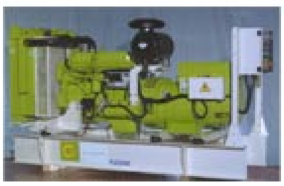
THE CHINA SUSTAINABLE ENERGY PROGRAM

中国可持续能源项目

Research on Cogeneration Policy in Shanghai



Shanghai Energy Conservation Supervision Center

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Preface

Cogeneration is a technology used to simultaneously generate power and heat to improve energy efficiency. It is not a new technology, for it has existed since the emergence of thermal power plants and has been improving with time. It is also called combined heat and power (CHP). The main principle for cogeneration is that the system should be based on heat demand to optimise energy efficiency. Users of cogeneration can be a single building, an enterprise, or a district with a heating or cooling demand.

The energy efficiency of large-scaled central coal-fired power plant in China is only 30-40 percent. In Shanghai, it is approximately around 37 percent. The highest efficiency that coal-fired power plant can reach is approximately 45 percent, while that of gas-based combined cycle power plant is as high as 60 percent. As a result, large amounts of energy are wasted through large cooling towers. In addition, there are losses in the transmission of electricity, estimated to be around 6 percent of total delivered electricity in Shanghai.

When the waste heat is used during generation, it is referred to as CHP. Cogenerated electricity can reach efficiencies of over 90 percent. Generally, compared with the conventional electricity-only power station, the efficiency of cogeneration can result in improvements of 15-40 percentage points.

Traditionally, the heat supply from cogeneration is realized by extraction steam turbine or back pressure steam turbine technologies. Now, cogeneration with gas-based internal combustion (IC) engines, gas turbines and combined-cycle systems are widely used in Europe and the USA. In China, heat supply is realized by waste heat boilers using exhaust gases. In addition, the heat from the cylinder jacket cooling water and lubricating oil cooling water of IC engines can be used. These three schemes are called gas-based cogeneration. Currently, even more advanced technologies for cogeneration, such as fuel cells and photovoltaic (PV) cogeneration are emerging.

Presently, Shanghai consumes 250 million m^3 of natural gas per year, primarily from the East Sea and only occupies 0.6 percent of total energy consumption. In the near future, large quantities of natural gas will be available from the western regions of China, China's East Sea, and possibly as imported LNG from overseas. Recognizing this, the Shanghai Municipal Government has set a goal of increasing natural gas consumption in the Municipality to 3 billion m^3 of in 2005. The issue now facing the Municipality is to determine the best use of the gas. Clean (gas-based) cogeneration is the one of solutions.

Combined with district heat supply, cogeneration has been used in Shanghai for over 40 years. The capacity of cogeneration in Shanghai is over 17 percent of the total electrical capacity in the city. However, almost all of the cogeneration in Shanghai uses coal fed to boilers and steam turbines. Although coal-based cogeneration is economically competitive with other energy options, it is not nearly as efficient or clean as the higher priced gas-based technology. Therefore, it is necessary to encourage NG-based cogeneration in Shanghai.

China's central government has given priority to the increased use of cogeneration and has issued a series of policies, laws and regulations to encourage and support its increased use. But there are no specific policies or regulations that govern or guide the use of cogeneration in Shanghai. In addition, technical, policy and economic barriers to expand use of clean cogeneration exist. It is believed that research to identify the barriers and identify policy options at the local level will lead to an increase in the use of clean cogeneration in Shanghai.

Financed by the U.S. Energy Foundation and the cooperation of the municipal government, consulting companies, power companies, environment bureau, architecture design institutes, terminal users and investors, Shanghai Energy Conservation Supervision Center (SECSC) conducted research on cogeneration policy in Shanghai and proposed policy options to increase use of cogeneration. This report summarizes the results of the study.

Chapter 1: Overview

I. Objective and Scope

This project aims to investigate the status of existing barriers clean cogeneration development in Shanghai and to identify policies to potentially remove the barriers. In addition, the intent of the project was to recommend a policy framework for future analysis to support the municipal decision-makers on CHP development in Shanghai.

The scope of this research is clean energy with the following characteristics:

- Electricity generation based upon meeting heating demands (to optimize the efficiency of the systems)
- Optimization of energy utilization
- Minimum environmental impact

II. Methodology

The methodology used for the project included the following components:

- Involve stakeholders in gathering information and in reviewing the results
- Utilize international experts to gather information on the experiences of developed countries to learn from these experiences
- Develop and deploy a tool to analyze the options from a local perspective
- Conduct a workshop with key policy makers and experts to discuss the results of the study and to determine the next steps.

By using this methodology, the results are likely to be more "real-world" than previous studies on the subject.

III. Project Outputs

The following outputs, discussed in detail in the report, include:

- Assessment on the status of cogeneration in Shanghai
- A model was developed to conduct analysis on the economic and environmental factors associated with cogeneration
- Research has been conducted on:
  - Current state and local policies for cogeneration
  - The current status and price trends of energy in Shanghai
  - The use of cogeneration in the management and economics of peak power loads in Shanghai

- How cogeneration can be used to manage peak and non-peak natural gas loads by assessing the viability of cogeneration as an interruptible user of natural gas, thus obtaining a much lower natural gas price.
- How to change environmental policies to promote cogeneration development.

- Study of cogeneration experiences in the United States and Europe to determine how their lessons could provide guidance to China.
- Barriers to the expanded use of clean cogeneration were determined and options for addressing them identified.

IV. Policy Options

The following policy options were identified to address the barriers:

- Encouraging cogeneration companies to operate as peak shavers, in addition to generating power in line with heat demand.
- Adopting a two part tariff for the electricity sold to the grid during periods of high electric system demand. Two part tariffs are a means of taking into account costs of both generated electricity (KWh) and capacity (KW) involved in peak shaving operation.
- Adopting time-of-day price for sale of electricity to the grid. Time-of-day price means the selling price of electricity to the grid is different at different times. For example 0.61 Yuan per kilowatt hour from 6 o'clock to 22 o'clock and 0.30 Yuan per kilowatt hour from 22 o'clock to 6 o'clock.
- Cogeneration plants could adopt the double fuel system, gas and oil, and could use oil instead of natural gas between peak load periods of natural gas.
- Encouraging cogeneration to become an interruptible natural gas user, to get the lower tariff of buying NG.
- Developing the transparent and equitable interconnection rule between the cogenerators and the electricity network especially for self use & small scale CHP companies and encouraging the electricity industry to provide the technology support and service for small scale CHP;
- Encouraging the manufacture of gas-based cogeneration equipment in Shanghai to reduce the cost of investment and maintenance.
- Developing output-based standards (to provide incentives for increased energy efficiency) and increased SO_2 emissions fees; launch SO_2 trading to encourage the environmental benefits of gas-based cogeneration through incentives
- Promoting a self-generating & small scale CHP consultant industry, and encouraging ESCO's and public utilities to take part in the investment, construction and management of CHP;
- Establishing a CHP association to promote the development of CHP.

V. Beneficiaries

The following are the main decision-makers of CHP in Shanghai, who are also the supporters of this project. The above policy options may serve as a valuable reference for them when making future decisions.

- Shanghai Economic Commission
- Shanghai Developing and Planning Commission
- Shanghai Price Administration Bureau
- Shanghai Environmental Protection Bureau

VI. Social Benefits

The research results will be used for CHP decision-makers to make related decisions on cogeneration to achieve the following social benefits:

- Improved use of energy in Shanghai
- Reduce greenhouse gases (CO_2) emissions and other pollutants, such as SO_2 and NO_x
- Support the national "Transferring Natural Gas from the West to the East" project
- Reduce costs and improve the competitiveness of industry and commerce
- Enhance the safety of electricity supply
- Attract more and more people to take part in the development of CHP
- Increase investment while providing more employment opportunities.

Chapter 2: Current status, Future Development and Necessity of Cogeneration in Shanghai

I. Current status

In the year 2000, the total capacity of CHP in Shanghai was 1.6 million kilowatts, 17.3 percent of total generation capacity of 9.3 million kilowatts. Currently in Shanghai, there are 69 sets of cogeneration units with a total heat supply of 45.1 million GJ and electricity generation of 7.1 billion kilowatt-hours, which accounts for 13.9 percent of the total electricity generation of the city. The average ratio of heat to electricity was 1.75 in 2000.

In general, the power department in Shanghai classifies cogeneration systems into three categories: (1) cogeneration for power plants, (2) cogeneration for self -use and (3) generators for energy integrated utilization. Strictly speaking, some of the generators for energy-integrated utilization cannot be called cogeneration systems because they do not offer heat supply. One such example is the Shanghai Bao Steel Company, a combined-cycle generation unit using blast furnace gas as fuel. However, for the purposes of this study, these systems are included as cogenerators since they are very similar to cogeneration in both technology and policy. Chart 1 shows the proportions of generation capacities of different cogeneration systems in Shanghai. Chart 2 shows the proportions of electricity generation of different cogeneration systems.

Chart 1: Proportions of capacities of different cogeneration systems in Shanghai

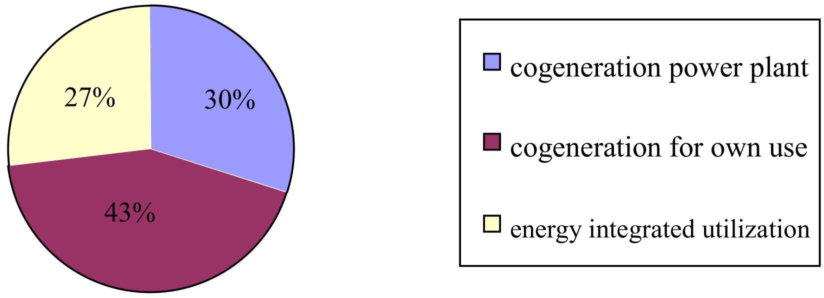
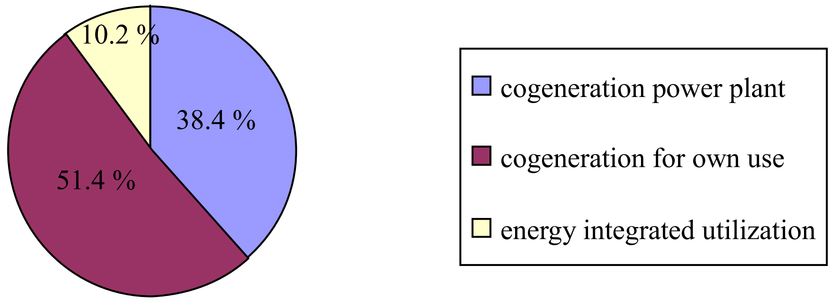


Chart 2: Proportions of electricity generation of different cogeneration systems in Shanghai



It is common knowledge that most CHP plants are coal-based. To illustrate the problems facing clean cogeneration in Shanghai, one needs only to look at the gas-based plants in operation or planned. There is only one small-scale gas-fired cogeneration in operation in Shanghai. It was built in District Heating/Cooling Station, Pudong International Airport in 2000, with a gas turbine supplied by Solar Company. The electrical capacity is 4,000 KW, but the generator has a load of only 2,000 KW, because the load of the station was enlarged in the designing phase and it is difficult to transfer the excess power from the station to other buildings in airport. This problem will be solved this year or the next with the help of the power utility. A second small-scale cogeneration plant is being built in a hospital. This unit will use a spark ignition reciprocating engine. The electrical capacity is only 400 KW. The plant is designed to provide the base load of electricity and heat, any shortfall is supplemented with electricity from the utility electricity network, and heat from the standby boiler. However, the interconnection of the hospital's and the utility electrical network is restricted. The hospital is negotiating with the utility for economic and technical terms.

In addition, several large-scale gas-fired combined cycle based cogeneration plants are being planned. Some overseas investors are interested in these projects. These plans will be applied in the industrial development zones in Shanghai. Under present requirements, the total co-generated electricity must be sold to the utility grid (because "wheeling" is unavailable) and heat will be sold to the enterprises on site through the local heating network. For these plans, the main problem that has been encountered is that the cogenerated electricity price is not competitive with conventional coal-fired power plants.

The characteristics of the current cogeneration projects in Shanghai are as follows:

- Cogeneration in Shanghai is mostly composed of coal-fired boilers and steam turbines, mainly used in central utility, petrochemical, steel, printing and dyeing, and paper making industries
- More than one-half of the cogeneration is combined with district heat.
- The ratio of heat to electricity of cogeneration is usually high.
- Gas-based cogeneration is in its infancy with one small project, a 4,000 KW gas turbine cogeneration unit in the Shanghai Pudong International Airport, in operation and another being built at a hospital.
- Investors of cogeneration consist of the government, the private sector, electricity companies, and foreign investors.
- Cogeneration often has good economic benefits. The main reasons are the low price of coal and the high price of the electricity sold to the utility.

II. Future development

With its development of more than 40 years, cogeneration has played an important role in Shanghai, currently accounting for more than 17 percent of the total generation capacity of Shanghai. However, most of the cogeneration uses coal fed boilers and steam turbines, with high emissions of SO_2, NOx and CO_2, lagging behind technologies used in other parts of the world. This is not commensurate with the goal of making Shanghai one of the most suitable cities in China for living and working. Thus, gas-based cogeneration should become the direction of cogeneration development in Shanghai. There are potential users for gas turbines, combined-cycle systems and IC engines in the city, which can match the demands of various users.

We should develop clean cogeneration adhering to the following conditions:

- Electricity generation should be based on the heating demand, while achieving the lowest ratio of heating demands to electricity generation.
- Optimizing energy utilization. Reasonable use of heat produced during the electricity generation while reaching the lowest heat efficiency state.
- Minimum environmental impact. Using clean energy such as natural gas while reducing the emissions of NOx, for example using low-NOx burners.

The scopes of research are gas-based cogeneration units which meet the above three conditions.

III. Necessity of developing gas-based cogeneration

As pointed out in the 10th Five-Year plan of energy, Shanghai should aim toward the goal of "using the integrated advantage as an international cosmopolitan city to enhance the competitiveness of Shanghai". At the same time, Shanghai should take the opportunity of "transferring natural gas and electricity from the west to the east" to promote the use of clean energy while reducing the use of coal. By doing so, Shanghai can gain control of coal consumption to optimize the energy structure, secure the energy safety, strengthen the reform of the energy management system so that Shanghai can improve its energy efficiency and protect the environment.

The key driving factors for clean cogeneration in Shanghai are:

1. Fulfillment of the state regulation to carry out a sustainable development strategy

Cogeneration is an advanced technology with high energy efficiency. It can improve the output of effective energy with high conversion efficiency at a lower fuel cost, and with a much lower environmental impact. To a city like Shanghai with the highest rate of energy consumption per square meter, development of clean cogeneration can be built within the residential area to supply heat and power with a high efficiency.

2. The requirements of environmental protection

Shanghai is one of the state acid rain control areas. SO_2 emissions in 2000 reached 460 thousand tons and, according to the 10th Five-Year Plan, must be reduced by 20 percent. The problem largely is an outgrowth of Shanghai's heavy reliance on coal, which makes up 65 percent of the energy consumed. Options to reduce coal use that will be implemented include establishing 'non-coal' areas and encouraging the use of natural gas. Now, research is underway to determine how to use NG efficiently. Gas-based cogeneration is a priority since it can reduce CO_2, NOx, SO_2, CO, O_3, emissions as well as sewage and solid waste and conserve the limited gas that will be available.

3. The requirements for energy security

Shanghai is China's largest city of industry, science and technology, and information. It is also the largest energy-consuming city. For a city like Shanghai, gas-based cogeneration can reduce the dependence on imported energy. Moreover, gas-based cogeneration is suitable to many different kinds of fuels, which can strengthen the security and ability of the energy system to meet an emergency. Additionally, when gas-based cogeneration reaches a certain scale, its advantages of customization, small-scale, decentralization and soft start-up can enhance the secure supply of energy. During emergencies, for example, when the main utility is shut down, these separate power units can contribute to the security and ability of the utility to meet an emergency.

4. Meeting the demand of implementing and supporting the state policy of developing

the western region of China

It is the economic and political demand to develop the western region of China. However, whether the development can be successful depends on how well the east region can use the resources from the West. Shanghai, as the terminal user and the largest market for gas from the West, should make its contribution to applying the advanced and high efficiency technologies for using natural gas.

5. Economic efficiency

Cogeneration has been widely used throughout the world as an environmental-friendly, high-efficiency, flexible, and dependable technology. If gas-based cogeneration is used in place of conventional coal-fired systems, long-term economic efficiency benefits will result. Gas-based CHP is clean and efficient and therefore possess benefits that are not currently considered in economic analyses.

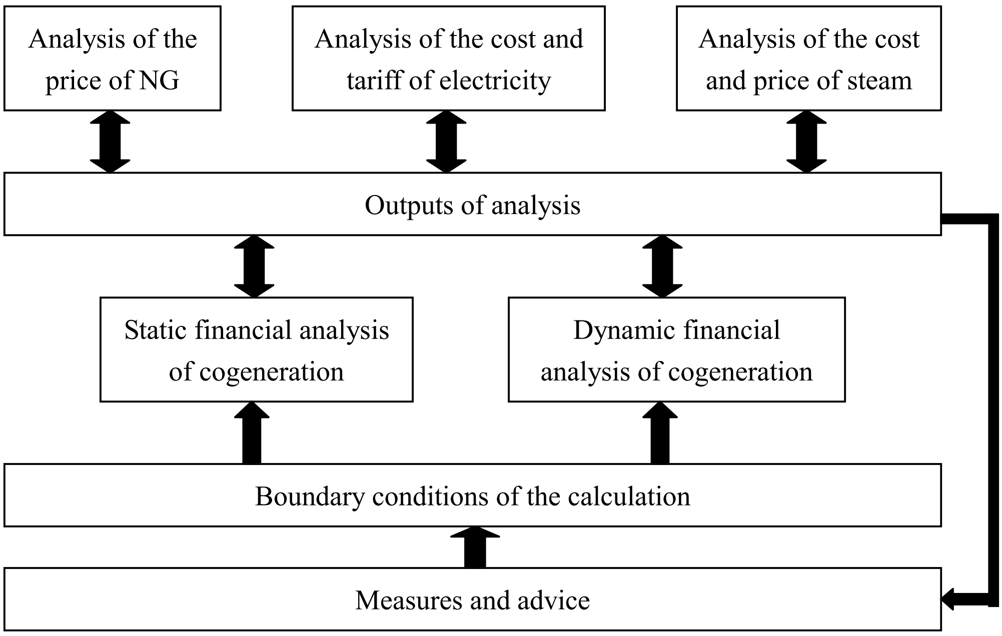
6. Advanced gas turbine technology can be advanced in China through use as part of cogeneration systems bringing valuable benefits.

Though the technology of gas turbines used for cogeneration applications is mature throughout the world, the domestic development of this field lags 10 to 15 years behind. Currently, most of the gas turbines used in Shanghai are imported, especially those that are small and middle-sized. Shanghai lacks the experience in designing key components and the integrated system. Many overseas companies want to open the market of cogeneration application with their advanced technology and products. The gas turbine technology is the most important option in the world's energy markets; it is a symbol of the scientific competence of a country.

Chapter 3: Financial Analysis Model for Gas-Based Cogeneration

Current thinking in China is that it is necessary to develop gas-based CHP in Shanghai for environmental, social and long-term economic and security reasons. The development of gas-based CHP in Shanghai has been explored for many years. However, few units have been placed in operation, largely because of the restricted interconnection between the cogenerators and the grid and its lack of market competitiveness to sell the power.

In this study, financial analysis of gas-based IC engine cogeneration, gas turbine cogeneration and combined cycle gas turbine cogeneration has been conducted. To do this, a model was developed that enables one to propose options, assess them and determine the results. With the outputs, the modeling enables development of policy proposals to address barriers. The functions of the analysis model include:



The objective of this analysis is to improve the development of gas-based CHP by developing appropriate policies to remove the barriers, including economic barriers that CHP is facing in Shanghai. This section summarizes the results of the analyses.

I. Price of Natural Gas and its Development Trend in Shanghai

Natural gas prices are under government control and will continue to be. Currently, the price of natural gas from the East Sea is 1.9-2.1 RMB/m^3 for enterprises. The price of gas from the West to the East is still undecided, however, a department of the national government said that the average guiding price of gas from the West to the East would be 1.29 RMB/m^3, and the guiding gateway price in Shanghai is 1.35 RMB/m^3. But the pressure and calorific value of natural gas from the West have yet to be determined. It can be forecast that the price of NG in Shanghai will go down in the future with the gas from the West to the East arrival, but it will be not lower than 1.6 RMB/m^3 with gateway price plus the cost of municipal pipe-net infrastructure investment and operation. In this research, the lowest price of natural gas is defined in 1.6 RMB/m^3, it is available for large-scale cogeneration, but for small-scale cogeneration, the rate is 2.0 RMB/m^3. The rate below the 1.6 RMB/m^3 may be available if the consumer of NG would like to become the interruptible one. The lower calorific value of natural gas is 8500Kcal/Nm^3.

II. Electricity Tariff and Its Development Trend in Shanghai

1. Current status of electricity tariff

The average electricity tariff for coal-fired power generation that is sold to the grid is 0.31 RMB/kWh. The tariff varies from plant to plant. Also, the tariff for cogeneration is different in different cases. A tariff on excess electricity generated by small-scale and self-use CHP unit is usually only 0.1755 RMB/kWh, while the tariff of one coal-fired CHP plant with district heating in an industrial developing zone reaches 0.622 RMB/kWh.

Currently, the tariff on electricity sold to residents is 0.61 RMB/kWh in Shanghai. Time-of-day tariff is beginning to take hold for residential applications in Shanghai. For this option, the tariff in peak times (6:00—22:00) is 0.61 RMB/kWh, while the tariff in non-peak times (22:00—6:00) is 0.35 RMB/kWh.

The electricity selling price to enterprises consists of two parts: (1) price of the amount of electricity (kWh) and, (2) base demand price, which is paid per month and depends on the capacity (KW). The table below summarizes the tariffs.

Time		Sectors	400 V	10 kV
Price of per kWh (RMB)	Peak 8:00~11:00 18:00~21:00	Industry	0.871	0.865
		Hotel	1.021	1.015
		Commerce	0.901	0.895
	Normal 6:00~8:00 11:00~18:00 21:00~22:00	Industry	0.568	0.562
		Hotel	0.676	0.670
		Commerce	0.644	0.638
	Off-peak 22:00~6:00	Industry	0.295	0.289
		Hotel	0.346	0.340
		Commerce	0.306	0.300
Basic price	Capacity of Maximum demand (RMB/KW•month)		18	18

2. The development pattern of the electricity tariff

The development pattern of the electricity tariff is affected by three factors:

（1） The balance of power supply and demand

It is estimated that the highest peak power load will be 13,400—14,500 MW in 2005 in Shanghai, with an annual average increase 6 percent to 8 percent; the total consumption of electricity will reach 65—73 billion kWh, with annual average increase 4 percent-6 percent.

The general development pattern of power demand in Shanghai in the 10th Five-Year Plan period is:

- The general power demand will increase steadily but at a lower rate than in the 9th Five-Year period.
- The proportion of power demand of the tertiary industry will increase, the power demand of secondary industry will increase, but its proportion will decline, and the power demand of residents will increase.
- Power capacity will increase by 3,835 MW including 2,400 MW of coal-fired units, 1,375 MW of gas-based units and 4-6 MW of wind units. In addition, 3,635 MW of new capacity will be imported from other provinces by 2005.

The highest peak power load will be 14,500 MW in 2005; it will be balanced between the power supply and the power demand in the tenth Five-Year period. Therefore, the tariff of electricity will not rise because of lack of electricity supply.

（2） The power utility reform

The direction of power utility reform in the future will be: (1) to separate the generation and grid; (2) to restructure the power utility; (3) to establish a competitive power market, build an operation regulation and governmental supervision system for the power market; (4) to establish a new power tariff deciding procedure; (5) to set the standard of the emissions levy and develop the mechanism of using clean energy; (6) to attempt to supply electricity for large-scale enterprises directly from power plants and break the monopoly of the utilities, and to develop the reform of the power management system in rural areas.

Shanghai is one of the six provincial experimental units for developing a competitive electricity market. During the pilot period, 10-15 percent of total capacity will participate in market competition. It is expected that the power tariff will not decrease because of the limited competition in near future.

（3） The cost factor

Cost issues are separated into two parts:

First is the price of natural gas. Currently, the price of natural gas is three or four times that of coal, according to LCV. The electricity generated by gas-based power plant will increase in the tenth Five-Year period, and this will result in increasing the cost of electricity, but because the small proportion of gas-fired power plant in total, the increasing will be limited.

Second is to increase the levy for SO_2 emissions. The levy for SO_2 emissions is currently 0.2 RMB/kg in Shanghai and will increase considerably in the future. Although the amount of increase is not yet known, considering that the cost of desulphurization is 3 RMB/kg and assuming an SO_2 emissions factor of 0.008kg/kWh, the cost will increase 2.4 cent/kWh if the desulfurizing installation will be set up in the all coal power plants in Shanghai.

From the above analysis, we can conclude that there is a small possibility of a decrease in the electricity tariff in the 10th Five-Year Plan period. On the other hand, the increase would be limited. But the difference between the peak time tariff and vale time tariff will increase, and it will increase from three times to four times.

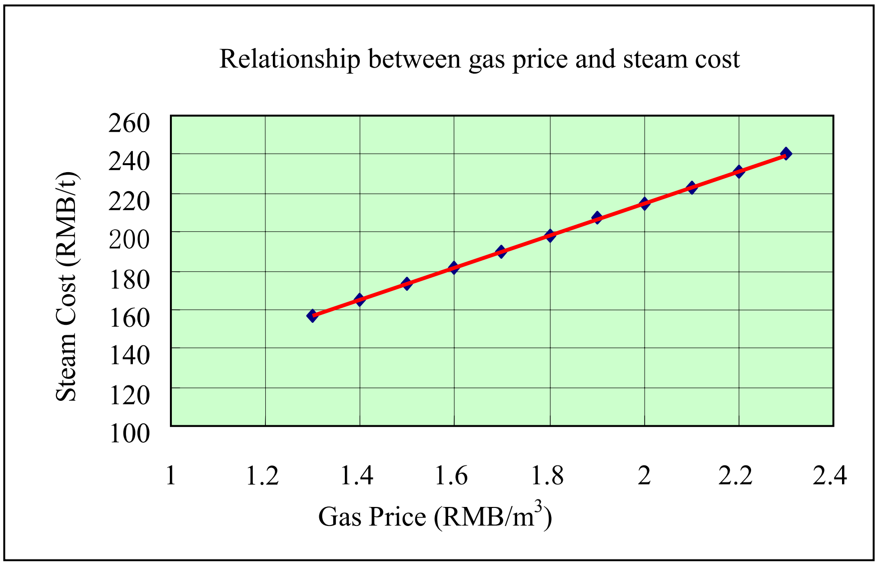
III. Cost analysis of distributed gas-based boilers and the price of district heating

1. Heat cost analysis of distributed gas-based boilers

Distributed gas-based boilers are a simple heat supply system, but with low energy utilization. As a benchmark to compare with CHP, the heat supply cost of distributing gas-based boilers was analyzed. The results are as follows:

Investment of boiler and construction (per ton steam):	250,000 RMB/ton
Labors for gas-based boiler (per ton steam):	3 workers/ton
Wage and welfare/per person:	50,000 RMB
Period of depreciation of boilers:	10 years
Water, electricity and maintenance cost:	5 RMB/per steam ton
Average efficiency of boiler:	85 percent
Annual operation time:	4,000 hours
Price of natural gas for small-scale industry users:	2 RMB/m^3
Cost of per ton steam:	214 RMB/ton

The following figure shows the relationship between gas price and steam cost. It is clear the relationship is linear.



2. The price of district heating in Shanghai

In Shanghai, district heat has combined with CHP. Most district heat companies use coal as fuel, and the price of coal is much lower than the price of NG. The heat supply companies in Shanghai and the price of heat are as follows:

Company	Heat Price (RMB/GJ)
Companies of the utility	15.55—22.16 (43.4—61.9RMB/t)
Gaoqiao	26.65—29.00 (74.4—81.0 RMB/t)
Xinhuo	40.00 (111.7 RMB/t)
Taopu	40.77 (113.9 RMB/t)
Zhangjiang	49.85 (139.2 RMB/t)
Jinqiao	44.36 (123.9 RMB/t)
Minghang	47.09 (131.5 RMB/t)
Qingpu	40.90 (114.2 RMB/t)

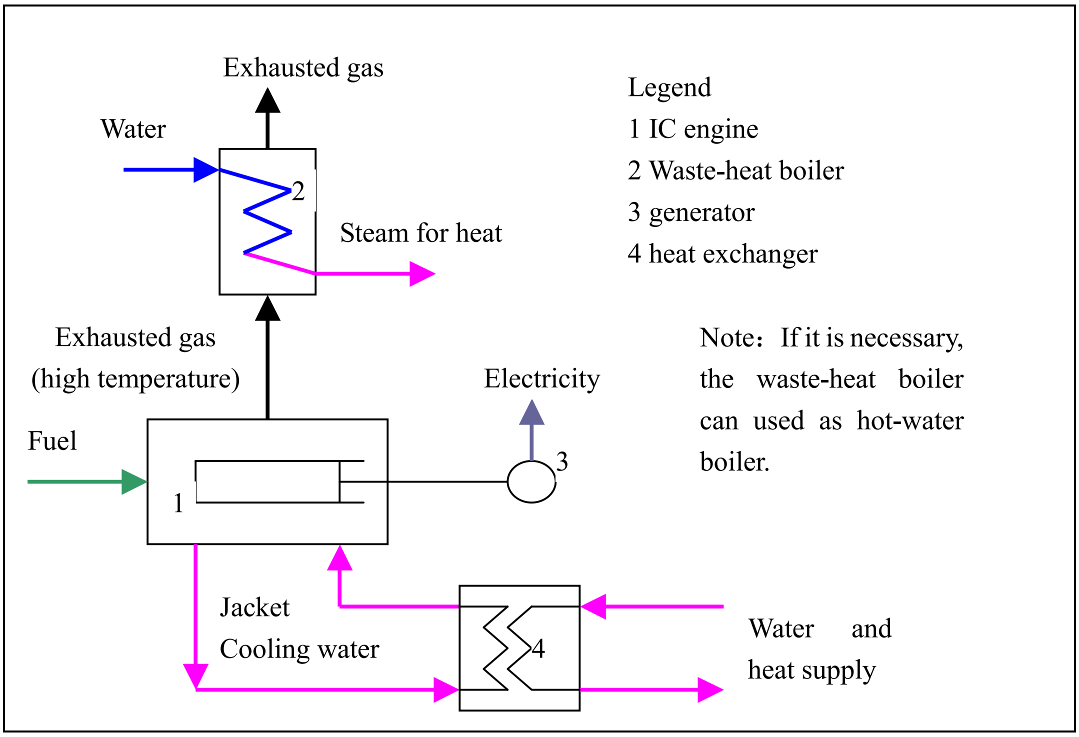
Notes: steam with 1 GJ heat value=0.358 ton steam (saturated steam with 16Kgf/cm^2 pressure)

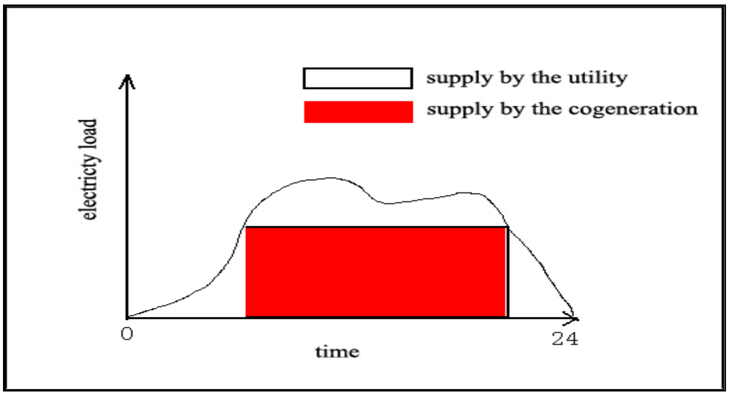
As this analysis shows, the cost of producing steam using gas-based boilers is not competitive with the coal-based district heating at the current NG price. Even in the future, when the NG price is 1.6 RMB/m^3, the cost of producing steam (180 RMB/m^3) is still not competitive.

IV. Financial analysis of gas-based IC-engine CHP of 400 KW

The waste heat contains three parts: exhausted gas from cylinder (400℃-700□), cooling water from the cylinder jacket, and cooling water of lubricating oil. The small-scale IC-engine with power less than 1000 KW is suitable to produce heat water. The flow diagram of a gas-based IC-engine CHP system see follows:

This kind of CHP system is suitable for medium and small-scale hospitals, hotels and indoor swimming pools. The key to successful operation of IC-engine CHP is to analyze the load of heat and electricity, and to choose the suitable capacity of CHP, to ensure more full-load operation time. For example, the enterprise would buy the additional electricity that it needs during peak times from the utility. During the periods when electricity demand at the enterprise is low, the cogeneration unit would closed and the total demand would be supplied by the utility, because the power price is low in these periods and the efficiency of cogeneration would also be low if the unit run at such low load. The electricity generated by this kind of CHP system is suitable to interconnect to the utility but not to sell to the grid. The diagram for the best structure of power load in a day is as follows:



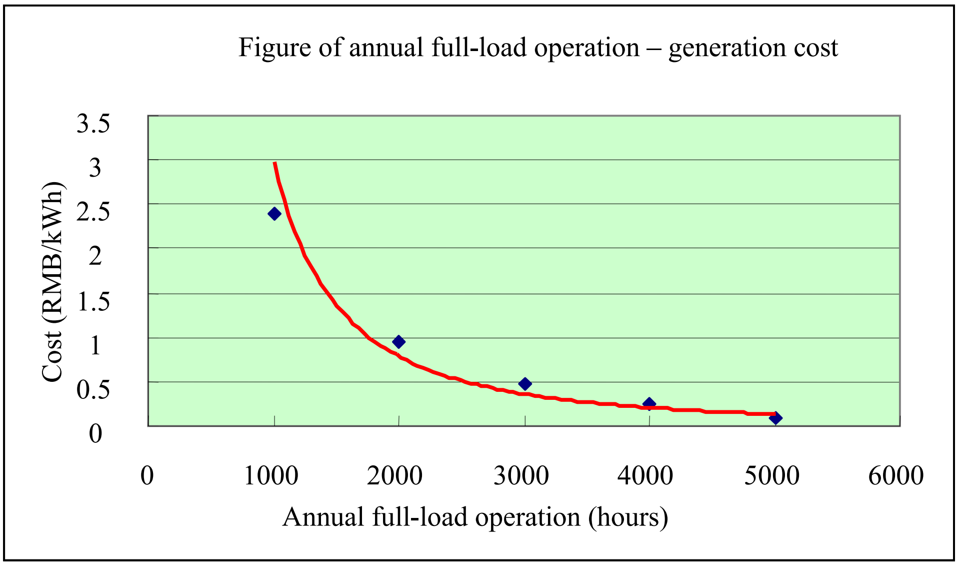


The figures of the financial analysis of IC-engine CHP of 400 KW in one case are:

Capacity	406 KW
Consumption of fuel	1213 KW
Waste heat recovery	691 KW
Annual full-load operation time of equipment:	4000 h
Annual consumption of natural gas:	49 million m^3
Price of natural gas:	2 RMB/m^3
Annual electricity generation:	1.624 million kWh
Annual gas cost:	982 thousand RMB
Annual waste heat recovery equal to steam:	3962 ton
Annual benefit of steam:	848 thousand RMB
Wage and welfare:	150 thousand RMB
Cost of equipment:	3272 thousand RMB
Annual depreciation value of equipment:	182 thousand RMB
Annual maintenance cost:	70 thousand RMB
Cost of per kWh electricity:	0.24 RMB
Efficiency of generating electricity:	33 percent
Total efficiency:	90 percent
Payback period:	2.5 years

In the above case, we assume the price of gas is 2 RMB/m^3; small-scale cogeneration is a small user of natural gas. This figure is likely in the near future. As we know the cost of the distributed gas-fired boiler steam, we think the benefit of cogenerated steam will come from the waste heat instead of gas-fired boilers, so the benefits are the same as the cost of steam generated by gas-fired boilers.
We can see in this case, the cost of electricity is competitive prices of electricity the utility sells to the user. Here the annual full-load running time is 4000 hours. In some buildings, air-conditioning is the main energy consuming equipment, and it is hard to reach 4000 hours of full-load operation time.

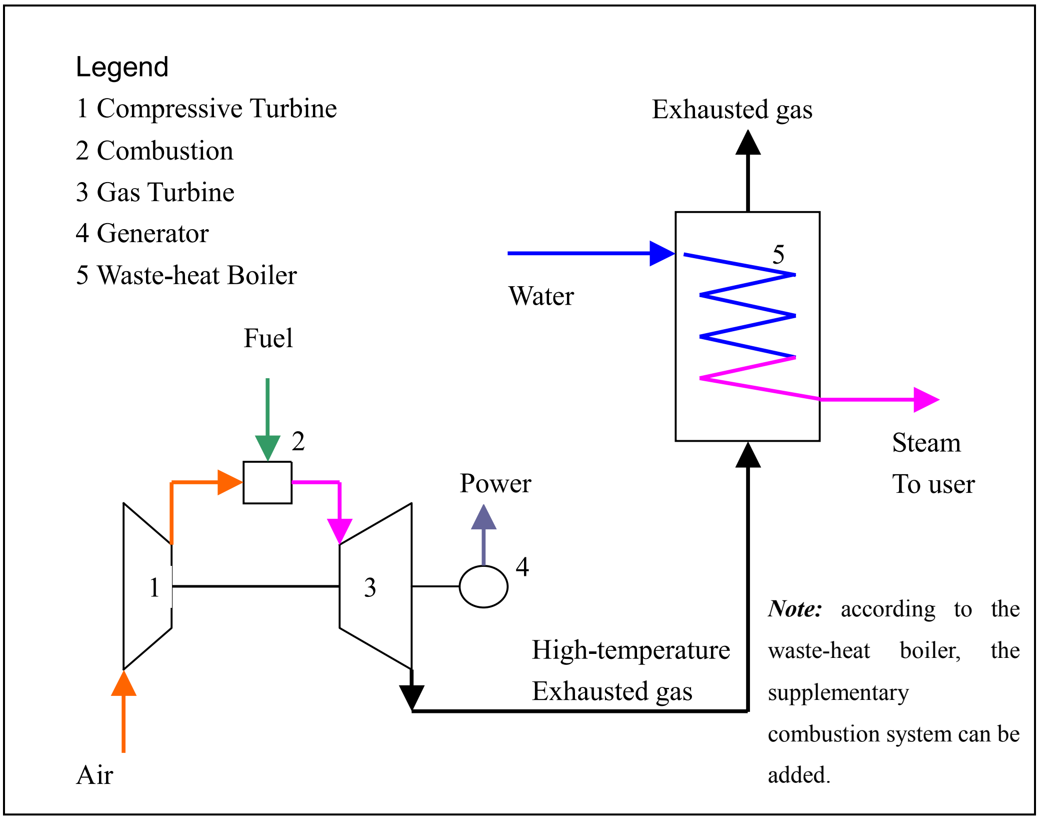
If we assume the boundary condition as same as above case and only change the full-load operation time, we can find the relationship between the cost of electricity generation and annual full-load operation time. The figure showing the relationship is as follow:



From the figure, we can see that the electricity generation cost will rise with the reduction of full-load operation time. After a time of less than 2,500 hours, the increase is intense. When the operation time decreases to 2,000 hours, the generation cost will rise to 1 RMB/kWh, which is not economically competitive.

V. Financial analysis of gas turbine CHP of 4,000 KW

The diagram of a gas turbine CHP system is shown below. Exhaust gas under high temperature and high pressure is emitted by the gas turbine (more than 400℃) with excess oxygen. The waste heat boiler will recover the heat and produce steam.



The exhaust gas of the gas turbine can also be used in direct-fired absorbed lithium bromide chiller or other heater to recover the waste heat.

This type of gas turbine CHP scheme can apply to airports, public buildings and industry.

The figures of financial analysis of self-used gas turbine CHP of 4000 KW in one case are as follows:

Capacity of gas turbine:	4000 KW
Capacity of waste heat boiler:	11t/h
Unit consumption of gas turbine:	12607kJ/kWh
Full-load operation time:	4000h
Annual natural gas consumption:	5668 thousand m^3
Price of NG:	2 RMB/m^3
Annual electricity generation:	16 million kWh
Annual gas cost:	11.33 million RMB
Annual steam produced by waste heat boiler:	44000 ton
Cost of steam:	215 RMB/ton
Annual benefit of steam:	9.416 million RMB
Wage and welfare:	350 thousand RMB
Cost of equipment:	36.28 million RMB
Construction:	864 thousand RMB
Annual depreciation of equipment:	2.016 million RMB
Annual depreciation of construction:	28.8 thousand RMB

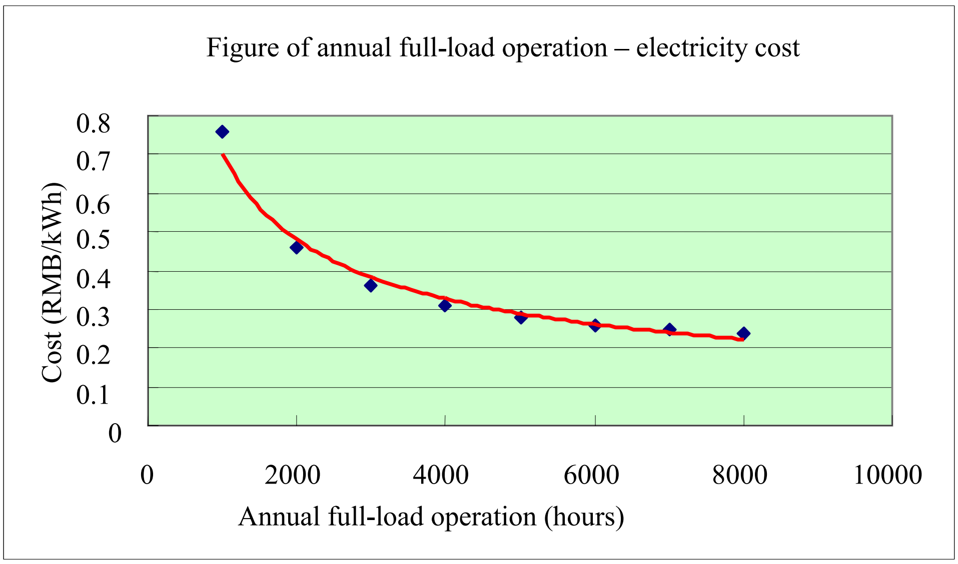
Annual maintenance cost:	68.8 thousand RMB
Cost of per kWh electricity:	0.31 RMB/kWh
Efficiency of generating electricity:	28 percent
Total efficiency:	83 percent
Payback period:	6 years

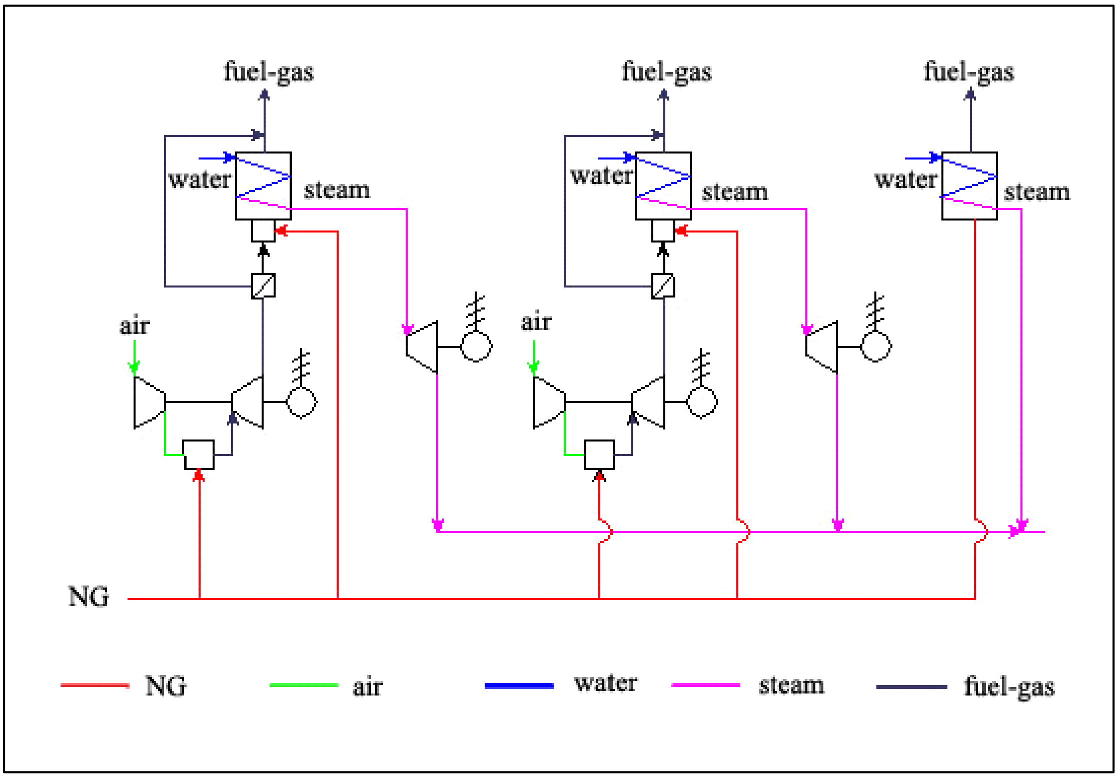
The situation of this case is similar to the IC-engine cogeneration, but the electricity generated is a little costly. The relationship between annual full-load running time and cost of electricity is as follow. We also can see that the key of successful in this kind of cogeneration scheme is to analyze the load of heat and electricity, in this base; we can ensure enough full-load operation time to keep the competitive electricity.

VI. Financial Analysis of Combined Cycle Gas Turbine (CCGT) CHP of 50MW

Combined Cycle Gas Turbine (CCGT) Cogeneration consists of a gas turbine and steam turbine with high generation efficiency. The main types of steam turbines are back-pressured and extraction turbines. This technology has application to industry in development zones, large-scale enterprises, and electric utilities.

Of the following case, the CCGT cogeneration is applied to an industrial zone. Electricity produced by CHP will be sold to the grid; the steam will be sold to different users through a district heating network. This system contains: two gas-based generation units, two waste heat boilers, an extraction turbine, a back-pressure turbine and a peak-shaving boiler. The system flow chart is as follows:





Technical parameters:

Gas turbine generation unit:	2×40MW
Waste heat boiler:	2×65t/h, 5.29Mpa, 450□
Extraction turbine:	8000 KW, 40t/h, 1.27MPa
Back pressured turbine:	5000 KW, 65t/h, 1.27Mpa
Peak-shaving boiler:	50t/h, 1.27Mpa

Figures of analysis:

Capacity of power:	93MW
Steam output of steam turbine:	105t/h
Steam output of peak- shaving boiler:	50t/h
Operation time of CCGT unit:	7000 hours
Operation time of peak-shaving boiler:	3000 hours
Annual electricity generation:	651000000 kWh
Annual steam output:	885000 ton
Price of natural gas:	1.6 RMB/m^3
Electricity tariff sold to the grid:	0.43RMB/kwh
Heat price:	190RMB/ton
Gas consumption:	216.28million m^3
Benefit from power sold:	263.13 million RMB
Benefit from heat sold:	168.15 million RMB
Pay for natural gas purchase:	302.79 million RMB
Total investment of unit:	465 million RMB
Investment of heat network:	25 million RMB

Labor:	40 people
Wage and welfare/per person:	50 thousand RMB
Wage and welfare:	2 million RMB
Value-added tax rate (electricity):	17 percent
Value-added tax rate (Heat):	13 percent
Additional tax rate:	10 percent
Income tax rate:	15 percent
Remnant rate:	10 percent
Flowing capital:	8 million RMB
Annual depreciation:	20.93 million RMB
Operation and maintenance fees:	9.30 million RMB
Value-added tax (heat):	3.82 million RMB
Value-added tax (electricity):	8.38 million RMB
Value-added tax:	12.20 million RMB
Additional tax:	1.22 million RMB
Income tax:	6.35 million RMB
Dynamic investment payback period:	14.4 years (including 1 year construction)
IRR (after tax):	9.4 percent

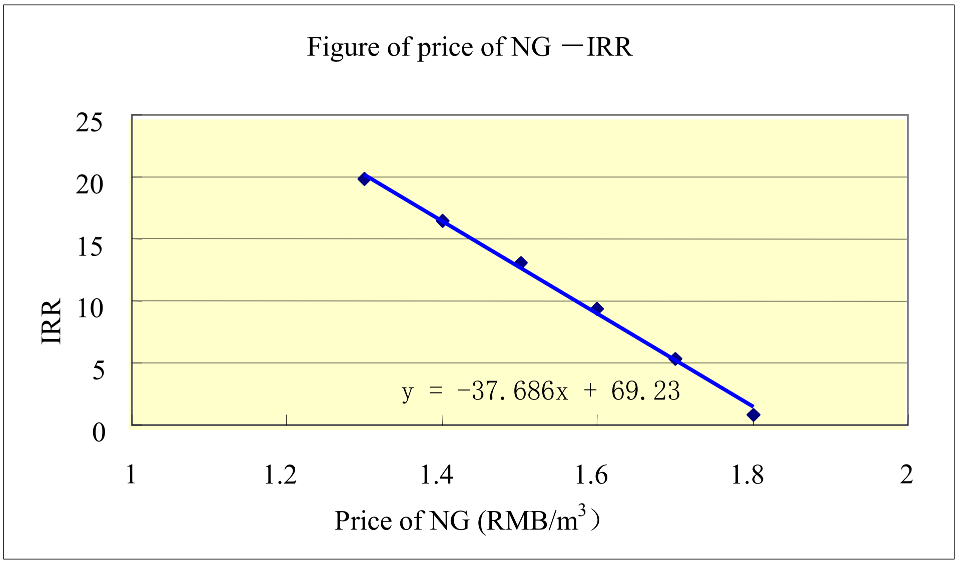
We can see the economic benefit of the project is passable in above assumptive case.

Currently, the natural gas price in industry for Shanghai is 1.9—2.1 RMB/Nm^3. The average power tariff – the price which power plants can sell electricity to the grid is 0.31 RMB/kWh. The steam price is 40—130 RMB/ton.

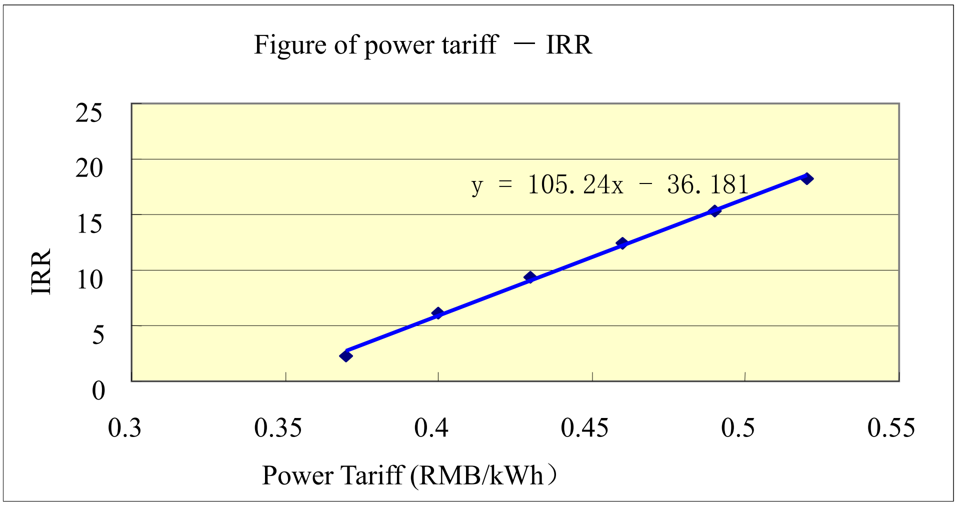
According to the current natural gas price of 1.9- 2.1 RMB/Nm3, electricity sold to the grid average price is 0.31 RMB/KWh, therefore, the price of heat is 40-130 RMB/ton. But it should be noted that currently centrally supplied heat uses coal, therefore its heat price is very low. Accordingly, in above case it is obvious that to buy natural gas at 1.6 RMB/Nm3 for cogeneration and sell the electricity at 0.43 RMB/KWh to the grid would be difficult; also, a heat cost of 190 RMB/ton would be a hardship for consumers.

Here, we analyze the relationship of the various prices and internal rate of return (IRR).

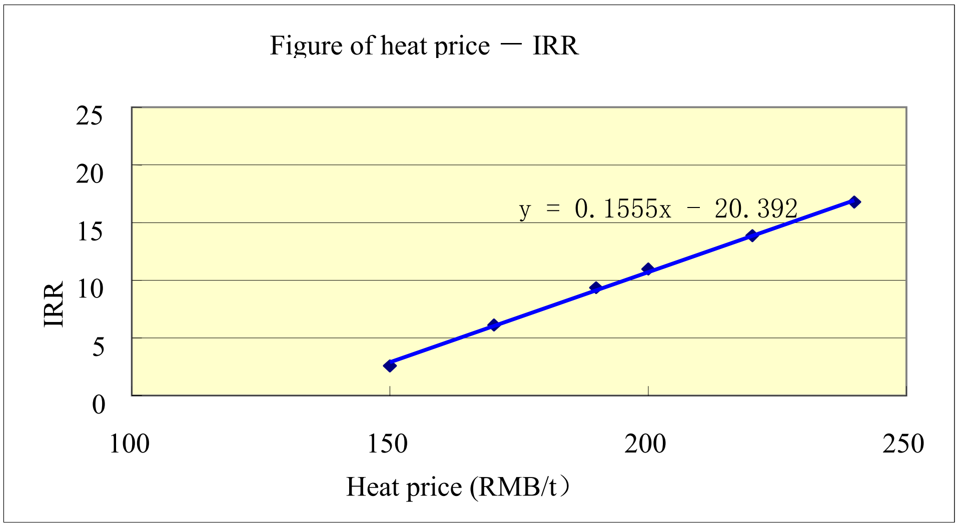
Following figure shows the relationship of natural gas price and IRR:



The relationship of power tariff and IRR is shown as follows:



The relationship of heat price and IRR is shown as follows:



All three factors analyzed in these sensitivity analyses could have great effects on the IRR. A 10 percent change in natural gas price will change the IRR by 65 percent. A 10 percent change in the power tariff will change the IRR by 48 percent. A 10 percent change in the heat price will change the IRR by 32 percent. Among them, the most sensitive factor affecting the IRR is natural gas price, then the power tariff and the heating price. Therefore, to encourage clean CHP systems in Shanghai, moderate increases in one or all of these prices will have very dramatic effects on attracting investment.

VII. Model analysis of enhancing the price competitiveness of gas-based CHP

Based upon the analysis conducted in the above case studies, it was concluded that the cost of electricity generated by a well-designed and operated gas-fired cogeneration system is lower than the price that the grid would charge electricity consumers and some time higher than the buying price than conventional power sold to the grid. This means that, the electricity from gas-fired cogeneration could be economically beneficial it is used by the owner himself or it may be competitively sold directly to end-users if it does not have to go through the grid.

Because "wheeling" " or direct supply is not available in Shanghai, large-scale electrical output-based cogeneration must sell the co-generated power to the utility grid, which is not economically competitive with electricity from conventional coal-fired power plants because of the low relative price of coal vs. natural gas.

Because of the reform of China's electric power sector, electric power generators are now beginning to operate on a competitive basis. In this new environment, it is unlikely that high priced natural gas-based electric power will be viewed favorably.

However, maybe some measures could be taken to improve the competitiveness of large-scale electrical output-based cogeneration. Some examples include:

- Establishing a time-of-day power tariff policy that varies between power generated during peak and non-peak periods. As shown in the previous analysis, large-scale CCGT CHP used for peak-shaving can produce electric power at the higher prices that it can be sold at during peak periods.
- Establishing a favorable price policy for interruptible NG users. Cogeneration plants can adopt dual-fuel systems -- gas and oil -- using oil instead of natural gas during peak natural gas load period, so get a lower tariff of buying NG.

Using these policy options as a basis, an IRR of 9.9 percent can be achieved while using gas priced competitively and while producing electricity that is competitively priced. The results of the analysis for a dual-fueled combined cycle gas turbine CHP of 50MW are summarized in the following:

Annual peak time of power	2190 hours
Annual hours of interrupting of natural gas	1000 hours (suppose)
Power tariff sold to the grid in peak time	0.6 RMB/kWh
Power tariff sold to the grid in other time	0.31 RMB/kWh
Favorable natural gas price for gas users	1.3 RMB/m^3
Light oil price	2.5 RMB/kg
Steam price	165 RMB/ton
Dynamic pay back time	13.8 years
IRR	9.9 percent

We can see that if we adopt a double fuels system, the project will have profit and IRR is 9.9 percent, the power tariff will have competitiveness.

As of now, western gas has yet to arrive in Shanghai, so we can only assume the peak time of nature gas and peak-shaving cost. The steam price mentioned above is 165 RMB/ton. It is competitive with the steam price of distributed ask grantee) coal-fired boiler.

We must establish a favorable price policy for peak-shaving power and the interruptible NG users to improve the development of CHP.

VIII. Conclusions

（1） The price of natural gas, power tariffs, and steam sales price are all critically important factors that influence the competitiveness of gas-based CHP. The most sensitive factor is the price of natural gas, and followed by the power tariff and steam sales price.

（2） The power tariff is likely to remain the same in the 10th Five-Year plan period. However, it is likely that the difference between the tariff for peak and non-peak times will increase, offering the opportunity for gas-based CHP designed for peaking applications.

（3） The cost of steam from distributed gas-fired boilers is too high and is not acceptable to users. Thus, the users can reduce the cost of steam by being supplied by CHP.

（4） Self-generated gas-based CHP when used on-sitethere is not much excess electricity to sell to the grid is competitive when compared with the electricity sold by the Shanghai power company.

（5） The power tariff currently offered by the power company is based upon coal-fired generation and is not sufficient to make natural gas-based CHP competitive.

（6） If favorable price policies for peak-shaving power and interruptible natural gas users are imposed, the competitiveness of output-based and gas-fired CHP will be enhanced.

Chapter 4: CHP in U.S. and EU

I. CHP in the United States

In 1998, CHP in the United States produced 306 billion kilowatt-hours (kWh) of electricity, 54 percent of which was consumed by the co-generators, the rest was sold to electric utilities. Co-generated electricity represents approximately 9 percent of all electricity generated in the United States. Natural gas is the primary fuel used for cogeneration in the U.S. In 1998, co-generators produced 195 billion kWh of gas-based electricity. This represents 64 percent of all electricity produced by co-generators. Coal (17 percent) and renewable energy (13 percent) are the other primary fuels used.

The proportion of electricity produced by gas-based co-generators in the U.S is very high, because of its many merits, including the following, are calculated into economic decision-making by project developers:

- low construction cost
- short construction period
- low pollution
- high energy efficiency
- on-off operation facility
- convenient for peaking shaving
- flexible layout

The price of natural gas in the U.S is lower than in China. It makes gas-based co-generators in U.S more economical than in China. And, although the price differential between natural gas and coal favors coal by 2.5 to 1, the many merits of natural gas still make it the fuel of choice. However, the natural gas price fluctuations in the past two years are having some effect on decisions to use gas, except in very efficient plants, like cogeneration plants. Average gas prices in the U.S. in 1998 are shown in the following table (Unit: Cents/m^3).

Year	Civilian	Commercial	Industry	Generation
1998	19.33	15.48	8.69	6.71

The actions of the U.S government encouraging cogeneration are to normalize the electricity market and implement the incentive and pilot policies.

In the early days of electricity generation in the United States, on-site generation of electricity and heat at industrial facilities was relatively common. Central utilities were just developing and were not as economically competitive or reliable as on-site generation. However, as the reliability of central electric generation increased and price decreased, on-site industrial cogeneration continued to be used only in industries with high steam demand, high capacity utilization and available low cost waste fuels.

By the 1970s, to take electric power supply markets from CHP, monopoly central station electric utilities used their muscle and anti-competitive practices to:

- Refuse to purchase electricity from CHP.
- Demand high payments for standby and back-up power needed by the industrial facilities in the event that the power received from CHP is either inadequate or unavailable to meet the facility's needs.
- Set prohibitive requirements for interconnecting the CHP plants to the grid.

To open the market for CHP by removing the barriers it faced, the Public Utility Regulatory Policies Act of 1978 (PURPA) was passed into law. The law authorized non-utility generators (qualifying facilities or QF's) who met certain requirements to sell electricity to the purchasing utilities. QF's included CHP facilities that met minimum efficiency and operating requirements (including power to heat ratios of less than 18), and small power production facilities whose energy source was no more than 25 percent fossil fuels. All electric utilities were required to purchase power from QF's at their avoided cost. QF's were exempt from many burdensome regulations that regulated utilities had to comply with. In addition, electric utilities were required to provide back-up service to QF's at reasonable rates. The Federal Energy Regulatory Commission (FERC) was authorized to implement PURPA. As a result of the passage of PURPA and its implementing regulations, a competitive power generation market was, for the first time, created in the U.S.

Because investment in cogeneration became very profitable, more and more companies came into the market, most of whom were more interested in selling electric power than heat. Many utilities began receiving electricity capacity offers from QF's that were in excess of the utility's incremental requirements. To counter these problems, the Energy Policy Act of 1992 (EPACT) was passed in U.S. Utilities began instituting competitive bidding to select the projects that they needed for incremental capacity requirements. All generators operated in these competitive power generation markets. As a result of this increased competition, power tariffs declined. This slowed the growth of CHP in the U.S.

CHP still face many barriers in the U.S. These include the following. Many of them are similar to those CHP is facing in China. Actions taken to address them offer insights as to actions that China can take to address them.

1. **Interconnection** of DG to the transmission and distribution grid appears to be the major impediment to DG.[i]

    - **Non-uniform requirements** among utilities and states for interconnecting to the grid. As a result, small DG projects face cumbersome, time consuming, and costly problems for each project they develop.

- Utilities historically have had substantial discretion over interconnection requirements, and have often used that discretion to develop **requirements that vary considerably** from one utility to the next without appropriate technical or economic justification.
- Required equipment and custom engineering analyses are **unnecessarily costly and duplicative** (e.g., adding 15 percent to the cost of a PV project analyzed in case studies).
- **Contractual and procedural requirements** for interconnection are burdensome and, some believe, overly complex and costly.
- Application and interconnection **fees** are viewed as arbitrary and, particularly for smaller projects, disproportionate.
- To determine issues associated with local distribution system capacity constraints that CHP projects might effect, **pre-interconnection studies** are required by most utilities, the costs for which are often passed on to the CHP developer, potentially adding significantly to their costs. In addition, often no time schedule commitments are made by the utilities for completing the studies adding further uncertainty to project development.

2. The relatively **high capital costs** of CHP technologies.
3. **Lack of utility experience** in assessing and making decisions on small CHP projects.
4. Utilities often require **insurance and indemnification** of CHP developers that are very expensive, especially for small projects.
5. Existing **business practices and business models** often reflect the old regulated electricity industry dominated by vertically integrated utilities and central station power plants that offer little incentive to encourage CHP.
6. CHP projects must adhere to **building, electrical, safety and environmental requirements**. In general, national codes and regulations do not cover CHP technologies or are designed for larger, central station power generation facilities. Therefore, CHP projects get delayed until the claims of the developers are validated and the officials decide how to handle the applications.
7. **Backup or standby charges** are claimed to be excessive.
8. Other charges of concern to CHP developers include: (1) **exit fees** (fees charged to customers who decide to self generate and thereby avoid fees associated with stranded base load utility assets), (2) **distribution wheeling charges** for the delivery of power to wholesale or retail customers other than the utility itself, and (3) **transmission and distribution demand charges**. In addition, the charges imposed often do not reflect the benefits to the grid that CHP might provide.
9. **Buy-back rates**, the rates that utilities will purchase back electricity from self-generators, is often very low.
10. **Tax policies** provide little incentive for CHP (e.g., depreciation schedules for electricity-generating equipment are, on average, three times longer than those for similar-sized manufacturing equipment).
11. Lack of a fully **competitive electric power industry**.

12. **Environmental regulations** are currently not administered in such a way as to give credit to CHP technologies that reduce emissions by increasing system efficiency.

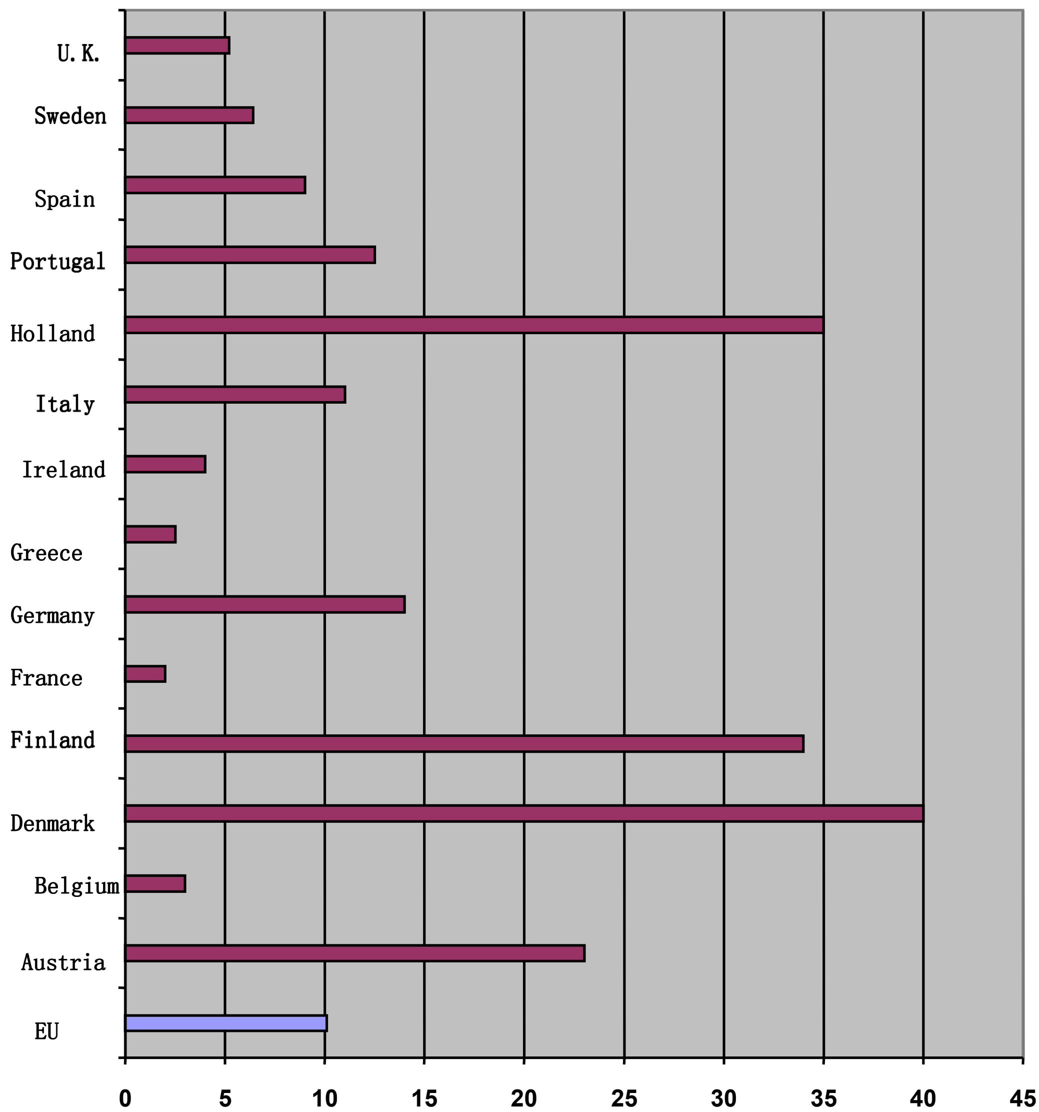
The U.S. government has identified CHP as a very important option to improve energy supply reliability and environmental performance. As a result, it has orchestrated a partnership with industry and others to remove the barriers discussed above. They have undertaken a variety of initiatives, including:

- Exploring the use of output based environmental standards (standards that are based upon the energy output of a plant) that would benefit energy efficient technologies.
- Environmental certification of small turnkey CHP designs would allow any project using the certified design to be automatically permitted without the current long, drawn-out process.
- Expanded information dissemination activities, including creation of a CHP web site.
- Federal guarantees for back-up power to onsite power facilities at just and reasonable rates.
- Increased funding for developing advanced technologies that could reduce the capital and operating costs of CHP. The largest effort has been placed on developing advanced turbine systems with high efficiencies and low nitrogen oxides emissions. In addition, research is being conducted on fuel cells, micro-turbines, and advanced reciprocating engines.
- Setting goals for energy efficiency for the government, including expansion in the use of CHP at government facilities.
- Supporting various organizations to develop standardized interconnection standards and working with legislators to have them consider changes in the laws to require them.
- Developing legislative proposals to revise tax laws to create tax credits and more favorable depreciation schedules for cogeneration plants.

II. CHP in the European Union

Cogeneration development is uneven in the European Union (see figure 1). Currently, the average country share of cogeneration power production is 10.1 percent. The European Commission announced the strategic target of raising the average country share of cogeneration power production to 18 percent by 2010. Supporters of cogeneration in Europe have suggested that this is raised to 30 percent in light of the difficulties anticipated in meeting Europe’s Kyoto Protocol commitments. This 30 percent goal has already been achieved in some countries such as Finland, Denmark and Holland.

Fig. 1：Cogeneration as a share of national power production



The principal barrier that exists in the EU, that also exists in the U.S. is the monopoly of the power market., The European Commission is devoting much attention to this issue, especially in light of trying to encourage the liberation activity of Power Market and the development of cogeneration.

The future for CHP in Europe is uncertain. At the current time, historically low power prices in some countries, high gas prices and country policies like the New Electricity Trading Arrangements in the UK have halted, and in some cases reversed, growth in CHP. For the future, several policies and programs of the EU could support CHP, including:

- A CHP strategy has been adopted.[ii] The strategy defines targets for CHP in the EU, and defines a framework for greater coordination between the various EU policies that impact on cogeneration. However, the strategy has no force of law, and as a result, is not expected to yield much.

- An EU Directive on CHP which is expected to be adopted in the next year or so. If approved, the Directive would provide a legal mandate for governments to take action on CHP.
- The Directive Concerning the Common Rules for the Internal Market of Electricity was passed. In 1996, the EU Council of Ministers agreed to the Directive, which requires electric power market opening according to a schedule (e.g., 25 percent by early 1999, 33 percent by 2005). The Directive could eliminate many existing obstacles to CHP (that are very similar to those encountered in the U.S.) by: (a) ending the monopolistic hold that electric utilities had, (b) ending prohibitions against wheeling of power, (c) reducing problems cogenerators had in getting utilities to purchase their electric power at reasonable prices, (d) reducing high tariffs for stand-by and top-up supplies, and (e) ending predatory pricing against possible competition. However, to date, the main impact of the Directive has been to significantly reduce power prices in Germany.
- The EU ratified the Kyoto Protocol committing European States to reducing greenhouse gas emissions. In its Kyoto Protocol compliance plan, the EU recognized the importance of increasing use of CHP to meet the reduction targets. In fact, CHP accounts for 20 percent of the European reduction. To date, little impact on CHP has resulted although introduction of emissions trading across Europe should provide a major boost for CHP.
- A Directive on Emissions Limits from Large Combustion Plants is under consideration. The Directive would significantly tighten limits on the release of sulfur dioxide, nitrogen oxides and particulate matter from combustion plants with a fuel consumption capacity of at least 50MWt, including gas turbines. The proposal explicitly recognizes the higher efficiency of CHP systems. In fact, the Directive says that CHP must be used unless the operator can demonstrate that it is not technically and economically feasible.

There are many commonalties and some marked differences between the barriers to cogeneration in Europe and the United States. One difference is the ability of the European Union to create policies and guidelines that the EU member states adhere to, with some differences in approach, schedule and outcome. In the U.S., in many cases, states move in the directions they choose, within broad federal guidelines.

The principal barriers that exist in the EU as well as the U.S. are:

- Limited access to the electric power grid
- High prices for back-up power and for access to back-up power
- Low prices paid by utilities for power produced from CHP facilities

In addition, although there has been much success in developing a competitive electric power industry in the EU, the market is still dominated by the utilities that had monopoly positions before electric power reform. Many of these utilities do not believe that decentralized power is relevant. Also, lack of specific measures to reduce greenhouse gas emissions (e.g., emissions taxes, tradable permits, and tax incentives) is impeding growth of CHP in both the EU and the U.S. This must be coupled with adequate supplies and reasonably priced natural gas that can be delivered to markets.

In addition, there are other barriers that are less significant and that are different from or related to those found in the U.S. For example, in Western Europe[iii]:

- The Directive Concerning the Common Rules for the Internal Market of Gas was passed (2000). Although this Directive should result in reduced gas prices in the EU, and therefore, favorable conditions for cogeneration, a provision in the Directive that gives the States authority to cap the amount of CHP capacity if there is risk of unbalancing the electricity market, could limit its use.
- The two main energy market liberalization directives (on electricity and gas) must be implemented. It remains to be seen that the Directives will be implemented so as to increase competition, increase transparency in pricing, create reasonable prices for back-up electricity, and provide reasonable tariffs for cogenerated electricity that is sold to the grid and for excess heat.
- Technology development is needed to advance technologies such as gas turbines, micro-cogeneration, and fuel cells.
- Lack of awareness and distrust of CHP by those who do not have experience in using it impede its expanded use. Tied to this is the need to collect comparable statistics on energy use in Europe, upon which rationale energy and environmental policies can be based.
- Lack of coordination among the many activities of the EU to define policies and programs to support CHP.
- Specific energy goals and requirements for public institutions of the EU do not exist. A large percentage of the energy that is consumed in the EU is done so by government activities.

In Eastern Europe, besides the barriers noted above, additional barriers exist that are associated with the lack of policy initiatives to address institutional, regulatory, technical and financial barriers. These barriers include:

- Bureaucratic procedures
- Lack of an appropriate legal framework within which projects can be undertaken
- Incorrect pricing formulas for heat and power
- Lack of understanding and initiatives to utilize advanced, modern financing techniques
- Outdated equipment

- Lack of information and knowledge
- Lack of experience with modern cogeneration schemes, and
- Lack of incentives (e.g., financial, risk reduction) to attract foreign investment and foreign technology.

More information on the U.S. and European cogeneration activities are provided in the attached.

Chapter 5: Barriers Analysis and Policy Suggestions for the Development of Clean Cogeneration in Shanghai

Many barriers to the full development of CHP in China exist. Previous Energy Foundation studies have identified them and proposed solutions to address them. On the level of central government, a series of policies and regulations to encourage and support the development of cogeneration have been issued during the last few years. Of significance, is the *Stipulation for Cogeneration Development* (called *1268 file*) published by the State Development and Planning Commission (SDPC), the State Economic and Trade Commission (SETC), the State Environmental Protection Bureau (SEPB) and the Ministry of Construction in August 2000, and funded by the Energy Foundation. It is the regulation to carry out the *Energy Conservation Law of the People's Republic of China*.

This study focused on the most critical barrier facing gas-based CHP in Shanghai, that of its inability to compete on economic grounds with coal-based systems under current gas pricing and electric and steam tariff structures. As a result of this work, the following policy options have been identified for further consideration:

- Encouraging cogeneration companies to operate as peak shavers, besides generating power in accord with heat demand.
- Adopting a two part tariff for the electricity according the instruction to sell to the grid during periods of high electric system demand. Two part tariffs is a means of taking into account costs of both generated electricity (kWh) and capacity (KW) involved in peak shaving operation.
- Adopting time-of-day price of electricity for sale to the grid. Time-of-day price is a means of the price of electricity for sale to the grid is different at different period, for example 0.61 Yuan per kilowatt hour at 6 o'clock to 22 o'clock and 0.30 Yuan per kilowatt hour from 22 o'clock to next day 6 o'clock.
- Cogeneration plants could adopt the dual fuel system, gas and oil, and can use oil instead of natural gas between peak load periods of natural gas.
- Encouraging cogeneration to become an interruptible natural gas user, to get the lower tariff when buying NG.
- Improving the rule of interconnection between the utility grid and self used & small

scale CHP to make the rule transparent and equitable and encourage the electricity industry to provide the technology support and service for small scale CHP;

- Industrializing the manufacture of gas-based cogeneration equipment in Shanghai to reduce the cost of investment and maintenance.
- Developing output-based standards (to provide incentives for increased energy efficiency) and increased SO_2 emissions fees; launch SO_2 trading to give incentives for the environmental benefits of gas-fired cogeneration.
- Promote a self-generating & small scale CHP consultant industry, and encouraging ESCO's and public utilities to take part in the investment, construction and management of CHP;
- Establish a CHP association to promote the development of CHP.

Detailed analysis of the above options is as follow:

I. Enhance the ability of gas-based cogeneration to compete on the economic grounds for sale to the grid

We usually consider the most critical barrier to developing cogeneration is the monopolistic hold that electric utilities had, such as on power interconnection, access to the grid, power tariff and so on. But, according to the research, we know the most critical barrier is the inability of gas-based cogeneration to compete on the economic grounds. The following five options are helpful to enhance the ability of gas-based cogeneration to compete on the economic grounds.

A. Give favorable power tariffs and NG prices to the cogeneration enterprises involved in power peak shaving and are interruptible natural gas users. It is true that the natural gas price will be kept high for some time to come. According to the above analysis, the cogeneration enterprises involved in power peak shaving and are the interruptible natural gas users can get favorable price options, which can enhance its competitiveness in the market.

1. Feasibility study to involve in peak/load shaving of power

(1) Technology analysis

A gas turbine and steam turbine combined cycle power plant is more flexible than coal-fired and nuclear power plants, especially gas turbine plants. It can rapidly start and stop, and achieve so-called dark startup. For example, PG6561B gas turbine's startup time is 16 minutes while its emergent startup time is only 10 minutes. Thus, it can adapt to be a power peak shaver. Compared with steam turbine system of same capacity, gas turbine and steam turbine combined cycle system has a shorter startup and shutdown time. Moreover, extraction turbine cogeneration can satisfy both heating and power demands within a certain load range. Therefore, it is technically feasible to use gas turbine cogeneration to realize power peak shaving.

(2) Policy analysis

The eighth item in the *Stipulation for Cogeneration Development* says that "In the first year of generation, the contract of selling electricity to the grid should be signed according to the annual average ratio of heat and power as well as its general efficiency confirmed in the feasibility study. When the heat supply and safe operation is ensured, CHP can be involved in the peak/load shaving of power (except back pressure turbines)."

The ninth item in the *Stipulation for Cogeneration Development* says that "Power plants should make a best operation scheme according to the heat demand and aim for the primary goal of satisfying the heat demand. When the local power management department makes up plans for cogeneration plants, it should fully consider the heat demand change and energy savings. It is not allowed to limit the heat supply by electricity instruction and force the plants to reduce the pressure and temperature of steam; otherwise, it will be indicted and asked for compensation."

The *Stipulation for Cogeneration Development* also confirms that gas turbine cogeneration should reach 55 percent of the general average heat efficiency and more than 30 percent of the annual average ratio of heat to power.

Above is the policy in which cogeneration could play a role in power peak shaving.

2. Feasibility study for interruptiblenatural gas users

Technically speaking, gas turbine and its combined cycle system are the primary stable users of natural gas. Most of current gas turbines are equipped with dual-fuel burner which can burn alternate fuel such as oil between the peak NG demand periods. Thus, gas turbine cogeneration can reduce the pressure of natural gas peak shaving and the gap between vale and peak load by using other fuel to reduce the natural gas storing cost of the equipment.

The Tenth Five-year Plan for Energy Development Specific Plan of Shanghai shows that interruptible natural gas users can receive a favorable energy price. Therefore, we can develop such users who can reduce or stop using natural gas during the rush hour of gas supply and provide them with preferential policies.

3. Summary

It is feasible to include cogeneration in power peak shaving and become interruptible natural gas users both from technology and policy standpoints.

When the gas-based CHP involve in peak/load shaving of power, the utility grid should give the addition electricity purchase except one depend on heat. This

additional electricity will get also a high price.

All gas-fired power plants have their own backup fuel tank which can be used as a substitute. During the peak load of natural gas supply, gas-based cogenerations can use backup fuel as a substitute to shave the peak load. We can offer such users fairly a low natural gas price in order to encourage their contribution to NG peak shaving as well as improve their competitiveness on the economic grounds.

B. Centralizing the high heat demand companies during the city planning and project approval. It is heat demand that decides the success of a cogeneration project. Some projects have poor profits due to low heat demand; therefore, it is recommended to centralize the high heat demand companies during the city planning and project approval to meet the requirement of cogeneration.

C. Industrializing the manufacture of gas-based cogeneration equipments in Shanghai to reduce the cost of investment and maintenance. As the main part of cogeneration system, gas turbines have been manufactured in China since the end of 1950's. However, there is still a big gap compared with the developed countries. We have no advantage in gas turbines. Currently, about 90 percent of gas turbines in China are imported, for the remaining 10 percent, the key part of the gas turbine also depends on imports. So the cost of investment and maintenance is high. Therefore, the industrialization of the equipment in Shanghai is vital for reducing the cost, encouraging the investment and improving CHP competitiveness in the market. We can introduce the method of binding bid to attract overseas manufacturers to invest or make over core manufacturing technology into China. It is expected to get the support of public debt funds to cultivate factories to speed the localization of cogeneration equipment manufacture.

II. Promote the development of cogeneration through the implementation of environmental protection policy

A. Increase the levy for SO_2 emissions, launch the SO_2 emissions trade and develop output-based standards to reward highly efficient operations and environmental benefit for gas-based cogeneration. The current levy for SO_2 is only 0.3 RMB per kilogram, which nearly means nothing to the cost of coal-fired generation enterprises. Therefore, we should increase the levy and launch the SO_2 emissions trade between power plants in order to encourage power plant to do desulfurization by marketing economic mechanism. The competitiveness of cogeneration can be improved by increasing the environmental cost of conventional coal-fired plants to transfer the environmental benefit into economic benefits.

We can provide a similar subsidy policy for clean energy boilers to small-scale gas turbine cogeneration systems that replace coal-fired boilers.

Launch the SO_2 emissions trade between power plants, expand into the distributing coal-fired boilers as soon as possible and promote the replacement of distributed coal-fired boilers by clean energy district cogenerations.

Some of the levy of SO_2 emissions is proposed to be used as subsidy of investment of cogeneration.

B. Provide a similar subsidy policy for clean energy boilers as was provided for small scale gas turbine cogeneration systems that replaced coal-fired boilers. According to the *Implementation of replacing coal boilers and industry furnaces by clean energy boilers in Shanghai* issued in May 2001, the government provides 40,000 RMB subsidies per ton steam to the coal-fired boilers and industry furnaces listed by both the municipal environmental protection bureau and Shanghai economic commission. We hope a similar subsidy policy will be provided for clean CHP that replace distributed coal-fired boilers.

C. Finance the newly and expanded cogeneration system using clean energy. According to the Chapter 2 and Chapter 3 talking about the current situation of cogeneration in Shanghai and model analysis of economic operation of cogeneration, we can see that certain policy support should be given to cogeneration projects using clean energy due to higher fuel cost. It is supposed to take from the levy of SO2 (next is NOx) as the subsidy for newly and expanded cogeneration projects, at the same time, spare some quotas for them.

III. Promoting the development of small scale cogeneration for self use

For the small-scaled cogeneration system for self-use, since its generation cost is competitive compared with the price of electricity from the grid, so it can get good economic benefit if the full load operation time can be guaranteed. The main problem of current such cogeneration system with low efficiency is the miscalculation of heat and electricity demand. Though it can get good economic benefits, its development in Shanghai is slow due to the following reasons:

- Lack of professional consulting services
- Lack of successful case
- Lack of dissemination of CHP
- Lack of cognizance of CHP

The following are the policy options for the development of small-scaled cogeneration system for self-use in Shanghai:

- **Promoting CHP consultant industry, and encouraging ESCO and public utility to take part in the investment, construction and management of CHP.**
- **Drawing operative and transparent access to the electricity network for**

self-use & small-scale CHP companies and encouraging the electricity industry to provide the technology support and service for small scale CHP.

IV. Establishing a CHP association to promote the development of CHP

Establish a CHP association consisting of cogeneration enterprises and users, energy conservation organizations, manufacturers of cogeneration equipment and investors. The association will be a mechanism that will promote the healthy development of CHP. It will also serve as a bridge between users and public power department and assist the decision-makers of related government departments to development strategies for cogeneration in Shanghai.

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