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China's Thermal Electricity Production and Relative Carbon Dioxide Emissions for the period 2012-2020

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During the last decade much more coal in China has been used for electricity generation in order to drive the economic growth. However, under the pressure of China's deteriorating natural environment, more alternative new technologies for thermal electricity generation are introducing to increase efficiency of power output and reducing the air pollution and carbon dioxide emissions, such as Natural Gas Combined Cycle (NGCC) and Integrated Gasification Combined Cycle (IGCC). At present time, insurance of energy security supply by diversification of types of fuel and energy resources and accelerated development of efficient technologies for generation have become a precondition for sustainable development of many countries' economies. This study will focus on the issues on China's NGCC and IGCC generation sectors, with the objective to provide a detailed outlook of impacts by these new technologies on China's traditional coal-based power structure and environmental situation by 2020.

1. Introduction

The previous years knew many works on the CO_2 capture as well on the fundamental aspect (Cadours and Bouallou, 1998) as on the experimental aspect (Cadours et al., 1987). These works make it possible to consider the CO_2 capture in power plants (Descamps et al., 2005; Amann et al., 2007). Today, many reports in China have shown Chinese NGCC and Clean coal generation will have opportunities to grow fast. An installed capacity with 250 MW, the latest IGCC power plant will began to run in Tianjin in this year, and it is just beginning of GreenGen project. The next step, we will have the Carbon Capture System (CCS) with capture capacity of CO_2 at 3 MT annually very soon. 44 billions of US dollars in 2009 and 33.3 billion dollars in 2010 are invested in building or converting the generation plants in China, and nearly half of these investments are gone into the thermal generation type, such as conversion the small-scale coal-fired power plants, construction NGCC and IGCC, and so on.
According to the CNPC reports, China's natural gas consumption increased from 24.5 bcm to 88.7 bcm, with annual growth rate of 15.4 % from 2000 to 2010. The current construction of natural gas pipelines achieves the large progress. By the end of 2009, about 38,000 km gas pipelines have been built with total transmission capacity of nearly 90 bcm per year. LNG also has been developed and the import volume has exceeded 900 MT in 2010. The share of city residential gas and gas for generation will have increased significantly. In the future, gas consumption for power generation will accelerate by 2015, with its share in national total consumption up to 21 % (2 % in 2009). The total estimated amount of China's natural gas consumption for generation sector will be 63 bcm in 2020 from 22 bcm recorded in 2010 (Duan, 2010)

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China is also the world's leading renewable energy producer, with an installed capacity of 152 GW. Total hydro-electric output in 2009 was 615.64 TWh, constituting 16.6% of all electricity generated. China's total wind power capacity reached 2.67 GW in 2006, 12.2 GW by 2008, and it will be over 20 GW by 2020. In 2006, China had 9 nuclear power units with a total electric capacity of 6.99 GW and total output of 54.8 TWh, accounting for 1.9 % country's total electricity produced. Total nuclear electricity output respectively will be more than 70 GW by 2020 (Bradsher, 2009)
All these facts can tell us, China has contributed a lot for limiting air pollution and CO_2 emissions, as well as keeping the security power supply in order to meet the national GDP growth. In this study, we will attempt to collect all recorded data and evaluate together to have a hypothesis of China's electricity situation by 2020 and forecast the new result of CO_2 emissions.

2. Reference Data Collection

The referenced data in this study is begun from 2009. The structure of China's power industry is seemly expected to remain unchanged for a long time. Coal-fired power output amounts to at least 78% of the national total output. Some experts estimated that China's coal-fired power generation will be in a stage of stable development until 2020, and installed capacity will remain at more than 70 %.
Economic growth rate is estimated to keep average level at 7 %, so we can briefly infer the total annual electricity produced increasing rate is at the same level, but I supposed from 2016, the electricity produced rate will reduced to 6 %, because more efficient utilities will be used and this is an optimistic estimate. The total annual investment also will follow the increasing rate of GDP at 7 %, and still keep to invest nearly 50 % to the traditional coal-fired, NGCC and IGCC power sectors.
The real data for 2009 and some professional growth rate forecasts show the total thermal electricity produced: 2,750 TWh (Coal-fired 2,695 TWh and NGCC at 2%=55 TWh) and that the average thermal plants' working hours are 4,000 hours. The nuclear power plants present installed capacity of 7 GW and output is 54.8 TWh, and average running is 7,840 hours (annual growth rate at 25%). For hydro-power plants, total output is 615.6 TWh and wind power plants' output is 25 TWh with capacity of 12.2 GW, and average running is 2050 h (annual growth rate at 5.5 % for reaching capacity of more than 20 GW by 2020). For 2010, the total investment is 33.3 billion USD, 50 % is for the traditional coal-fired power plant, IGCC and NGCC and average efficiency of NGCC is 43 %. The total natural gas consumption of NGCC is 22 bcm (Energy conversion parameter is 10.83 kWh/m^3). We supposed for calculation: China's NGCC capital price is 510 USD/kw; China's IGCC capital price is 1,000 USD/kW (optimistic estimate, real today's price is 1,400 - 1,700 US$/kW); NGCC efficiency after 2015 will be 53 %; IGCC and NGCC operating hours will be increased to 5,000 hours after 2015 and the annual consumption of natural gas for NGCC is according to the forecast by CNPC (e.g. 22 bcm in 2010, 49 bcm in 2015 and 63 bcm in 2020).

3. Evaluation Methods

For evaluation methods, we calculate every total electricity produced amount in each year by using increased rate 7 %, and 6 % after 2015. According to the annual consumption of natural gas for NGCC, we calculate the annual output of NGCC, and additional amount of output will be calculated to get the result of annual investment on NGCC; we use 50 % of total investment in each year less the investment on NGCC to get the result of annual investment on IGCC or conversion the traditional coal-fired plant into IGCC. Hydro-power will still remain at 701 TWh, because many reports have indicated China as a country of water shortage and in this decade China will make more efforts to develop nuclear power plant and hydro-power will remain very small growth rate. Nuclear power will be at 25 % annual growth rate by 2020 and wind power will remain at 1.05 % annual growth rate by 2020.

4. Forecast Result

At first, investment proportion and quantity will decide the growth trend of each type of electricity output capacity. As we supposed previously, if China remain the total investment level at 33.3 billion in USD keeping increase rate at 7 % annually, which is according to the GDP growth rate's estimate by government? Another hypothesis with investment is the China's government will still give half of total

investment on the traditional coal-fired, NGCC and IGCC sectors and another half investment goes to the nuclear, hydro-power and wind power plants. Next step, we will exam whether the half investment can be enough to convert the old coal-fired plants or to develop new NGCC and IGCC plants' construction.

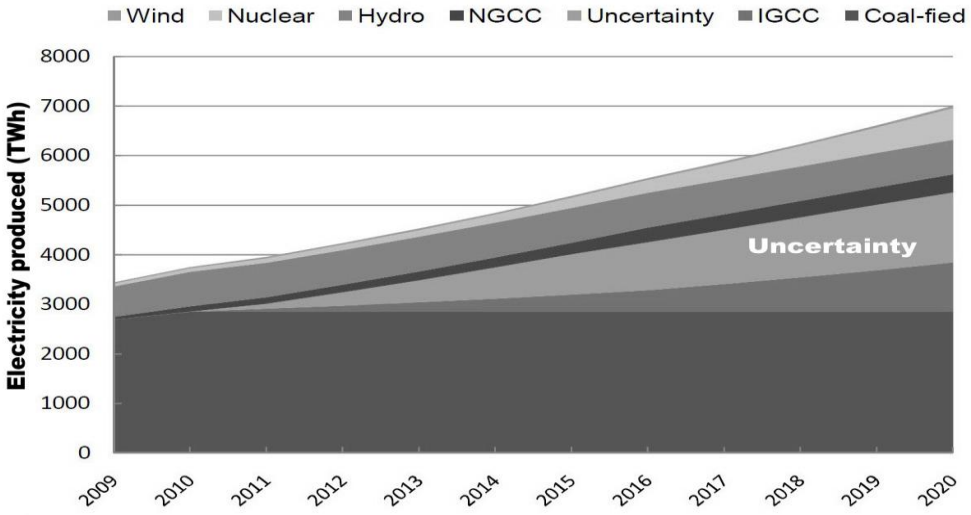

Figure 1: The Forecast of China's Electricity Produced by Types

By using the forecast on the annual consumption on natural gas generation plants from CNPC (China National Petroleum Corporation), we can translate it into annual electricity output by NGCC and the growth of NGCC installed capacity, then we continue to make this growth into the new capital investment on NGCC. Besides this annual investment on NGCC, we imagine all the left investment could cost for building the new IGCC plants to meet the growth of economic growth with more energy requirement. If any left capital after paying on NGCC and IGCC, we can use this left investment to convert some old coal-fired plants into the new ones, but the result is negative that we have never gained the left money to do so. Oppositely, we have the result of a large gap of an uncertain electricity output, which means there are no thermal plants to fill this gap from 2010 to 2020 and this uncertainty is increasing significantly. In 2020, the gap will become 1,417.3 TWh that is nearly equal to the half of total thermal plants' output in 2010. (Figure1).

Secondly, one question is coming that how much investment can be added to recover this gap. We supposed to make the additional investment on NGCC because of four reasons. Firstly, the price of NGCC is quite lower than the others (Average price:
NGCC 510 $/kW, Coal-fired with Filter system 620 $/kW, IGCC 1,400-1,700 $/kW); secondly NGCC efficiency is high (In China, Today is 43 % - 53 %, Future ≥ 60 %); thirdly NGCC is permitted to develop in China's economic growth zones, where are consuming the most energy in China today and finally low CO_2 emissions in NGCC without using CCS.
The calculation result has the positive and negative on both sides (Figure 2). The positive result of the investment analysis is after 2016, the investment is still keeping increasing at 6 % to 8 %, which can be fitted for the estimate of GDP growth rate. After 2016, since we supposed NGCC's efficiency increases from 43 % to 53 % and running hours from 4,000 h to 5,000 h, the result becomes better and better and the investment begins to be less and less and decrease rate is about at 5 %. So, it means by increasing the efficiency enhancing using NGCC to generate power can help to use less investment to cover that increasing gap of uncertain power demand.

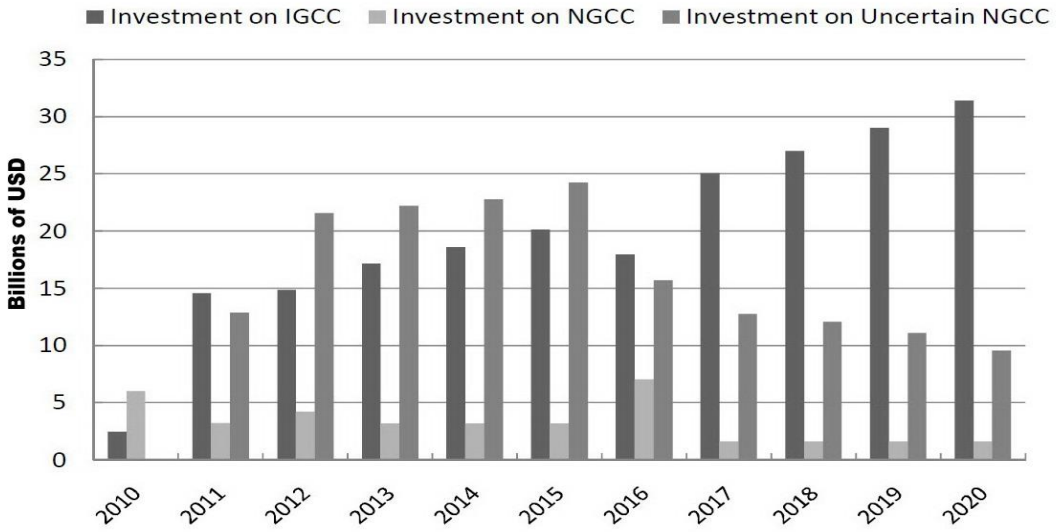

Figure 2: Investment Forecast in China's NGCC and IGCC Generation Sectors

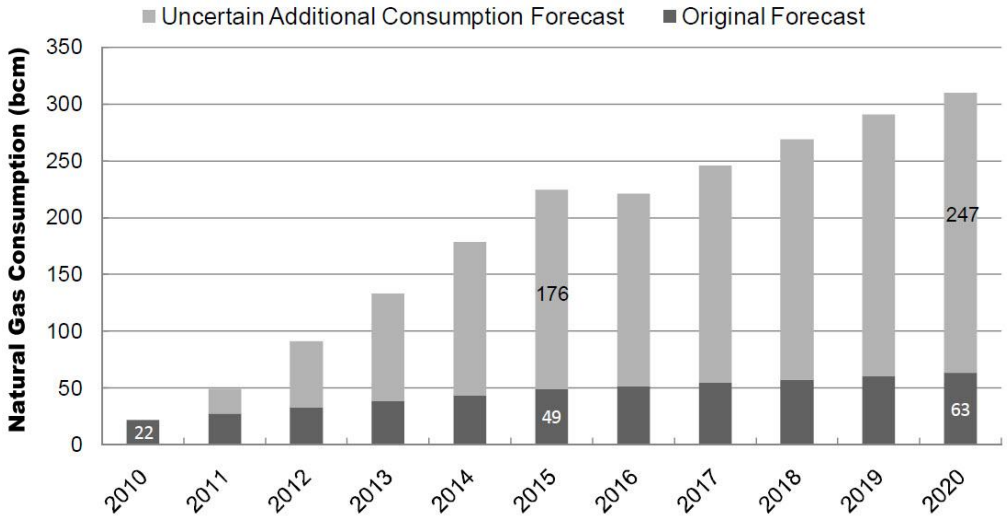

Figure 3: China's Natural Gas Consumption Forecast on NGCC plus Uncertainty

The negative result is that the total investment on thermal generation sector is still too high and increasing demand of natural gas for new NGCC will be impossible to realize (Figure 3)
If our hypothesis were realized, the total demand on NGCC in 2015 would be 224.6 bcm, which is nearly equal to the total high growth scenario reference forecasted by CNPC (242.4 bcm) (Duan, 2010). In 2020, 309.1 bcm on NGCC with our hypothesis compared to the total demand of 317.5 bcm estimated by CNPC has become the impossible mission for China's natural gas market's growth rate, because it means all the consumption volume of natural gas will contribute for China's NGCC's demands only. Another negative result comes from CO_2 emissions expectation analysis. Let's suppose China could enlarge the national rapid growth of demand of natural gas in the next decade to fulfill the requirements of the amount showing in Figure 3 (225 bcm in 2015 and 310 bcm in 2020), which is showing in Figure 4.

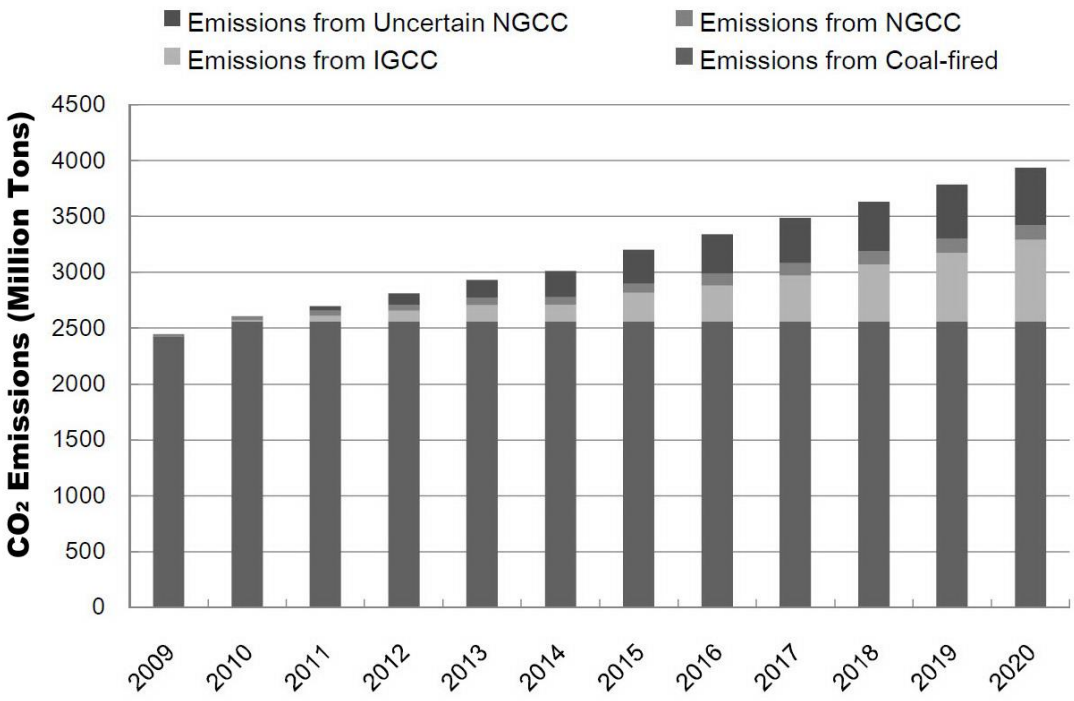

Figure 4: CO_2 Emissions Forecast in Natural Gas and Coal-based Generation Sectors

This result is kind of optimistic analysis to say the future power generation plants' development could rely on NGCC not coal-based plants. Some experts have pointed out China's emissions are projected to grow by 6.5 % per annum and to total about $5.8 \cdot 10^9$ t by 2030 (Sheehan and Sun, 2006), but the result of Figure 4 is much worse than that and it will come five years earlier by 2025.

In fact, for helping our environment's reason, we should improve the IGCC power plants and convert the old coal-fired power plants at the same time by using large China's coal reserve, but the annual investment for new IGCC will be much higher than NGCC and China has to increase the capital cost on thermal power plants. Could this thinking become true? We will use another research result from the side of coal consumption not from natural gas to evaluate it again.

According to EIA (U.S. Energy Information Administration) forecast in 2009, China's total coal consumption approximately will be 70 Quadrillion Btu in 2015, which is about 20,500 TWh (1Quadrillion Btu=293,083,000,000 kWh). Current research is showing that the coal-based power plant can use 40 % of total coal consumption for generation (reported by China Chemical Industry Publication 2009), and this rate is keeping increase right now, then we suppose the raising rate is 6 %-7 % (according to GDP growth rate). The result in 2015 with coal-based consumption is about 56 %. We also set the average coal-fired electricity output rate is 38 %, so the electricity output will be 4,362.4 TWh deduced by EIA's result, which is very close to our forecast's result of 3,665.3 TWh (coal-fired output plus uncertain output). That is why we can predict the most possibility of recovering the future uncertain electricity will be using by increasing traditional coal-fired power plants in China, and will be neither NGCC nor IGCC.

5. Conclusion

Under the current investment scale on China's power industry, the coal-based electricity generation will remain unchanged for a long time, and investment on coal-fired power plants will still rank first. China's

electricity output will be boosted by accelerated process of industrialization and urbanization, and projected to have an average annual growth rate of 6 % to 7 % in the next ten years. It is also possible that this study may be underestimating the current rate of growth in CO_2 emissions of China. For helping the global environment and national economic growth, China's power industry will require a great deal of investment. But, how to make this large and limited investment match the economic growth and environmental protection has become a big question for us? "Efficiency" can be one of answers, increasing power generation efficiency is the key to reduce the investment on average new installed capacity, as well as increasing industrial power consumption efficiency will help to increase enhancing productivity within the limited power supply. In fact, how to use our resource is much more important than how much we can use with our resource.

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