Achieving Low-Carbon Development in APEC's Communities by Using Higher-Efficiency and Cleaner Gas-Fired Cogeneration Technology

APEC Energy Working Group

May 2013

APEC Project EWG 20/2011A

Produced by

SinoCarbon Innovation & Investment Co., Ltd

For
Asia Pacific Economic Cooperation Secretariat
35 Heng Mui Keng Terrace
Singapore 119616
Tel: (65) 68919 600
Fax: (65) 68919 690
Email: info@apec.org
Website: www.apec.org

APEC#213-RE-01.8

Contents

List of Tables and Figure

Abbreviation

APEC	Asia-Pacific Economic Cooperation
BAU	business-as-usual
CARB	California Air Resources Board
CCGT	Combined Cycle Gas Turbine
CDM	Clean Development Mechanism
CHP	Combined Heat and Power Generation
GDP	Gross Domestic Product
GHG	Greenhouse Gas
HRSG	Heat Recovery Steam Generators
NCCS	National Climate Change Secretariat
RGGI	Regional Greenhouse Gas Initiative

Executive summary

Fighting global climate change, reducing carbon dioxide emissions has already formed a consensus within the globe. APEC economies are addressing the threat of global climate change by many technologies and methodologies. Gas-fired cogeneration is an advanced technology that by firing clean natural gas can provide cleaner electricity to the grid and centralized supply heat/cold to the residents and buildings, meanwhile which can replace the existing dispersion heating supply by the fossil-fired heating.

The purpose of this study is trying to identify the barriers for implementing gas-fired cogeneration technology in China, propose suggestions on how to overcome these barriers. Moreover, the economic and environmental benefits of the natural gas cogeneration technology would be assessed, promote gas cogeneration technology to build low-carbon city and community more efficient.

The report includes three parts:

The first part is introduce low carbon regulations in APEC economics, including the Australia; Canada; China; Japan; Republic of Korea; New Zealand; Singapore and United States. The research contents cover the regulations, policies and state strategies about carbon reduction and new energy industries. Especially the research paid much attention to Chinese regulations, policies and strategies for developing Natural-gas cogeneration technology.

The second part is research on the natural gas cogeneration technology, including the technical principles of the natural gas cogeneration, the principles of carbon emission reduction, application status and development potentials of the natural gas cogeneration technology, assessment on the economic & environmental benefits of the natural gas cogeneration technology, and contribution of the natural gas cogeneration technology to the city and community.

The third part is identify the barriers for implementing gas-fired cogeneration

technology in China, and proposes suggestions on how to overcome these barriers. At the basis of above research, we propose use the GHG methodology to overcome the barriers.

Providing solid study finding, this research report will support the promotion and application of advanced gas-fired cogeneration project for contributing to the low carbon development objectives of APEC economics.

1. Background

The main APEC member economics are keen to put themselves on the low carbon development path. And the APEC Leaders are committed to develop policies for encouraging the green industries and promote sustainable growth through implementing low carbon regulations and policies. In the other hand, APEC economies are addressing the threat of global climate change by many technologies and methodologies. Through introduction of low-carbon technologies in city planning to boost energy efficiency and reduce fossil energy use is vital to manage rapidly growing energy consumption in urban areas.

Gas-fired cogeneration is an advanced technology that by firing clean natural gas can provide cleaner electricity to the grid and centralized supply heat/cold to the residents and buildings, meanwhile which can replace the existing dispersion heating supply by the fossil-fired heating.

A project called “Achieving Low-Carbon Development in APEC’s Communities by using Higher-Efficiency and Cleaner Gas-Fired Cogeneration Technology” is launched by APEC. Through this project, why the gas-fired cogeneration technology will help communities to achieve low carbon development, what barriers will be for implementation of the technology, and how to overcome the barriers will be researched. The project has been divided into three research tasks, including research on low carbon regulations in APEC economics; research on the natural gas cogeneration technology in China; The barrier research on gas-fired cogeneration in China.

Providing solid study finding, this research will support the promotion and application of advanced gas-fired cogeneration project for contributing to the low carbon development objectives of APEC economics.

2. Low Carbon Regulations in the world

This chapter is primarily responsible for introducing the current low carbon regulations in APEC economics. Firstly, the national carbon regulation studied will include the members of the Australia; Canada; China; Japan; Republic of Korea; New Zealand; Singapore and United States. Secondly, the research contents will cover the regulations, policies and state strategies about carbon reduction and new energy industries. Thirdly, the project will pay much attention to the Chinese regulations, policies and strategies for developing Natural-gas cogeneration technology.

2.1 International Low Carbon Regulations

2.1.1 Low Carbon Regulations in APEC economics

2.1.1.1 Australia

On 8 November 2011, the Australian Senate finally passed a bill to introduce a domestic emission trading scheme. The Australian government declared that it would formally launch a cap-and-trade market from 1 July 2012. By sending a signal of carbon prices to the market, it aims to accelerate the transformation of its domestic economy, reduce carbon emission and stimulate the investment in clean energy. This is also the beginning for Australia to transform its economic development pattern.

The carbon price mechanism is the key issue of the package plan known as clean energy legislative package which was passed by Australian Senate on Nov, 8th, 2011 and also a major policy measure to achieve Australia’s greenhouse gas emissions reduction target.

Australia will levy a fixed price at 23 AUD (equal to 160CNY) per ton of CO_2 over 500 large enterprises in the energy, transportation, industrial and mining sectors, the emission of which accounts for over 60% of the total in Australia. The price will increase by 2.5% annually. After three years, the system will turn to a cap-and-trade mechanism automatically. The fixed carbon price is equal to carbon tax for the large enterprises.

2.1.1.2 Japan

Japanese government attaches great importance to low-carbon economy. In the construction of the low-carbon society law system, Japan has established an legal system of energy which guides by the basic law of energy and includes the coal legislation, the oil legislation, the natural gas legislation, the power legislation, the new energy legislation, the nuclear legislation. The energy legal system formed a pyramid. In May and June 2008, the Japanese Diet passed the amendments of the *Energy Conservation Law*, the amendments of *Act on Promotion of Global Warming Countermeasures* and the *R&D Capacity Strengthening Law*. In October 2008, Japan formally decided to try the domestic emissions trading system. The Ministry of Economy, Trade and Industry decided to revise *Alternative Energy Act*. Because of perfect legislation and strict enforcement, Japan has become the world's highest energy efficiency.

2.1.1.3 Republic of Korea

The Government of the Republic of Korea announced a new national strategy for “low-carbon, green growth” in 2008. The strategy is underpinned by The Basic Law on Low Carbon and Green Growth, passed in early 2010. The Law provides legal grounds for setting reduction targets, emission reporting system, cap-and-trade system and vehicle emission standards. However, cap-and-trade system has been objected by industries and later postponed from 2013 to 2015.

The Law introduces greenhouse gas emission limitations and trading scheme. As transitional movement, a mechanism of managing greenhouse gas emissions has been built and implemented. It incorporates 468 companies covering 70% of total emissions into governmental management system under which companies must report greenhouse gas emissions to the government while the latter will review and verify companies' performances and impose a fine of 10 million KRW for every ton of CO_2 over the baseline.

On May 2, 2012, the Korean National Assembly passed a law introducing a national carbon trading scheme by 2015. This is truly significant moment because it makes Korea the first Asian member and the fourth country after EU, New Zealand and Australia in the world to legislate emission trading scheme.

2.1.1.4 New Zealand

In November 2002, the New Zealand Parliament passed *Climate Change Response Act 2002*.

In September 2008, the Bill included a GHG emission trading plan and began to conduct forestry carbon sink programs since January 2008. However, the trading plan was met with ups and downs. In November 2009, the legislation of the plan was amended again. In 2010, finally succeeding in introducing a domestic GHG emission trading mechanism, New Zealand established the second mandatory greenhouse gas total control and emissions trading mechanisms.

With an extensive coverage, according to the amended bill, the New Zealand Emission Trading System covers all the sectors and GHGs within New Zealand without a cap. With a gradual model for implementation, different industries will enter into the ETS at different phases. The forestry carbon sink program took the lead in entering into ETS on January 1, 2008. As fixed energy emission sources, the industry sector and fossil fuels were included into ETS on July 1, 2010. The agricultural sector (accounting for 50% of the total emission) will be included on January 1, 2015. The period from July 1, 2010 to January 1, 2013 acts as a transition period for participants to better adept to the ETS.

2.1.1.5 Singapore

The Government of Singapore announced a national Climate Change Strategy for " Climate Change & Singapore: Challenges, Opportunities Partnerships". The Singapore Government Plans to improve energy efficiency in all sectors of the economy were included in its 2009 Sustainable Singapore Blueprint. Singapore pledged to reduce our emissions by 16% from the 2020 business-as-usual (BAU) level, contingent on a legally binding global agreement in which all countries implement their commitments in good faith. Although a legally binding agreement has yet to be reached, Singapore has nonetheless started to implement mitigation and energy efficiency measures which should reduce our emissions by 7% to 11% from the 2020 BAU level.

Recognizing that climate change affects the work and responsibilities of many Ministries and government agencies, the Government formed the National Climate Change Secretariat (NCCS) as a dedicated unit in July 2010 under the Prime Minister's Office to provide coordination at the highest level for Singapore's domestic and international policies, plans and actions on climate change. The NCCS also supports the work of the Inter-Ministerial Committee on Climate Change. Singapore's approach to addressing climate related challenges is four-fold: First, reduce carbon emissions in all sectors; Second, be ready to adapt to climate change effects; Third, harness green growth opportunities; Fourth, forge partnerships.

2.1.1.6 United States

On July 11, 2007, the United States Senate proposed the Low Carbon Economy Act. It means that low-carbon development path becomes an important strategic choice in the future. On February 15, 2009, the US issued the American Recovery and Reinvestment Act. Its total investment reached 787 billion USD. Its important content is the development of new energy which includes the development of highly efficient battery, smart power grids, carbon capture and storage, renewable energy such as wind and solar energy. On March 31, 2009, the Carbon Dioxide Information Analysis Center presented the American Clean Energy and Security Act of 2009.This act constitutes a low-carbon economy legal framework of the United States. On June 28, 2009, the US House of Representatives passed the American Clean Energy and Security Act. This was the first US program to respond to the climate change, which not only set a timetable for US to reduce greenhouse gas emissions, but also designed emissions trading. It tries market means to achieve the emission reduction targets with minimum cost.

Representative of the regional market systems currently planning and running are California’s emissions trading program under *Assembly Bill 32* and Regional Greenhouse Gas Initiative (RGGI).

1. California’s emissions trading program under AB 32

California has quickly moved forward to create the first comprehensive multi-sector greenhouse gas (GHG) reduction program in the United States. *Global Warming Solutions Act of 2006* or *Assembly Bill 32* requires the California Air Resources Board (CARB) to develop regulations and market mechanisms to reduce California's greenhouse gas emissions to 1990 levels by 2020, representing a 25% reduction statewide.

The CARB adopted the cap-and-trade regulation on Oct 20, 2011, making California the first American state to pass cap-and-trade program. California’s emissions trading scheme has been officially created after three-year negotiations. This is the second cap-and-trade program that covers multi-sectors in Asia Pacific region (after New Zealand). As the eighth largest economy in the world, California’s move is highly influential to the global market.

California has successfully led several regulatory-driven energy and environmental trends in the United States. The state has been the model for many progressive programs that are subsequently adopted on a larger scale, including energy efficiency policies (i.e., California's Appliance Efficiency Program that has been adopted be China), broad deregulation of the wholesale and retail electric markets in 1998, fuel economy standards that have are now being implemented on a federal level, and aggressive renewable energy portfolio standards.

2. Regional Greenhouse Gas Initiative

Regional Greenhouse Gas Initiative was officially launched on Jan 1 2009.

RGGI, the first mandatory emission trading scheme in electricity sector calls for a reduction in greenhouse gas emissions to 10% below 2008 levels by 2018. RGGI now covers power plants in ten states of Northeast US and western Atlantic. RGGI sets targets for two phases: Phase 1 (2009-2014) to stabilize CO_2 emissions at 2009 levels, Phase 2 (2015-2018) to reduce CO_2 emissions by 10% compared with 2009 levels, i.e. 2.5% cut every year. However in reality, RGGI is challenged by excessive allowance. 2009's and 2010's allowances were 50% and 15% more than actual emissions respectively. Excessive allowance is like to continue until 2018, driving auction price down to below \$2/tCO_2 in 2010. To make matters worse, New Jersey which was the participant complained RGGI unable to complete the greenhouse gas emission reduction targets, but increase the user's energy expenditure. May 26th, 2011, the New Jersey officially announced its withdrawal from RGGI. RGGI is trapped in a dilemma: on one side, an unreasonable cap on emission coupled with insufficient market demand due to economic crisis is detrimental to the realization of RGGI's goal, on the other side, tightening the cap would always confront political pressure, pushing this already troubled system to the brink of death.

2.1.2 Low Carbon regulations in other economics

2.1.2.1 The United Kingdom

As the first country to propose "low-carbon economy" in the world, the United Kingdom attaches great importance to the legislation of low-carbon economy. In 2003, the United Kingdom government released the *Energy White Paper 2003: Our Energy Future - Creating a Low Carbon Economy*.

In October 2006, British Government issued *the Economics of Climate Change*: the Stern Review and made a quantitative assessment to the economic impact of global warming. In March 2008, Britain promulgated *Climate Change Bill*, which makes UK the first country to establish a long-term legally binding in order to reduce greenhouse gas emissions and adapt to climate changes. On the July 15, 2009, the United Kingdom issued the *UK Low-Carbon Transition Plan* and the *UK Renewable Energy* Strategy. UK became the first country to set up carbon management plan within the framework of the government budget. At the same time, the matching program was issued such as the *UK Low Carbon Industrial Strategy* and the *Low-Carbon transport Strategy.*

2.1.2.2 The European Union

The European Union has developed a series of low-carbon economy laws and policies by balancing and coordinating its Member States. In March 2006, the EU issued the *Green Paper: an European Strategy for Sustainable*, *Competitive and Secure Energy*. On October 19, 2006 it announced the *Energy efficiency: The EU's action plan*. In January 2007, the Council of Europe issued *Energy and Climate Change Package* which underlines energy efficiency as a priority. On January 23, 2008, the EU's energy and climate change package was announced and five legislative proposals were put forward which included the *EU Carbon Emission Trading Scheme Amending Directive*, *Carbon Capture and Storage Directive*, *Renewable Energy Directive* and so on so as to achieve the ambitious plan to cut its greenhouse gas emissions by 20% by 2020 based on the 1990's emissions.

2.2 Low Carbon Regulations in China

2.2.1 Total Carbon Emissions Control Policy

At the Copenhagen climate change conference held in 2009, China put forward the objective of reducing the carbon emission intensity by 40-45% in 2020 in comparison with that of 2005, which was the main objective for middle-term carbon emission reduction. The "Twelfth Five-Year Plan" stated that the CO_2 emissions per GDP unit in 2015 shall be reduced by 17% in comparison with that of 2010, and also specified that the greenhouse gas emission of CO_2 for non-energy activity, which includes methane, nitrous oxide, hydro fluorocarbon, perfluocarbon and sulfur hexafluoride shall be controlled. The "*Work Program on the Control of Greenhouse Gas Emission in the Twelfth Five Year Plan*" breaks down the target of CO_2 emission reduction per GDP unit of the nation to the provinces (see the table below). These definite overall amount control policies provide a reference for the cap setting of carbon trading, but meticulous consideration is needed with respect to how to convert intensity objective into emission cap setting.

Table 1 CO_2 Emission Reduction Index per GDP Unit in various regions in China in the "Twelfth Five Year Plan[1]"

Region	Reduction of CO_2 emission per GDP unit (%)	Reduction of energy consumption per GDP unit (%)

[1] Data source: *Work Program on the Control of Greenhouse Gas Emission in the Twelfth Five Year Plan* http://www.gov.cn/zwgk/2012-01/13/content_2043645.htm

Beijing	18	17
Tianjin	19	18
Hebei	18	17
Shanxi	17	16
Inner Mongolia	16	15
Liaoning	18	17
Jilin	17	16
Heilongjiang	16	16
Shanghai	19	18
Jiangsu	19	18
Zhejiang	19	18
Anhui	17	16
Fujian	17.5	16
Jiangxi	17	16
Shandong	18	17
Henan	17	16

Hubei	17	16
Hunan	17	16
Guangdong	19.5	18
Guangxi	16	15
Hainan	11	10
Chongqing	17	16
Sichuan	17.5	16
Guizhou	16	15
Yunnan	16.5	15
Xizang	10	10
Shaanxi	17	16
Gansu	16	15
Qinghai	10	10
Ningxia	16	15
Xinjiang	11	10

2.2.2 Market Policy for Greenhouse Gas Emission Reduction Projects

China's greenhouse gas emission reduction project markets include Clean

Development Mechanism (CDM) market and voluntary emission reduction market. The regulations for CDM market have been promulgated in 2005 and revised in 2011; the administrative measures for domestic offset market were passed in June of 2012.

When Kyoto Protocol became effective in 2005, the CDM was launched at the same time. To promote the healthy development of the CDM market, China started to implement the *Interim Regulation for the Operation and Management of Clean Development Mechanism Projects* on June 30, 2004. On October 12, 2005, the National Development and Reform Commission, the Ministry of Science and Technology, the Ministry of Foreign Affairs and the Ministry of Finance issued the *Regulation for the Operation and Management of Clean Development Mechanism Projects*, which defined the permit conditions, administrative organization, implementation procedure and emission reduction volume proportion distribution of CDM. On August 3, 2011, in order to enhance the development of CDM projects in China, the National Development and Reform Commission, the Ministry of Science and Technology, the Ministry of Foreign Affairs and the Ministry of Finance jointly issued the *Regulation for the Operation and Management of Clean Development Mechanism Projects (Revision) (FGWL 2011 No. 11)*. According to the revised measures, the CDM project cooperation shall facilitate the transfer of environment-friendly technology in promoting energy conservation, improving energy efficiency, developing and utilizing new energy and renewable energy and recycling methane. In comparison with the original measures, the state establishes the CDM project review executive council; it is led by the National Development and Reform Commission and the Ministry of Science and Technology, the deputy chief is the Ministry of Foreign Affairs, the members are the Ministry of Finance, the Ministry of Environmental Protection, the Ministry of Agriculture and the China Meteorological Administration, each having its explicit responsibilities. According to the regulation, the earnings of CDM project belong to both of the state and the project implementation agency. In the new regulation, proportion for distributing trade volume of CDM project between the state and the project implementation agency also changed. Among them, for the project of nitrous oxide (N_2O) produced from adipic acid, the project of nitrous oxide (N_2O) produced from nitric acid, and the project of perfluorocarbon (PFC), the state collects 30%, 10% and 5% trade volume of CERs respectively; for other projects, the state collects 2% of its trade volume. The collected funds are used to support relevant activities coping with climate change. In addition to the administrative measures of CDM, on June 13, 2012, the National Development and Reform Commission issued the *Interim Regulation for the Administration of Voluntary Greenhouse Gas Emission Reduction Trading*. This regulation defined the basic framework of China's project-based voluntary greenhouse gas emission reduction trading, specified the trading products and trading places of voluntary emission reduction, new methodology application procedure and the procedure of accreditation of the verification organization qualifications, and also solved the problem of lacking credit system in domestic voluntary emission reduction market. While regulating the domestic voluntary emission reduction trading market, these measures will also be helpful in promoting domestic carbon market, which is an important step for building China's carbon trading system.

2.2.3 Policies for Carbon Trading Pilot Scheme

On August 18, 2010, the National Development and Reform Commission in Beijing launched the program of low carbon provinces and low carbon cities. Five provinces including Guangdong, Liaoning, Hubei, Shaanxi and Yunnan, and eight cities including Tianjin, Chongqing, Shenzhen, Xiamen, Hangzhou, Nanchang, Guiyang and Baoding are determined to undertake this program. This is for the purpose of accelerating the establishment of low carbon industry system, advocating low carbon green lifestyle and consumption pattern, and exploring China's road for transformation to low carbon development.

On October 29, 2011, the General Office of the National Development and Reform

Commission issued the *Notice on the Implementation of the Pilot Work of Carbon Emission Right Trading (FGWBQH (2011) No. 2601)*, which approved four municipalities including Beijing, Tianjin, Shanghai and Chongqing and three provinces or cities including Hubei Province (Wuhan), Guangdong Province (Guangzhou) and Shenzhen to conduct pilot program of carbon emission trading. According to the staged implementation route put forward by the National Development and Reform Commission, pilot trading will start in 2013, rudimentary national carbon trading market will basically take shape in 2015 and comprehensive trading will be conducted during the "Thirteenth Five-Year Plan".

On March 28, 2012, the pilot work of carbon emission trading in Beijing was officially launched and Beijing became the first region starting this program. In the "*Implementation Plan for the Pilot Work of Carbon Emission Right Trading in Beijing(2012 －2015)*" submitted to the National Development and Reform Commission, the carbon trading program in Beijing covered enterprises (institutions) with an annual average emission of 10,000 tons(direct or indirect) during 2009 and 2011. 600 enterprises and institutions will be included in Beijing carbon emission trading enforcedly. They will be given total emission objectives, allocated with CO_2 emission allowances. Also, these covered organizations shall implement the market participant emission report system.

With respect to the pilot program of carbon emission trading in Beijing, The emitting enterprises (institutions) in Beijing are the trading subject; emission allowances and CCER arising from voluntary greenhouse gas emission reduction in China are the trading products. Most of emission allowances will be allocated freely, while others via auction. Non-mandatory market participants are encouraged to participate; trading is to be conducted in a market-oriented mode; the market management mechanism is to be improved and the market supervision service organization is to be established.

On July 31, 2012, Shanghai issued the *Opinions of Shanghai People's Government on* *the Implementation of the Pilot Work of Carbon Emission Trading*. According to the pilot plan of Shanghai, the subject matter of carbon trading in Shanghai is mainly CO_2 emission allowances. Besides, some project based greenhouse gas emission reduction certified by the state or Shanghai may be included in the trading system as supplements. Shanghai will initially distribute free carbon emission allowances to pilot enterprises. The objective of pilot work in Shanghai is to establish a carbon emission trading market with certain compatibility, openness and demonstrative effect, and try to advance other regions in the establishment of carbon trading market. The participants of carbon trading pilot work in Shanghai are the key enterprises with an annual CO_2 emissions above 20,000 tons in the industries of iron and steel, petrochemistry, chemistry, nonferrous metal, electric power, building material, textile, paper making, rubber and chemical fiber, as well as the key enterprises with an annual CO_2 emissions being above 10,000 tons in the non-industry sectors such as aviation, port, airport, railway, commerce, hotel and finance. According to statistics, there are about 200 enterprises participating in the pilot work in Shanghai. Their annual CO_2 emissions total about 110 million tons, accounting for nearly a half of the total emissions of the city. The trading of carbon emission allowances in Shanghai is conducted on the trading platform of Shanghai Environment Energy Exchange.

On August 28, 2012, the *Decision of the Standing Committee of the Shenzhen People's Congress on Strengthening the Management of Carbon Emission (draft)* was submitted to the Seventeenth Meeting of the Standing Committee of the Fourth Shenzhen People's Congress for review. The Standing Committee of the Shenzhen People's Congress authorized the municipal government in exploring carbon emission allowance distribution mechanism and trading mechanism, and strengthening the construction of carbon emission trade supporting system. According to the Decision (draft), key carbon emission enterprises and buildings in the administrative region of Shenzhen shall be included in carbon trading pilot. The entity subject to carbon emission control violating the Decision or emitting carbon in excess of its emission allowance will be penalized.

On September 11, 2012, the pilot work of carbon emission trading in Guangdong Province was also officially launched. The carbon trading pilot in Guangdong is characterized by three stages: the first stage(2013-2015) is the trial period, the second stage(2016-2020) is the perfecting period, and the third stage（beyond 2020）is the mature operating period. Participants of the pilot work of carbon trading in Guangdong are the key enterprises with an annual CO_2 emission above 20,000 tons in any year between 2012 and 2014 in the industries of power, cement, iron and steel, ceramics, textile, petrochemistry, nonferrous metal, plastics and paper making. As the statistic data shows, approximately 827 enterprises will be covered by the emission trading scheme, accounting for 42% of the energy consumption of the whole province. In addition, the transportation and building sector will also be covered at the end of "Twelfth Five-Year Plan". Notably, the forestry carbon sink is under consideration in Guangdong pilot, which will become part of the offset mechanism in Guangdong emission trading.

Tianjin promulgated carbon finance policies before the pilot work of carbon trading. In March, 2008, the State Council issued the *Reply on the Overall Program for the Associated Comprehensive Reform Test in Tianjin Binhai New Area (GH [2008] No. 26)*, which demanded that Tianjin Binhai New Area shall establish CDM and emission trading markets. In October, 2009, the Tianjin National Development and Reform Commission issued the *Special Program for the Financial Innovation in the Associated Comprehensive Reform Test in Tianjin Binhai New Area*, which demanded that Tianjin Binhai New Area shall build a national financial reform innovation base to provide experiences and demonstrations for China, and shall conduct the comprehensive pilot work of emission right trading properly. In August, 2011, the *Overall Program for the Development of the Tianjin Emission Right Trading Market (JGFF [2011] No. 86)* stated that the market building including carbon emission trading shall be strengthened, Tianjin Emission Right Exchange was designated as the trading platform and authorized to fulfill the management function for the emission trading market. At present, the administrative measures for the pilot work of carbon emission right trading in Tianjin is being formulated.

The pilot work of low carbon development and the pilot carbon trading are essential for China to establish a carbon finance market; in particular, during the pilot work of carbon trading, local carbon finance market will be directly and gradually established.

2.3. CHP and Nature Gas Regulations

2.3.1 CHP in US

In 1998, Combined Heat and Power Generation (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 US 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 US 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.

2.3.2 CHP in the EU

Cogeneration development is uneven in the European Union (see figure 1). Currently, the average share of cogeneration power production is 10.1 percent. The European Commission announced the strategic target of raising the average 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.

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.

2.3.3 Policy and Legislation of Cogeneration in China

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 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 China 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 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 Ministry 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.

2.3.4 Natural Gas in the “Twelfth Five-Year” Plan

China plans to add 3.5 trillion cubic meters of proved conventional natural gas reserves during the 2011-2015 period, according to a latest development plan. The plan, compiled by the National Development and Reform Commission and approved by the State Council, also said that explorable reserves will reach around 1.9 trillion cubic meters. By 2015, China aims to bring its natural gas supply capacity to around 176 billion cubic meters, making the energy reachable to 250 million people, or 18 percent of the population, according to the statement.

The development plan comes as China's appetite for natural gas has grown substantially with the industrialization and urbanization initiatives amid government's efforts to cut carbon emissions.

Currently, natural gas makes up only around 4.6 percent of the Chinese primary-energy consumption, much lower than the international average of 23.8 percent. This leaves room for exploration potentials as the geological reserves of China's conventional natural gas is estimated at 52 trillion cubic meters, according to the statement.

Regarding the development of shale gas, a variety of unconventional natural gas, China plans to prove 600 billion cubic meters of geological reserves by 2015, with explorable reserves at 200 billion, the statement said, setting the output target of 6.5 billion cubic meters by that time.

China also vows to "basically complete" the assessment on China's shale gas potentials during the 2011-2015 period and master the key exploration techniques.

Based on statistics from the signed futures contracts, China's annual gas imports would reach around 93.5 billion cubic meters by 2015.

Summary

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 CO_2, or 13.6% of the world total, second behind the USA. Many projects estimate that China will be the leading emitter of CO_2 in the next 15-20 years.

Compared with other economics, China's high-quality energy is too little in its energy mix. Increasing natural gas' share in the primary energy is the main approach to an optimized energy mix. It is more urgent for the economically developed coastal regions in China to optimize the energy mix, and natural gas is of unique importance to the economic development of these regions. Compared with coal-fired generation, gas-fired generation has obvious environmental advantages: SO_2 emission basically removed, CO_2 cut by nearly 1/3 and NO_x reduced by 95%.

China must vigorously develop its natural gas market. With ever greater pressure on energy supply, China's coal supply is constrained by production capacity, transportation, safety and environmental concerns, and the room for large-scale development of hydro, nuclear and renewable energy is limited. Besides, coal takes up nearly 70% in the energy consumption mix, wherein the share of high-quality energy is too small, resulting in huge environmental pressures. It is more urgent in the economically more developed coastal areas to optimize the energy mix and improve the environment. Natural gas, a high-quality, efficient and clean energy source and material for chemical industry, plays an important role in optimizing the energy mix, protecting the atmospheric environment, easing the strained petroleum supply, improving energy utilization rate, promoting modernization of industries and commerce, and realizing the sustainable development of the national economy.

3. The Natural Gas Cogeneration Technology

The greenhouse gas, such as carbon dioxide, methane and nitrous oxide, has a strong ability in absorbing long-wave radiation in sunlight, by which the temperature on the earth could be kept within a suitable range for life. This effect is called greenhouse effect which is a kind of natural phenomena.

Nevertheless, the concentrations of carbon dioxide, methane and nitrous oxide in global atmosphere have increased markedly as a result of human activities since 18th century. Now the number is far exceed pre-industrial values acquired by testing ice cores spanning over thousands of years. Consequently, The global average temperature has increase about 0.6 ℃ during last the century. The global warming has resulted in some influence to ecosystem, such as sea level rise, glacial recession, melting of permafrost, early florescence, etc. The extreme weather, such as El Nino, arid, flood, heat wave, avalanche, storm, etc., occurs much more frequently and strong. Anthropogenic emission of greenhouse gas has been deemed to be the reason for global warming. The increasing carbon dioxide concentration is mainly because of fossil fuel use and land-use change, while increases of methane and nitrous oxide are primarily due to agriculture.

Carbon dioxide is the most important anthropogenic greenhouse gas. Prior to the industrial revolution, the atmospheric concentration of carbon dioxide was 280 ppm, which has increased to 379 ppm in 2005. The number of 379 ppm exceeds by far the natural range over the last 650,000 years. The primary source of the increasing concentration of carbon dioxide in atmosphere results from fossil fuel use. The annual amount of carbon dioxide emission from fossil fuel has increased from an average of 23.5 $GtCO_2$ in the 1990s to 26.4 $GtCO_2$ in 2000 to 2005.

In developing countries, switch from fuel with high carbon intensity, such as coal, oil, to clean fuel, like natural gas, is an effective way of mitigating the increasing concentration of carbon dioxide. In addition, improving the energy utilization efficiency is another feasible way. The industrial demand for electricity and heat is normally fulfilled by separately power and heat plants combusting coal or oil, which is low efficient and emits large amount of carbon dioxide.

In this chapter, a higher-efficiency and cleaner technology, natural gas cogeneration is introduced and studied. Meanwhile the benefits to environment of this technology are assessed as well.

3.1 History and Development of cogeneration

3.1.1 History of cogeneration

In the late 1870s, generator driven by reciprocating steam engine emerged in residential areas in Europe, after which the exhausted steam was recovered and utilized for heat-supply. This generating system is the prototype of cogeneration. Early in 20th century, the cogeneration system didn't get much development due to the scale benefit of generating separately. After Second World War, district heating system was applied widely in Northern Europe, the Soviet Union and other socialist countries in Eastern Europe, which also promoted the development of cogeneration in those countries, while the abundant and cheap resource restricted the development of cogeneration in other European countries. The Oil Crisis in 1973/1974 and 1979/1980 taught the western countries a lesson that district heat and cool supply based on cogeneration should be paid more attention on.

3.1.2 Cogeneration in Europe

As the cradle of cogeneration, Europe made a lot effort for developing cogeneration technology. In 2004, the well-known CHP Directive, of which the full title is *Directive on the promotion of cogeneration based on a useful heat demand in the internal energy market and amending Directive 92/62/EEC*, entered into force. The

Directive is for promoting the use of cogeneration in order to increase the energy efficiency and improve the security of energy supply. This is intended to be achieved by creating a framework for the promotion and development of high efficiency cogeneration. As required by this Directive, the member states are obliged to report about their analysis of cogeneration in their own countries, to promote cogeneration and show what is been done, to report on and remove barriers, and to track progress of high-efficiency cogeneration within the energy market.

Organizations like COGEN who serve as an important information hub for the most recent updates with in Europe's energy policy have assisted the governments a lot in their development of cogeneration. COGEN is Europe's umbrella organization representing the interests of the cogeneration industry, users of the technology and promoting its benefits in the EU and the wider Europe. The association is supported by the key players in the industry including gas and electricity suppliers, ESCOs, equipment suppliers, consultancies, national promotion organizations, financial and other service companies.

As a whole, the share of electricity generated by cogeneration is more than 11% now. However, there is a large difference between member states with variations between 45% to almost zero. In recent years, the high gas prices, inconsistent energy policies and relatively low electricity prices have kept the competitiveness of gas-fired cogeneration plant marginal in many member states. Europe has the three countries with the world's most intensive cogeneration economies, which are Denmark, the Netherlands and Finland. The share of electricity generated by cogeneration of the three counties is more than 30%. Cogeneration is also a significant contributor to the heat supply in Europe, which supplies more than 15%.

3.1.3 Cogeneration in the United States

The world's first commercial power plant, Pearl Street Station, set up by Thomas Edison was a combined heat and power plant, producing both electricity and thermal energy while using waste heat to supply heat to neighboring buildings. The efficiency of Edison's plant could reach approximately 50% relying on the recycling. By the early 1900s, regulations promoting rural electrification emerged, by which construction of centralized plants managed by regional utilities was encouraged. Meanwhile, the decentralized power generation such as cogeneration was discouraged. The development of cogeneration in the US stopped until 1978. The Congress realized that the efficiency of central power plants had stagnated; therefore buying power from other energy producers was encouraged by the *Public Utility Regulatory Policies Act*, which is a strong incentive to the development of cogeneration.

In recent years, the cogeneration in the US developed rapidly. There is approximately 82 GW of cogeneration installed in the US, which is 12% of the overall generating capacity. The ambitious but achievable goal of the US Department of Energy for the year 2030 is 20% of the generating capacity is supplied by cogeneration plants.

3.1.4 Cogeneration in China

In 1950s, with the experience of the Soviet Union, a lot of attention was paid on deployment of cogeneration. The share of cogeneration in overall generating capacity was increased from 2% in 1952 to 17% in 1957, which was the second largest in the world after the Soviet Union. After 1970s, with the rapidly developed economy, the fast paced electricity generation capacity increases have significantly bolstered the development of cogeneration in China. Until 2010, the total installed capacity of cogeneration is up to 130 GW, which account for 18.2% of the thermal generation capacity. Be different from other countries in the world, the fuel of the cogeneration plant in China is dominantly coal, in contrast natural gas and renewable fuels are used in other countries.

3.2 Technical principle of the natural gas cogeneration

3.2.1 What is cogeneration

Cogeneration, which is also called combined heat and power system, is to simultaneously generate both electricity and heat by an integrated system. The system is established based on a concept of ‘gradient utilization of energy’. The high grade heat with high temperature is used for generating power, while the low grade heat is used for heat-supply.

In conventional thermal power plant, after driving the steam turbine to generate electricity, a certain amount of heat contained in the exhausted gas is emitted into the natural environment through cooling towers, flue gas, or other means, which leads to a limited thermal efficiency lower than 40%. In cogeneration system, the heat in the exhausted gas could be recovered and utilized to generate power and heat, and the thermal efficiency could be up to 90% ideally. This means less fuel is needed to be consumed to produce the same amount of useful energy.

Cogeneration systems range in size from tens of kilowatts for single buildings powered by biomass or fuel cells, up to hundreds of megawatts for large industrial or commercial facilities powered by natural gas.

There are two kinds of cycles of cogeneration. Topping cycle plants primarily generate electricity from a steam turbine. The exhausted steam is then condensed and the low temperature heat released from this condensation is utilized for e.g. district heating or water desalination. Bottoming cycle plants produce high temperature heat for industrial processes, and then a waste heat recovery boiler feeds a power plant. Bottoming cycle plants are only used when the industrial process requires very high temperatures such as furnaces for glass and metal manufacturing, so they are less common.

3.2.2 Steam turbine cogeneration plant

The steam turbine cogeneration system consists of boiler and steam turbine. The typical fuel is coal. Since the high temperature flue gas generated during coal combustion cannot work directly, the heat contained in it should be transmitted to steam by the boiler. After driving the steam turbine to generate electricity, the steam (back pressure steam or extracted steam) with high temperature and pressure transforms into low grade steam, which will be used for heat-supply. The thermodynamic cycle is the “Rankin cycle”. There are two kinds of steam turbine cogeneration systems: back pressure steam turbine and extraction condensing steam turbine.

In back pressure steam turbine system, the steam exiting the turbine, called back steam, will enter the heat-supply process. The schematic is showing in Figure . The back pressure steam turbine system can be simply configured without high capital cost. The need of cooling water during operating is low and the overall efficiency is quite high. But in the meanwhile, the turbine for generating is large and the electricity generating depends on the heat needed, which means it cannot meet different users’ electricity and heat demands at the same time by adjusting workload.

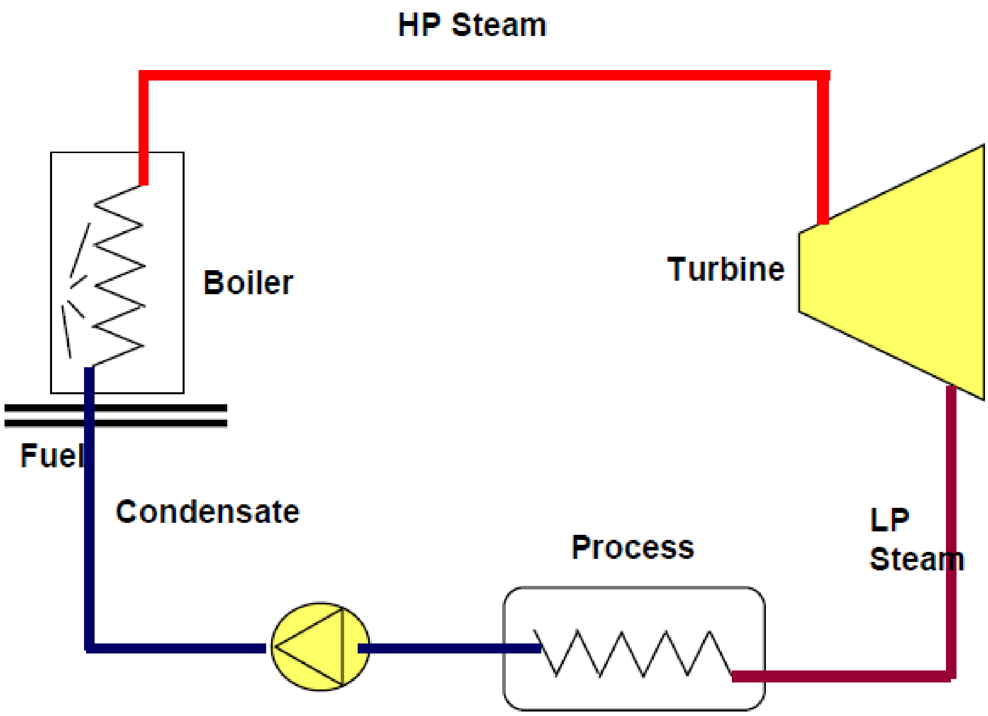

Figure 1 Back pressure steam turbine

In the extraction condensing steam turbine system, the steam for heat-supply is obtained by extraction from an intermediate stage of the steam turbine. Other remaining steam is exhausted. The schematic is shown in Figure 1. By means of extracting steam from intermediate stage, the generating workload and heat-supply workload can be controlled separately, but it also leads to a lower overall efficiency and a high capital cost.

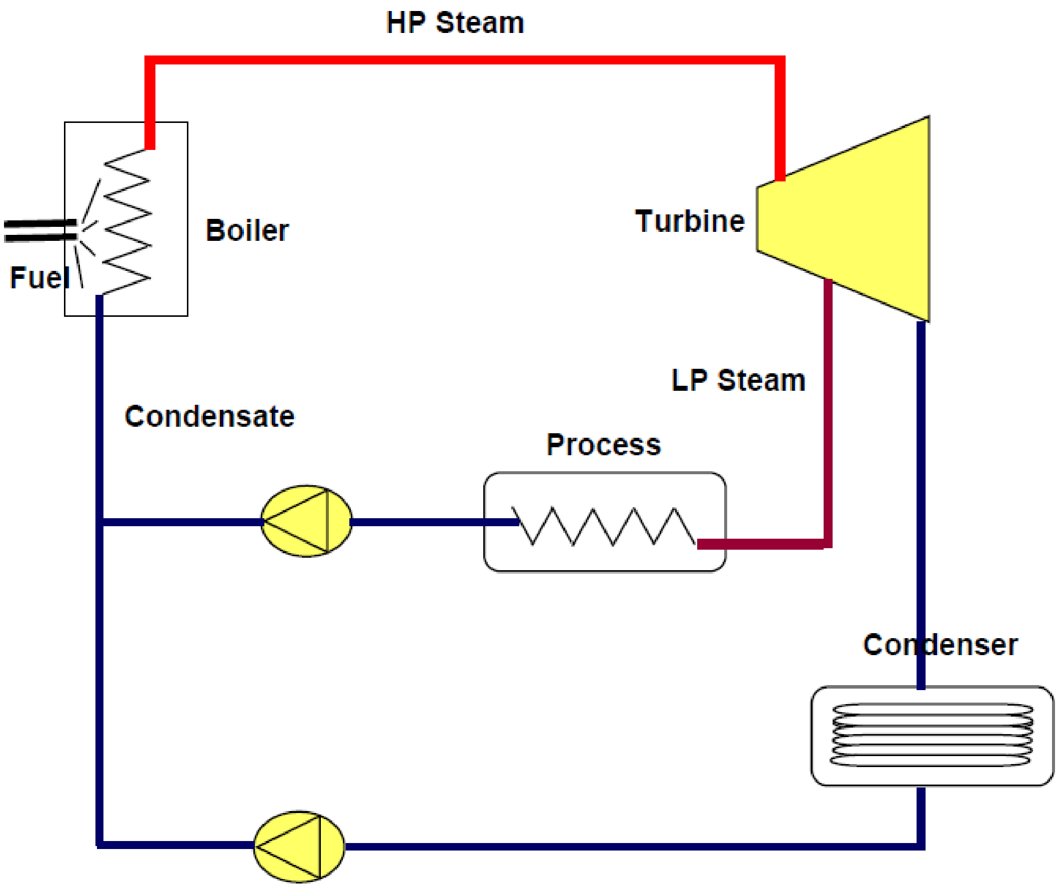

Figure 1 Extraction condensing steam turbine

Steam turbine cogeneration system is the oldest cogeneration system with capacities ranged from about 50 kW to hundreds of MWs. A large number of conventional thermal power plants have been transformed into this type, but due to the large emission of pollutants, new plants rarely employ this type of system.

3.2.3 Naturel gas cogeneration plant

Gas turbine plant

The gas turbine cogeneration system consists of compressor, combustor and heat recovery boiler. The typical fuel is natural gas or other gaseous fuel. The thermodynamic cycle is "Brayton cycle". There are two kinds of gas turbine cogeneration systems: single cycle and combined cycle.

In single cycle system, after compressed, the air and fuel gas enters the combustor. In the combustor, the combustion of the fuel increases the temperature of the gas stream to more than 1,000 ℃ and pressure to 1~1.6 MPa. The turbine is driven by the gas stream to generate electricity. The flue gas going out from the turbine with a temperature of 450℃~600℃, in which the heat contained is recovered by a heat recovery boiler for heat-supply. The schematic is shown in Figure 2. The efficiency of gas turbine can be higher than 30%, relatively the overall efficiency can be higher than 80%.

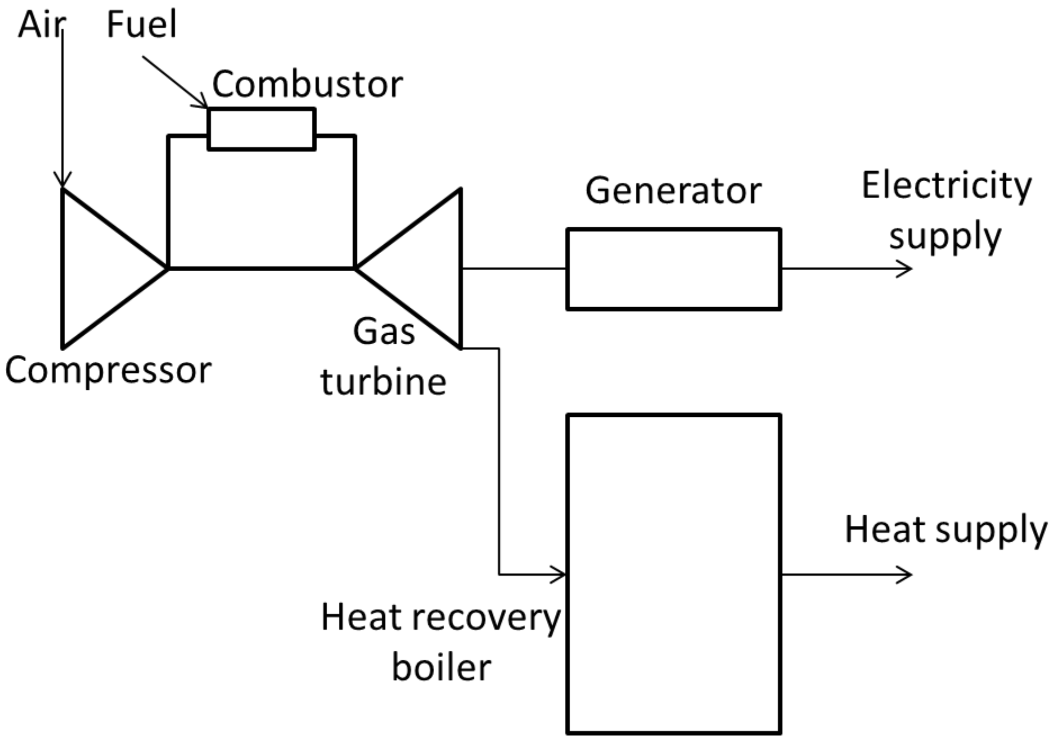

Figure 2 Gas turbine system with single cycle

In combined cycle system, a steam turbine is added after the heat recovery boiler to generate electricity since the heat recovery boiler can generate steam with high temperature. See schematic in Figure 3. The generating efficiency of combined-cycle system can reach 50%. In addition, the steam turbine installed after heat recovery boiler could be either back pressure steam turbine or extraction steam turbine.

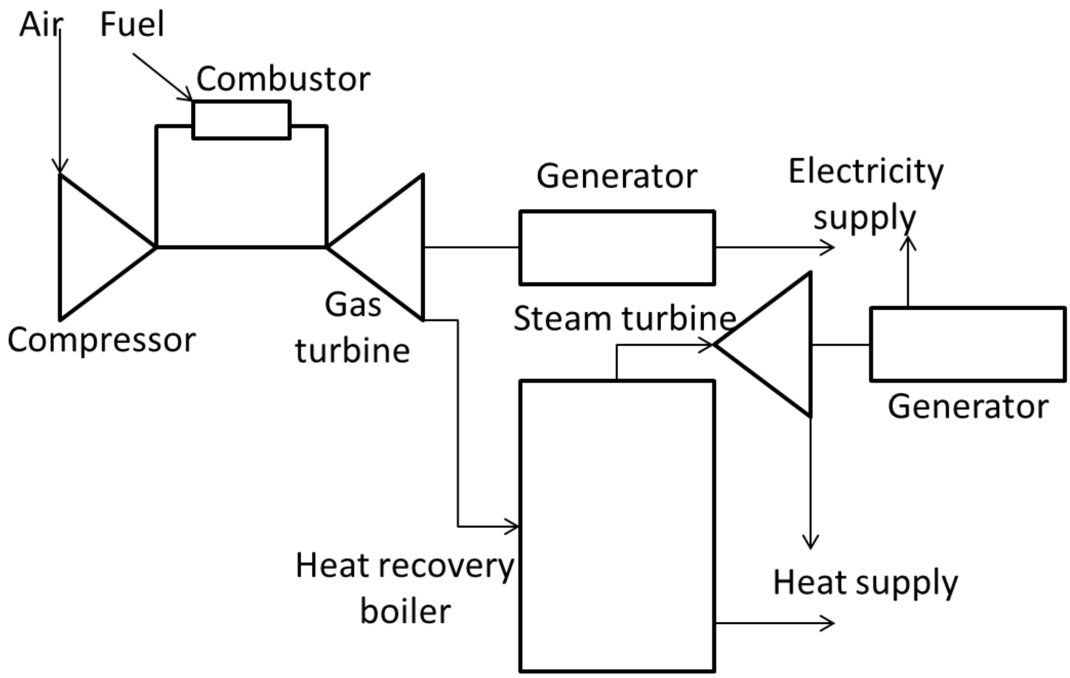

Figure 3 Gas turbine system with combined cycle

Gas turbine system is suitable for the workload that changing rapidly since it's flexible to start and stop. Natural gas is the most common fuel, other gaseous fuel such as oil refinery gas or oven gas. The installed capacity range varies from about 1 MW to hundreds of MWs. With help of rapidly gained technology progress, this type of system has become more economic and environment friendly. The producers of gas turbine include GE, ALSTOM, SIEMENS, SOLAR, ABB, etc.

Gas engine plant

A reciprocating gas engine can be more efficient than a gas turbine when the capacity is lower than 5 MW, so this type of plant is usually employed for small-scale plants. However, due to the heat released by cylinder and lubricating oil does not have high temperature and this heat account for a large amount, this type of plant cannot supply high grade heat. The manufacturers of gas engine include WARTSILA NSD, MANB&W, CATERPILLAR, etc.

3.2.4 Other types of cogeneration

Biofuel engine plant

Similar with gas engine plant, an adapted reciprocating gas engine or diesel engine is used depending upon which biofuel is being used. Another variant is the wood gasified cogeneration plant whereby a wood pellet or wood chip biofuel is gasified in a zero oxygen high temperature environment; the resulting gas is then used to drive the gas engine. The advantage of using a biofuel is one of reduced hydrocarbon fuel consumption and thus reduced carbon emissions.

Fuel cell

Molten-carbonate fuel cells and solid oxide fuel cells are to covert chemical energy into electrical energy. They have a hot exhaust and are suitable for heating. Fuel cell has the advantages of no pollution, high efficiency, widely application, no noise and ability of working continuously. The efficiency of generation is more than 40%, the overall efficiency can be more than 80%. At present, most of the fuel cells are still under development and very expensive. In view of the unique advantages of fuel cell, along with the promotion of this technology, fuel cell will play an important role in cogeneration.

3.3 Greenhouse gas emission reduction by natural gas cogeneration

3.3.1 Natural gas VS Coal and Oil

Natural gas is usually regarded as the cleanest fossil fuel. Composed mainly of methane, the primary products of the combustion of natural gas are carbon dioxide and water vapor, which are the same as the exhale of animals. Coal and oil are composed of much more complex molecules, with a higher carbon ratio and higher nitrogen and sulfur contents. This means when combusted, coal and oil release higher levels of harmful emissions, including a higher ration of carbon dioxide, nitrogen oxide (NO_x), and sulfur dioxide (SO_2). Coal and oil also release ash particles into the environment, substances that do not burn but instead are carried into the atmosphere and contribute to pollution. The combustion of natural gas, on the other hand, releases very small amounts of sulfur dioxide and nitrogen oxides, virtually no ash or particulate matter, and lower levels of carbon dioxide, carbon monoxide, and other reactive hydrocarbons. The comparisons between natural gas and coal and oil according to US Environment Protection Agency's data are shown in Table .

Table 2 Fossil Fuel Emission Levels- Pounds per Billion Btu of Energy Input

Pollutant	Natural gas	Coal	Oil
Carbon Dioxide	117,000	208000	164,000
Carbon Monoxide	40	208	33
Nitrogen Oxides	92	457	448
Sulfur Dioxide	1	2,591	1,122
Particulates	7	2,744	84
Mercury	0.000	0.016	0.007
Source: EIA - Natural Gas Issues and Trends 1998			

3.3.2 Emission reduction by cogeneration

The cogeneration technology achieved reasonable gradient utilization of energy from high grade to low grade, which leads to a high efficiency. According to the different capacity and configuration, the overall efficiency could reach 70% to 90%, which is closed to the thermal efficiency of boiler, while the boiler can only supply heat. Figure 4 shows the energy flow charts of a combined cycle cogeneration system with a capacity of 50 MW and a relative separately generation system. The efficiency is analyzed based on the energy delivered to users. Apparently, to deliver the same amounts of electricity and heat, the primary energy consumed by separately generation is 57.53% more than cogeneration. Therefore cogeneration can supply same service with less fuel consumed i.e. less greenhouse gas emission.

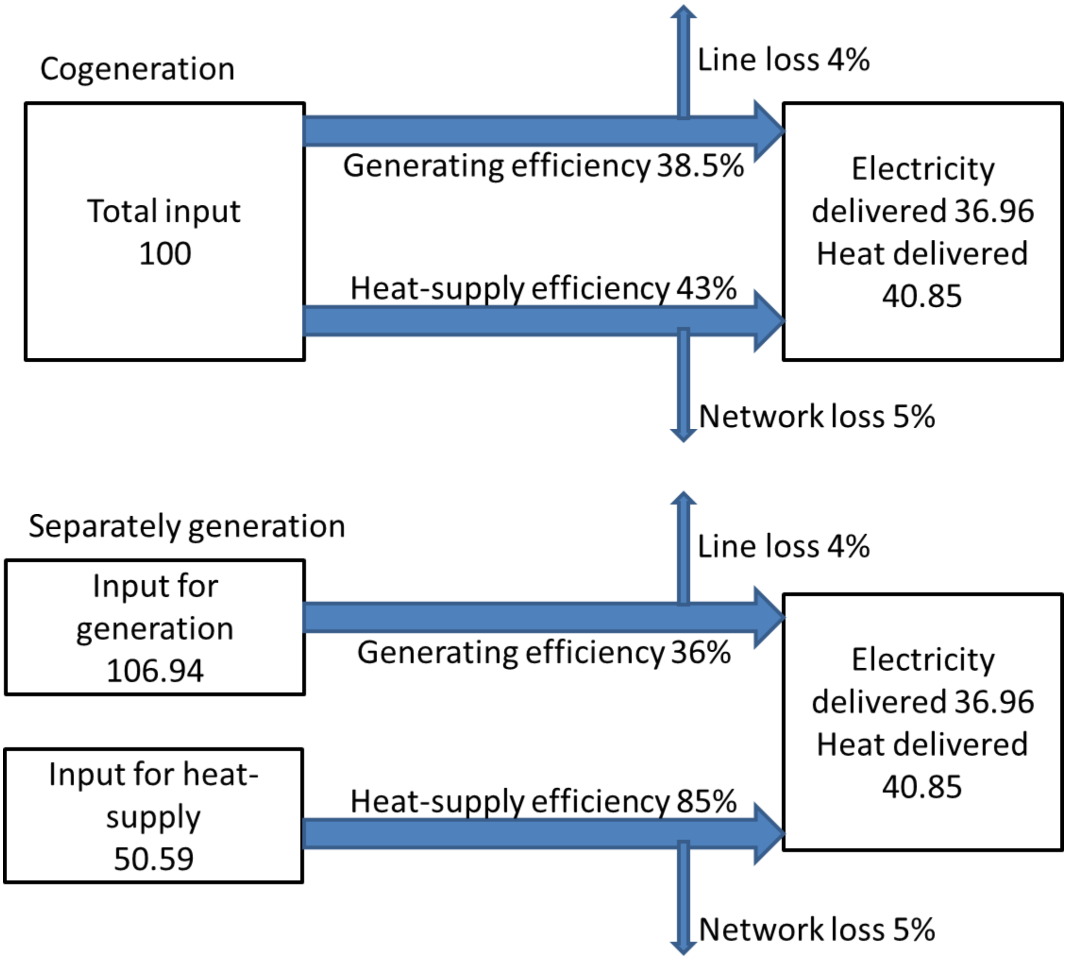

Figure 4 Comparison between cogeneration and separately generation

With the rapid technical progress, gas turbine with low emission level deployed widely. At present the concentration of NO_x in exhausted gas could be controlled at about 33~51 mg/m^3. Furthermore new types with lower emission are under development.

Summary

Facing the serious fact that the earth is getting warmer, people started to think about how to mitigate the increasing concentration of greenhouse gas in atmosphere. Cogeneration as a technology with a high efficiency can result in emission reduction when delivering the same amount of electricity and heat by conventional plants. Furthermore, by employing the clean fuel natural gas and the low emission gas turbine, the cogeneration system can reduce emission even more. Decentralized cogeneration plants with smaller installed capacity will be the trend in future, since the onsite plants lead to lower transmission loss.

In western countries, cogeneration has achieved great development and large share in overall generation capacity. Meanwhile cogeneration helped those countries get much greenhouse gas emission reduction. China started to deploy cogeneration at an early time and got a certain achievement, but there is still a long way to go, as most of cogeneration plants are still coal-fired with a poor efficiency. Switching fuel from coal to clean fuel and developing cogeneration system with high efficiency are the top priority topics for China.

4. The Barrier Research Report on Gas-fired Cogeneration Technology in China

4.1 The Development of Cogeneration in China

4.1.1 The Status of Cogeneration in China

Energy savings and environmental concerns of district heating systems have remarkable influence on the development of society and national economies. China is now undergoing a stage of extensive urbanization and industrialization. The annual rate of new construction for residential buildings is approximately 2000 million square meters, which accounts for about 40% of worldwide residential construction. As a consequence, heating areas in China have boomed dramatically in recent years, particularly in the urban areas within the national twelve Five-Year Plan period (2011–2015). An objective of 15% primary energy savings on the basis of unit floor area in the district heating sector has been set during this Five-Year period.

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.

The energy efficiency of large-scaled central coal-fired power plant in China is only 30-40 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.[2]

---

[2] Zhi-Gao Sun. Energy efficiency and economic feasibility analysis of cogeneration system driven by gas engine,[J] Energy and Buildings 40 (2008) 126–130.

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 China. 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[3] .

4.1.2 The Current Implementation Status of Gas-fired Cogeneration Technology in China

Cogeneration with gas-based internal combustion 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.

Gas-fired power plants were traditionally used in offshore oil drilling platforms, or as peak load power plants. But recent years have seen a strong trend towards gas-fired

[3] Data source: Evaluation of cogeneration market in China

power plants as a main electricity and heat resource. Going forward, given rising coal prices versus the increasing availability of natural gas, equipment such as gas turbines and heat recovery steam generators (HRSG) are expected to grow at a much faster rate.

Table 3 Low estimation of thermal efficiencies of gas-fired boilers in China.[4]

Capacity of gas-fired boiler (MW)	0.7	1.4	2.8	7	14	24.5
Thermal efficiency (%)	83	85	86	88	90	92

In 2011, gas-fired power plant capacity reached 33 GW: a growth of 24% from 2010. By 2015, the installed capacity of gas-fired power plants is expected to reach 60 GW, implying a compound annual growth rate of about 20%. GCiS forecasts a total spend of CNY 60 billion on gas turbine and HRSG equipment for cogeneration between 2011 and 2015.

By 2011, China had economically recoverable natural gas reserves of 3.8 trillion m^3 (and an additional 25 trillion m^3 in recoverable shale gas), ranking third in the world. Several long-distance pipelines were completed between 2010 and 2011 as overall construction peaked with plants, pipelines and supply stations coming online at the same time.

Gas turbine orders have shown significant growth in 2011 and this trend is likely to accelerate over the forecast period. Apart from gas supplies from inland China, expanding offshore gas drilling and import liquefied natural gas will also increase gas supply. Gas-fired power plant construction will continue in China's east and south

4 Hai-Chao Wang ,etc. Techno-economic analysis of a coal-fired CHP based combined heating system with gas-fired boilers for peak load compensation. [J]. Energy Policy39(2011)7950–7962.

coastal provinces, which have huge electricity demand.

District heating is also expected to drive considerable growth in gas-fired equipment demand. As of 2010, district heating with CHP supplied more than a third of all construction in northern cities and towns, the rest being heat-only boiler stations fuelled by coal or natural gas. To reduce energy waste and pollution from coal-fired localized boilers and to improve energy efficiency, cities including Beijing, Tianjin and Taiyuan have planned to restrict new heating plants to gas-fired technology. As shown in currently released plans, new heating plants in these areas have all adopted gas-fired cogeneration.

4.2 The Barriers for Implementing Gas-fired Cogeneration Technology in China

Current thinking in China is that it is necessary to develop gas-based CHP for environmental, social and long-term economic and security reasons. The development of gas-based CHP in China 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-fired cogeneration has been conducted. 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. The main factors that influence the economy of the cogeneration are natural gas price and electricity price

4.2.1 The Price of Natural Gas

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. the price of natural gas is three or four times that of coal.

Natural gas prices are under government control and will continue to be. The price of gas from the West to the East is still undecided The price of the coal for the existing boilers was set at the actual value in the area while that of the natural gas for the CHP system was assumed to be 4.30－5.26 $/GJ (18－22 $/Gcal), according to a reliable prospect that the natural-gas price will fall by some 30% from the present level of 6.21 $/GJ (26 $/Gcal) in the near future.

The average guiding price of gas from the West to the East is 1.38 CNY/m^3 in 2008. 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 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 CNY/m^3 with gateway price plus the cost of municipal pipe-net infrastructure investment and operation.

At present, the price of natural gas in China is higher than that in international market. The using of natural gas is being enlarged and its price will reduce with the increasing of natural gas consumption in future in China. More and more natural gas are used for electricity production. However, coal is used as the main fuel of power plant.

4.2.2 Electricity Tariff

The combined heating system can produce electricity itself, but this power usually cannot be directly harnessed to drive any kind of electrical equipment of the heating network, due to the separation between energy and the heating management sector in China. Instead, power is transmitted to the electric power grid. Therefore, the electricity used for heat production and distribution should be purchased from local industrial electricity commodities. The electrical equipment of a combined heating system mainly consists of water pumps for various purposes and accessories, such as ventilation, dust catching, fuel supplying and automatic controlling equipment.

The average electricity tariff for coal-fired power generation that is sold to the grid is 0.31CNY/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 CNY/kWh, while the tariff of one coal-fired CHP plant with district heating in an industrial developing zone reaches 0.622 CNY/kWh.

The electricity generated by gas-based power plant will increase in the twelve 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.

The other cost issues about electricity tariff is to increase the levy for SO_2 emissions. The levy for SO_2 emissions is currently 0.2 CNY/kg and will increase considerably in the future. Although the amount of increase is not yet known, considering that the cost of desulphurization is 3 CNY/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.

From the above analysis, we can conclude that there is a small possibility of a decrease in the electricity tariff in the 12th Five-Year Plan period. If electricity price increases, the cogeneration system driven by gas engine will be more profitable. While the current power price is not competitive for gas-fired cogenenration.

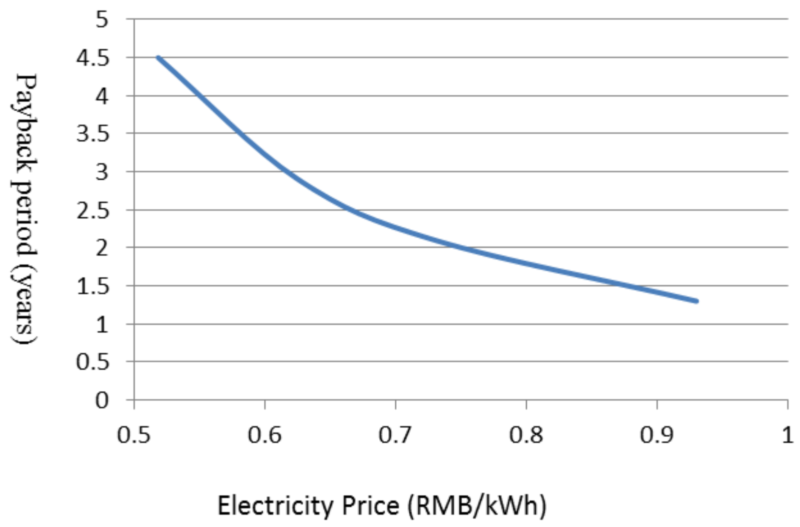

Figure 6 The effect of power price on payback period of cogeneration[5]

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

Take the CHP of 50MW in Shanghai for example.[6]

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.

[5] Data source :Energy efficiency and economic feasibility analysis of cogeneration system driven by gas engine

[6] Data source: Research on cogeneration policy in Shanghai

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 CNY/m^3
Electricity tariff sold to the grid:	0.43CNY/kWh
Heat price:	190CNY/ton
Gas consumption:	216.28million m^3
Benefit from power sold:	263.13 million CNY
Benefit from heat sold:	168.15 million CNY
Pay for natural gas purchase:	302.79 million CNY

Total investment of unit:	465 million CNY
Investment of heat network:	25 million CNY
Labor:	40 people
Wage and welfare/per person:	50 thousand CNY
Wage and welfare:	2 million CNY
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 CNY
Annual depreciation:	20.93 million CNY
Operation and maintenance fees:	9.30 million CNY
Value-added tax (heat):	3.82 million CNY
Value-added tax (electricity):	8.38 million CNY
Value-added tax:	12.20 million CNY
Additional tax:	1.22 million CNY
Income tax:	6.35 million CNY
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 CNY/Nm^3. The average power tariff – the price which power plants can sell electricity to the grid is 0.31CNY/kWh. The steam price is 40—130 CNY/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 CNY/Nm^3 for cogeneration and sell the electricity at 0.43 CNY/kWh to the grid would be difficult; also, a heat cost of 190 CNY/ton would be a hardship for consumers.

Summary

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 higher than that of coal-fired cogeneration system.

Because "wheeling" or direct supply is not available, 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.

However, maybe some measures could be taken to improve the competitiveness of large-scale electrical output-based cogeneration. The price of natural gas, power tariffs, and steam sales price are all critically important factors that influence the competitiveness of gas-based CHP. It is true that the natural gas price will be kept high for some time to come, and the factor of power tariffs is no change in the short time.

According to analysis of above, we can take carbon emissions trading system into account, because cogeneration as a technology with a high efficiency can result in emission reduction when delivering the same amount of electricity and heat by conventional plants. We can promote the development of cogeneration through the carbon market in the short time. Before we use this technology to participate in the carbon market, we need a methodology to quantify GHG emission reductions of the gas-fired cogeneration technology.

Reference

1. Wang Yao., Liu Qian, Carbon Finance Market: Globe Situation, Future Prospects and China's Stratagy [J], Studies of International Finance, 2010, Vol 09: 64-70.
2. Liu yang, Research on the market of chinese carbon finance in the context of low carbon eonomy [D], 2011, JiangSu University.
3. Wang Yao, 2010, Carbon financial: a global field of vision and China layout, China Economic Publishing House.
4. International emissions trading association, Greenhouse Gas Market 2012: New Markets, New Mechanisms, New Opportunities.
5. The China sustainable energy program, 2003, Research on Cogeneration Policy in Shanghai.
6. The China sustainable energy program, 2003, Market Assessment of Cogeneration in China.
7. The China sustainable energy program, 2006, Policy Study: Gas-fired Power Generation in China (Synthesis Report)
8. IPCC, 2007: Summary for Policymakers. In: Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change [Solomon, S., D. Qin, M. Manning, Z. Chen, M. Marquis, K.B. Averyt, M.Tignor and H.L. Miller (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.
9. ACEEE, 2010: Policy Brief. In: Combined Heat and Power and Clean Distributed Energy Policies [Anna Chittum, Neal Elliott]. Washington, D.C., USA.
10. H.I. Onovwiona, V.I. Ugursal, Residential cogeneration systems: review of the current technology, Renewable and Sustainable Energy Reviews, Volume 10, Issue 5, October 2006, Pages 389-431.

11. C.D Moné, D.S Chau, P.E Phelan, Economic feasibility of combined heat and power and absorption refrigeration with commercially available gas turbines, Energy Conversion and Management, Volume 42, Issue 13, September 2001, Pages 1559-1573.

12. J.L. Silveira, C.E. Tuna, Thermoeconomic analysis method for optimization of combined heat and power systems. Part I, Progress in Energy and Combustion Science, Volume 29, Issue 6, 2003, Pages 479-485.

13. X. Zhang, The application of natural gas and energy saving and emission reduction, Journal of Hebei University of Engineering (Social Science Edition), Volume 27, Issue 01, March 2010, Pages 31-32.

14. Zhi-Gao Sun. Energy efficiency and economic feasibility analysis of cogeneration system driven by gas engine,[J] Energy and Buildings 40 (2008) 126–130.

15. Hai-Chao Wang ,etc. Techno-economic analysis of a coal-fired CHP based combined heating system with gas-fired boilers for peak load compensation. [J]. Energy Policy39(2011)7950–7962.

16. Marbe, A.,Harbvery,S.,Berntsson,T.,2006.Technical, environmental and economic analysis of co-firing of gasified biofuel in a natural gas combined cycle combined heat and power plant.Energy31(10),1614–1619.

17. Research on cogeneration policy in Shanghai, the China sustainable energy program.

18. Market assessment of cogeneration in China, China energy conservation investment corporation energy resources international, Inc.