btu) and biomass (406 trillion Btu).

With such a large amount of wood and wood-related byproducts, 61 percent of the electricity was cogenerated using steam turbines supplied by bed boilers.

As the paper industry increased its use of electricity by 21 percent between 1988 and 1994, onsite electricity generation rose by 33 percent—21 percent between 1988 and 1991. Generators, other than cogenerators using combustible fuels, generated more than double the amount in 1991 than in 1988--2 billion kWh to 5.5 billion kWh. Also, the paper industry has historically been dominant in using renewable energy (mainly hydropower) to generate electricity onsite. Renewables used to generate electricity increased 46 percent--from 2 billion kWh to 2.9 billion kWh. However, between 1991 and 1994, as cogenerated electricity was increasing by 12 percent, electricity generated using renewables (solar, wind, hydropower, and geothermal) fell by 13 percent.

Electricity Generation in the U.S. Chemical Industry: 1988 to 1994

Approximately 33 percent of all onsite electricity generation in manufacturing took place in the chemical industry—46.8 billion kWh. Of this amount, 94 percent was cogenerated using at least two different cogeneration technologies. Because the chemical industry is the largest user of natural gas as feedstock and for process heating, it would be reasonable to assume that some of the 1994 cogenerated electricity came from the use of combined-cycle turbine systems, which can burn both natural gas and byproduct gases. Additionally, in 1994, the chemical industry was the second largest seller of electricity (7.7 billion kWh). It may be reasonable to assume that some of the electricity was cogenerated using the conventional combustion turbine that also burns natural gas. The conventional combustion system is the one used more frequently when there is excess capacity and electricity is sold.

As the chemical industry increased its use of electricity by 39 percent between 1988 and 1994, onsite electricity generation increased by 22 percent—electricity cogeneration increased by 27 percent. Renewable generated electricity is not present in the chemical industry and electricity generated by methods other than cogeneration using combustible fuels has been declining, 7 percent lower in 1991 than in 1988 (3.1 billion kWh versus 3.4 billion kWh, respectively) and 15 percent lower in 1994 than in 1991, (2.6 versus 3.1 billion kWh, respectively).

Future of Onsite Generation in the Manufacturing Sector in the U.S.

More than two-thirds of all the energy consumed in the industrial sector is used to provide heat and power for manufacturing; the remainder is approximately equally distributed between non-manufacturing heat and power and consumption for non-fuel purposes, such as raw materials and asphalt.

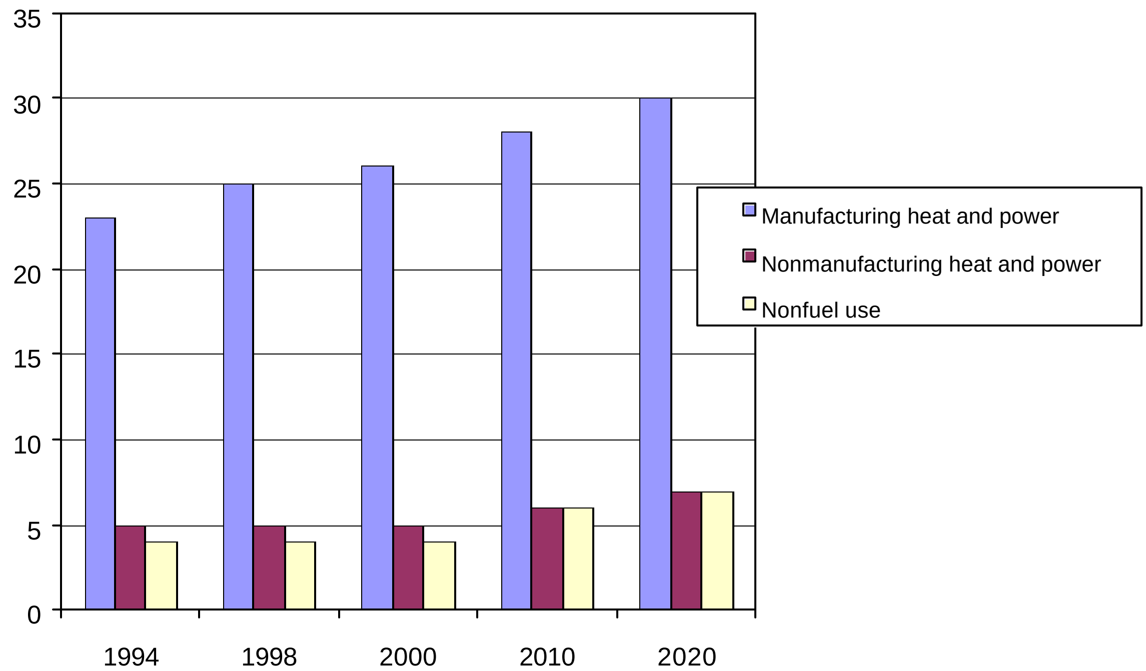
Non-fuel use of energy in the U.S. is projected to grow more rapidly (1.2 percent annually) than projected heat and power consumption (0.8 percent annually).[ii] (Figure 3). Petroleum refining, chemicals, and pulp and paper are projected to continue to be the largest end-use consumers of energy for heat and power in the manufacturing sector. These three energy-intensive industries used 8.9 quadrillion Btu in 1998. The major fuels used in petroleum refineries are still projected to be natural gas, and petroleum coke. In the chemical industry, natural gas will continue to account for two-thirds of the energy consumed for heat and power. The pulp and paper industry will continue to use the most renewables, in the form of wood and spent liquor.

Deregulation and full retail competition will lead to a substantial growth in customer choice. All customers, including manufacturers will be able to choose their electricity supplier. Another choice will be available—one where some, most, or all of the electricity is generated onsite, with or without electric utility involvement. Manufacturers, and especially the larger users of electricity in this sector, have, historically generated electricity onsite. It is unclear whether this trend will continue.

Electricity deregulation and environmental concerns may provide an impetus for the growth in electricity generation and especially in the growth of cogeneration. One private California study portrays distributed generation doubling by 2004. Their reasoning is that if utilities are to be competitive, they will need to provide additional services, and setting up a distributed generation system onsite may be one of their services.

In this future market, and even today to a lesser degree, onsite generation, and especially cogeneration, may have a growing appeal. The efficiency of cogeneration systems leads to cost savings and also savings in terms of emissions. Transmission and distribution losses of electricity are not factors in onsite-generated electricity as they are in electricity generated elsewhere. Additionally, there is concern that in a competitive market, reliability may become an issue. The summers of 1998 and 2000 were ones of power shortages and huge price increases in the Midwest and West. Volatility such as this may give rise to an increase in onsite electricity generation. Manufacturers who depend on reliable electricity, such as computer chip makers or those who use computer systems in their manufacturing process, are beginning to produce their own electricity.

Figure 3
Industrial Primary Energy Consumption by Industry Category, 1994-2020 (quadrillion Btu)



The future for cogeneration in the U.S. is in question, however. While estimates are that more than 90,000 MW of cogeneration capacity is technically available in the industrial sector, significant changes to the U.S. electric power sector bring both opportunity and concern to the cogeneration industry.[iii] Electric utility restructuring, coupled with the unbundling of various components of electric service gives customers more choice to optimize their energy services. Concerns over power reliability and advances in technology that allow smaller plants to be built with high efficiency, low cost, and minimal environmental impacts are allowing small-scale generation to compete with central station plants. Restructuring also introduces new players to the market, like energy service companies, that can facilitate the marketing and sales of small-scale generation systems.

However, large cogeneration installations depending on excess power sales must compete with other wholesale generators that might have advantages in terms of dispatch ability or cost, and competition may reduce retail electricity rates for large industrials, decreasing the value of power generated on-site. Other barriers to increased industrial cogeneration include:

- Grid interconnection – non-standardized interconnect requirements vary by state and utility requiring custom engineering and lengthy negotiations that add cost and time to system installation. This also makes it difficult to build standardized cogeneration systems.
- Standby/Backup charges – Potentially high costs are charged to electricity customers who require grid-based electricity to back up on-site generation.
- Stranded costs – recovery of stranded costs could result in imposing electricity tariffs for the sale and purchase of electricity by on-site cogenerators. These fees would hurt the competitiveness of cogeneration.

- Environmental regulations – current environmental regulatory practice is to limit air pollution emissions on the basis of per unit of fuel input. This gives no advantage to highly efficient technologies, like cogeneration.
- Site permitting – lengthy and costly permitting requirements are imposed for cogenerators that are inappropriate for these small, low polluting technologies.

Cogeneration in Europe

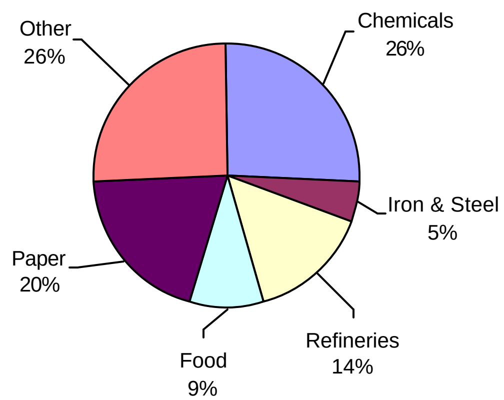
In 1997, the European Union (EU) had over 9,000 CHP units in operation that represented nearly 74 GW (13%) of Europe's 555 GW of the total installed generating capacity. [iv] Of the total 2.4 trillion MWh of electricity generated in the EU in 1997, 279 million MWh were generated from CHP plants. CHP plants also produced 163,000 MW of heat (2 million TJ) in 1997. The use of cogeneration by country ranges from 90% of the electric generation capacity in Denmark to 2% in Greece, France, and Ireland. Most European countries average between 10% and 20%.

Industrial CHP electrical capacity was over 33 GW, or about 45% of the total CHP electricity capacity in Europe. The heat capacity in the industrial sector was over 110 GW (net heat), or about 2/3 of the European total. This capacity is split among many industries. However, 74% of the electric capacity and 87% of the heat generation capacity in the industrial sector came from 5 industries: (1) refineries, (2) iron and steel, (3) chemicals, (4) food products, and (5) paper. As expected, these industries are the major producers of electricity and heat because they are the major consumers of electricity and heat in the industrial sector. The share of electrical capacity from each of these industries as compared with all of European industrial electrical capacity is shown in Figure 4 and summarized as follows:

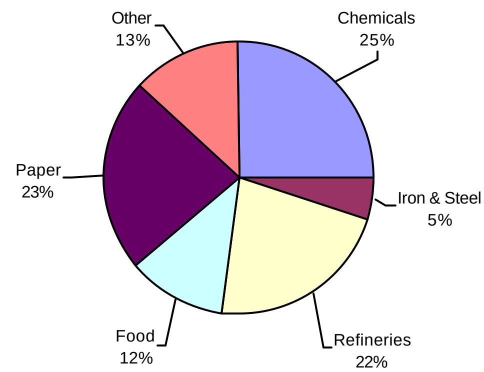
- Refineries (14% of electrical capacity and 22% of the heat capacity)
- Iron and steel (5% of electrical capacity and 5% of the heat capacity)
- Chemical industry (26% of electrical capacity and 25% of the heat capacity)
- Food products, beverages and tobacco (9% of electrical capacity and 12% of the heat capacity)

- Paper and printing (20% of electrical capacity and 23% of the heat capacity)

Figure 4
Industrial Use of Cogeneration in Europe
Electricity and Heat Capacity By Industry, 1997



Electrical Capacity Total - 33,461 MW



Heat Capacity Total - 111,021 MW

Industrial CHP electrical production was over 162,000 GWh and heat production was over 1.6 million TJ. As shown in Figure 5, 75% of the electrical production and 81% of the heat production in the industrial sector came from the same 5 industries:

- Refineries (16% of electrical production and 16% of the heat production)
- Iron and steel (6% of electrical production and 6% of the heat production)
- Chemical industry (26% of electrical production and 26% of the heat production)
- Food products, beverages and tobacco (6% of electrical production and 7% of the heat production)
- Paper and printing (21% of electrical production and 29% of the heat production)

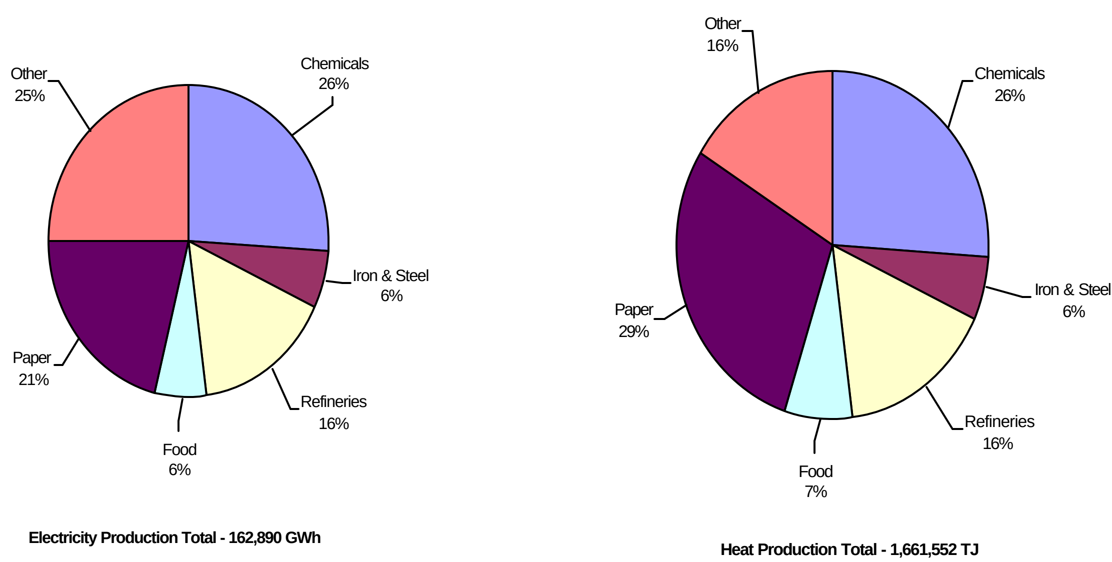
A variety of technologies have been used in the CHP plants in Europe. These include:

- Back pressure steam turbine – steam passes through a turbine before being exhausted from the turbine at the required pressure for the site. Condensing steam turbine – a proportion of the steam used by the turbine is extracted at an intermediate pressure from the turbine with the exhaust being condensed. Steam turbines can use a wide variety of fuels including coal, gas, oil, and waste-derived fuels. Steam turbines used in CHP applications typically range in size from a few MWe to over 100 MWe.

- Gas turbines often used aero-engine derivatives where fuel (gas or gas/oil) is combusted in the gas turbine and the exhaust gases are normally used in a waste heat boiler to produce usable steam, though exhaust gases may be used directly in some process applications. Simple cycle systems achieve electrical efficiencies of 22-30%. Combined-cycle systems utilize the steam from waste heat recovery boilers in steam turbines. Combined-cycles have electrical efficiencies approaching 45% with 20% heat recovery and a heat to power ratio of less than 1:1.

- Internal combustion engines (used in small systems up to 5 MWe) are based on auto engine or marine engine derivatives converted to run on gas. Both compression ignition and spark ignition firing is used. They operate at around 28-33% electrical efficiency with around 33-50% of the fuel input available as useful heat.

Figure 5
Industrial Cogeneration Production in Europe
Electricity and Heat Production by Industry – 1997

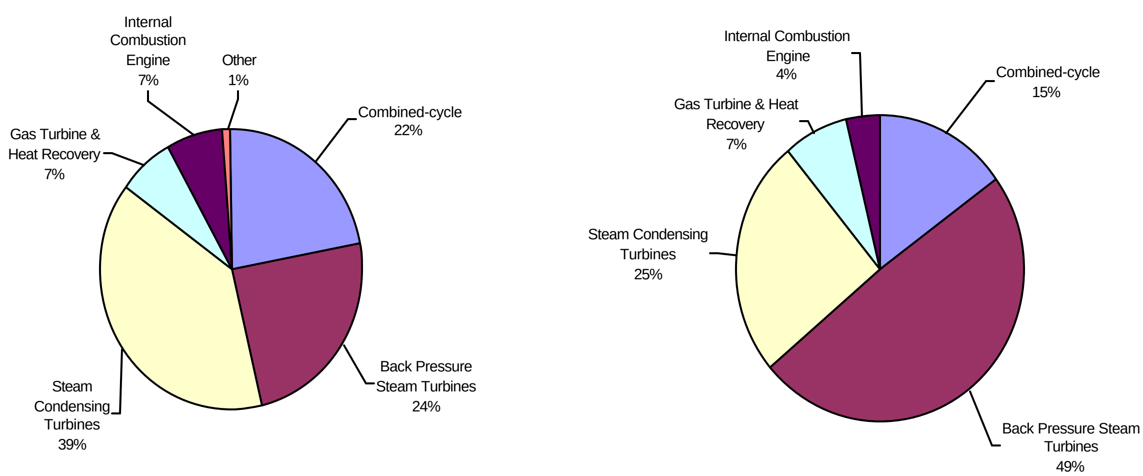


The distribution in use of the technologies for heat and electricity production (from all European CHP producers) is shown in Figures 6 and 7. Figure 6 shows the distribution by the amount of heat and electricity capacity in 1997. In summary:

- 22% of the electrical capacity and 15% of the heat capacity used combined-cycle technology
- 24% of the electrical capacity and 49% of the heat capacity used backpressure steam turbines
- 39% of the electrical capacity and 25% of the heat capacity used steam condensing turbines
- 7% of the electrical capacity and 7% of the heat capacity used gas turbines with heat recovery
- 7% of the electrical capacity and 4% of the heat capacity used internal combustion engines
- the remainder used a variety of other technologies.

Figure 7 shows the distribution by the amount of electricity and heat produced.

Figure 6
Technologies Used at European CHP Plants (Shares by Capacity)

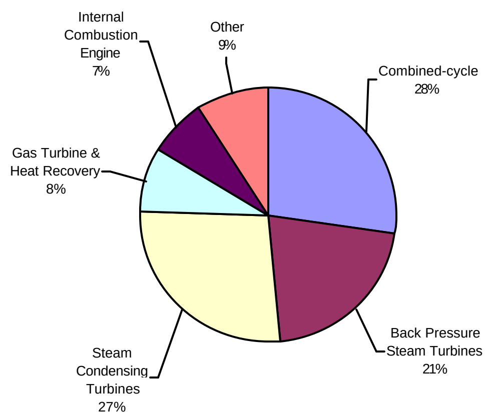


Electrical Capacity 1997 - 74,201 MW_e

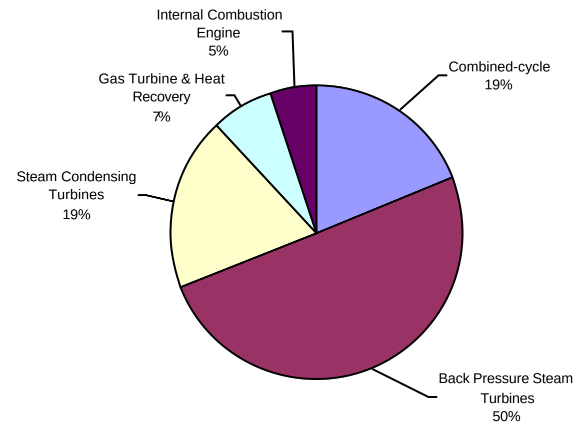
Heat Capacity 1997 - 163,335 MW_t

Figure 7

Technologies Used in Energy Production From CHP in Europe in 1997 (Shares By Production)



Electricity Production 1997 - 279,410 MW_h



Heat Production 1997 - 2,018,922 TJ

The fuels used in CHP plants in Europe included natural gas, liquid and solid fuels, combinations of solid and liquid, liquid and gas, and solid and liquid and gas, as well as biomass and waste fuels. Generally speaking, in their CHP plants: (1) the iron and steel industry uses blast furnace and coke oven gas and coal, (2) the chemicals industry uses natural gas and coal, (3) refineries use refinery gas, fuel oil and natural gas, (4) paper and printing uses natural gas, coal and waste fuels, and (5) the food industry uses natural gas.

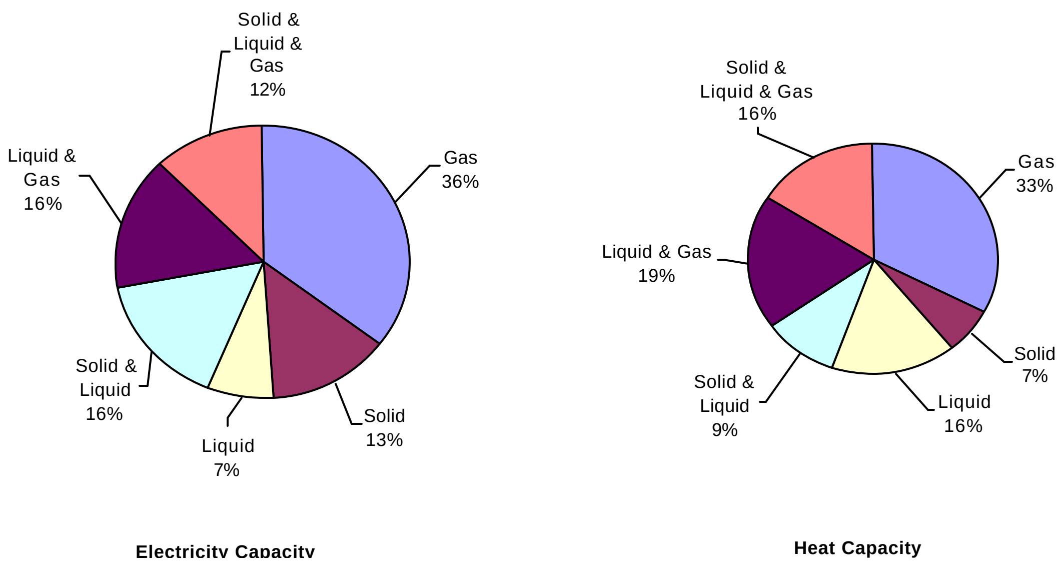
Figure 8 shows the distribution of fuel type used for cogeneration in Europe by electricity and heat capacity. The majority of the CHP plants in Europe used gas (natural gas and product gas, either alone or in combination with other fuels) for fuel (73% of the units).

The future for cogeneration in Europe is bright. This is because:

- Generally speaking, the price of gas is low. As a result, in the rapidly changing EU electricity supply industry, new natural gas plants have a significant economic advantage over new solid fuel-based plants.
- Concerns over environmental issues are growing. Because of lower specific emissions from cogeneration, especially CO_2, it is favored over less efficient and dirtier options.

Figure 8

Energy Production From CHP in Europe by Fuel Type – 1997



On the other hand, there is growing concern in the EU that it is becoming too dependent upon natural gas. As a result, it is possible that it will try to maintain a diversity of fuel use, adversely affecting cogeneration.

Clearly though, the EU is supportive of cogeneration. It addresses the 3 central tenants for its Energy Policy for the European Union: (1) competitiveness, (2) environmental protection, and (3) security of supply.[v] A strategy for promotion of cogeneration and district heating was outlined in an Annex to the EU's White Paper, *An Energy Policy for the European Union,* in January 1996. The strategy discussed tax, environmental and other means by which cogeneration could be encouraged. Some of these policy proposals have since been ratified.

As an indication of the interest in cogeneration in the EU, the United Kingdom has initiated an aggressive program for its promotion. It has resulted in a 9% growth in cogeneration capacity in 1999, bringing installed capacity to 4,239MWe. The UK's goal is to have 5,000MWe of cogeneration capacity by the middle of 2001.

Over the last decade, capacity of CHP in the UK has more than doubled, representing an

average growth rate over the period of 7 per cent per annum. CHP installations are dominated by schemes with an installed electrical capacity of less than 100 kWe (49 per cent of sites), and between 100 kWe and 999 kWe (34 per cent of sites). However, schemes larger than 10 MWe represent 81 per cent of the total electrical capacity. It is estimated that the total number of sites with CHP in the UK in 1998 was 1,313 with total installed capacity of 4,239 MWe. Of these, 361 sites (93 per cent of capacity) are in the industrial sector and 952 sites (7 per cent of capacity) are in the commercial, public and residential sectors.

[i] *Annual Energy Outlook 2000,* Energy Information Administration, U.S. Department of Energy, December 1999.

[ii] *Annual Energy Outlook 2000,* Energy Information Administration, U.S. Department of Energy, December 1999.

[iii] *Current Issues in Combined Heat and Power*, U.S. Combined Heat and Power Association, June 1999.

[iv] Raw data provided by Eurostat.

[v] *Cogeneration, District heating and cooling in the EU ENERGY POLICY*,, European Commission, June 1997.