Energy and Environment Research; Vol. 2, No. 1; 2012
ISSN 1927-0569 E-ISSN 1927-0577
Published by Canadian Center of Science and Education

Analysis on the Potential of Greenhouse Gas Emission Reduction in Henan's Electricity Sector

Zhang Shaohui[1,2], Wang Shanshan[1,2] & Zhang Ruiqin[1,2]

[1] Institute of Environmental Sciences, Zhengzhou University, Zhengzhou, China

[2] The College of Chemistry and Molecular Engineering, Zhengzhou University, Zhengzhou, China

Correspondence: Zhang Ruiqin, Institute of Environmental Sciences & The College of Chemistry and Molecular Engineering, Zhengzhou University, Zhengzhou 450001, China. Tel: 86-371-6778-1163. E-mail: rqzhang@zzu.edu.cn

Received: December 21, 2011 Accepted: January 6, 2012 Online Published: May 22, 2012

doi:10.5539/eer.v2n1p195 URL: http://dx.doi.org/10.5539/eer.v2n1p195

Abstract

Henan Province, located in the middle of China, is the typical case for a power system predominantly on fossil fuel and electricity sector, which is also the main emission source in Henan Province. In order to evaluate the potential for greenhouse gas (GHG) emission reduction of the electricity sector in Henan Province , this article analyses different development scenarios based on the "Long-range Energy Alternative Planning System" (LEAP) model to simulate diversification development patterns. Results showed that there is a potential reduction in GHG emission in the Henan's electricity sector. The government should design and implement different emphasis in different terms. For instance, we founded that the greenhouse gas emission are decreased considerably in technology priority scenario (8.7 $MtCO_2$) and energy structure optimization scenario (30.30 $MtCO_2$)compared with baseline scenario before 2020, in terms of emission intensity per power unit, during 2005-2020, technology priority scenario, energy structure optimization scenario, and baseline scenario descend by 16.1%, 19.1%, 14.2%, respectively. Ultimately, it gives some policy advice to the power industry in Henan province, the advanced generated technologies will be employed to reduce the greenhouse gas emissions greatly before 2015; however, renewable energy and energy structure adjustment will play the dominant role in reducing the greenhouse gas emissions in the long term. It is also suggested to develop carbon tax and "Clean Development Mechanism" (CDM) projects in Henan Province, such as renewable CDM projects, Methane recovery CDM projects, waste heat/gas/pressure recovery CDM projects, to contribute to the reduction of greenhouse gas emission in Henan's electricity sector.

Keywords: electricity sector, greenhouse gas emission, energy model, scenario analysis

1. Introduction

According to the International Energy Agency (IEA) (IEA, 2004), the electricity sector is the main source for GHG emission in China and it accounts for 50% of the nation's greenhouse gas emissions. Notoriously, Henan Province is rich in coal resources and is one of the important thermal power bases in China.

There has been a lot of research on GHG emission reduction in the electricity sector, which mainly focused on the emission mitigation potential and some relative economic evaluation and influencing factors analysis etc. (Shrestha et al., 1996; Nag & Parikl, 2005; Steenholf, 2007; Zhang et al., 2007; Gnansounou et al., 2004). For example, WenjiaCai evaluated three scenarios using the LEAP model to demonstrate that annual reduction potential of CO_2 emissions of China's electricity sector from 2000 to 2030 was 85Mtto 350Mt (WenjiaCai et al., 2007). Wetzelaeret reported that the mitigation potential for China's electricity sector would be 615 $MtCO_2$ in 2010 and 38% of this potential could be realized through the most cost-effectiveness mitigation measures (Wetzelaeret et al., 2007). Kroeze adopted RAINS Integrated Assessment Model (RAINS-IAM) to analyze business-as-usual (BAU) scenario plus three best practice technology (BPT) scenarios for emission mitigation of greenhouse gas from electricity production in China and India up to the year 2020, founded that all three BPT scenarios have a potential to reduce emissions to about half the 2020 BAU level (Kroeze et al., 2004). Steenhof used decomposition analysis method to show that electricity demand, efficiency of generation, and sources of energy were the three main influencing factors (Steenhof et al., 2007). Phananiramai used the Selective catalytic reduction (SCR) technology to reduced harmful emissions based on The SCR management Tool, which can help to plan decrease NOx emission (Phananiramai et al., 2011). Qiang pointed that the effective energy policy was the key to reduce GHG emissions in the electricity sector (Qiang & Yong, 2010). Xu showed that energy efficiency and energy structure were the main influencing factors (Xu & Jiang, 2006). WeiYiming indicated that coal consumption, generation of energy structure and emission were the main influencing factors of GHG emission reduction in China's electricity sector (Wei et al., 2008).

This study focuses on the emission reduction analysis in Henan's electricity sector. Mitigation potential research has been extensively investigated to analysis the China's electricity sector (WenjiaCai et al., 2010; Wetzelaer et al., 2007). However, there is no specific mitigation potential analysis of province-level. The reason to choose Henan Province as the research objective can be stated in two aspects. On the one hand, Henan Province is the typical case for a power system predominantly on fossil fuel, where there is a large population and is extremely rich in coal resource. In other words, Henan Province is China in miniature. On the other hand, in China, thermal power is the dominant form of power generation whereas Henan Province is the important thermal power base of China. With the thermal capacity improving, the greenhouse gas emission is increasing dramatically. Therefore, it is necessary to research the mitigation potential of Henan's electricity sector.

2. Henan's Electricity Sector Status

Henan, as a populous province, has more and more power demand with the steady and high-speed development of its economy, which then leads to the higher and higher energy consumption and greenhouse gas emissions. Figure 1 provides a historic context for understanding the trends during the middle and long term (NBS, 2000-2009). While the change in power generating capacity has been positive during 1978-2008, increase of 200.77 MW, 272.24 MW, and 117.14 MW during 2006, 2007, 2008, respectively. Therefore, it is significant to research on the emission-reducing potential of power industry in Henan Province.

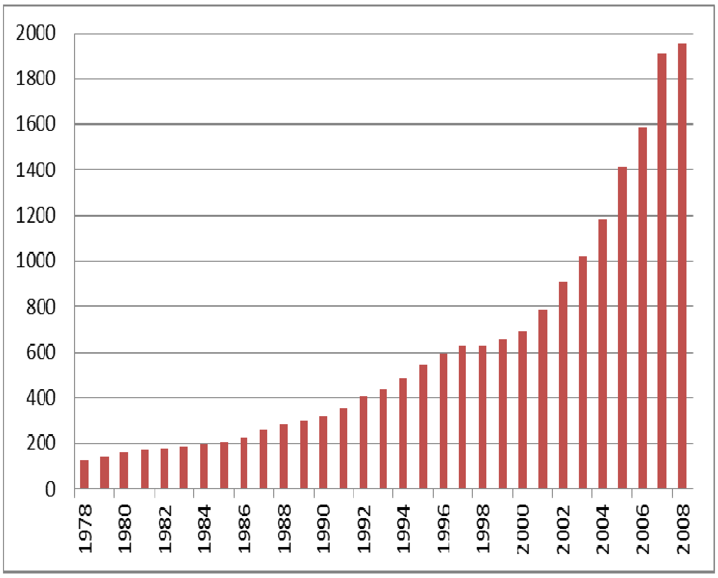

Figure 1. Recent trends in power generating capacity in Henan, 1978-2008

2.1 Analysis of Power Generation Structure

Henan province is currently dominated by thermal power generation, hydro and renewable power generation subsidiary. In 2008, the total installed electricity capacity reached 45.58 MkW; thermal installed electricity capacity reached 42.51 MkW, annual thermal-electric power generation capacity reached 188.3 billion kWh, nearly 93.3% of the total installed electricity capacity and 95.8% of the total power capacity generation, separately (Figure 2); hydro installed electricity capacity reached 2.94 MkW, annual hydro-electric power generation capacity reached 7.8 billion kWh; new energy installed electricity capacity reached 0.13 MkW, annual new energy-electric power generation reached 0.41 billion kWh.

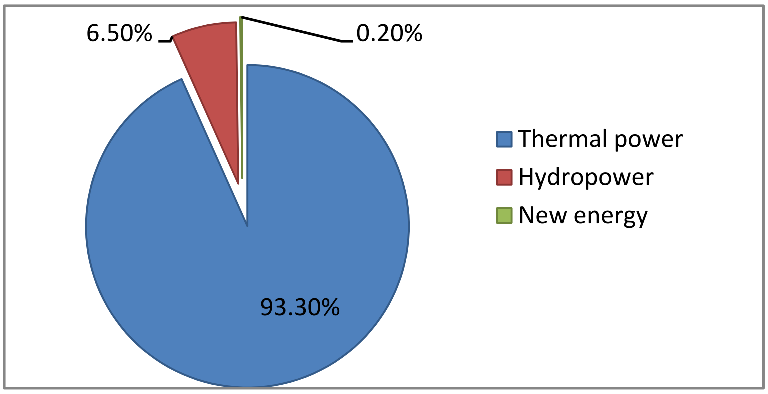

Figure 2. The capacity structure of Henan Province in the year 2008

Henan has abundant coal resources and reserves are relatively stable, which is the typical case for analysis the power system with fossil fuel, inter alia, dominated by coal resource. In 2007, output of coal in Henan Province reached 189 Mtce (million tons of coal equivalent), which is the third largest coal production province in China. Meanwhile, the convenient transportation provides advantageous conditions for building a thermal power base of China. However, there is great pressure for the sustainable production of coal. For example, the coal resources geology exploration efficiency is not high, the existing reserves only accounts for 2.4% of China, and the reserve-production ratio is lower than national average.

Henan produces a little oil and nature gas as its own energy accounting for 67% and 53%, respectively. Owing to the limitation of the resource endowment, the yield of the oil and nature gas reduces sharply, thus the contradiction of supply and demand is becoming more and more obvious. The central government implements west-east gas transmitting project and Sichuan gas transmitting Henan project to solve problems above.

In 2008, Henan renewable installed electricity capacity reached 2.78 MkW which accounted for around 6.3% of total installed electricity capacity, especially, non-hydro and hydro installed electricity capacity come up to 0.1935 MkW and 2.58MkW, respectively. The xiaolangdi and sanmenxia hydropower station installed electricity capacity achieved 1.94 MkW and 0.41 MkW, respectively. In addition, there were the others small hydro power developed 746 places whose installed electricity capacity reached 0.237 MkW. Nevertheless, the hydro-electric was facing to exhaust due to the limitation of the water endowment.

Wind power is the most mature way for a new energy power generation which has advanced technology, appropriate scale, and well commercial development. Although Henan belongs to weak wind area, it has three rich wind resource zones. Currently, Henan has built sanmenxia wind power station and fangcheng wind power plant, therefore, there has a large number of wind resource in an undeveloped state. Provincial government has established an ambitious target of wind power generation 0.2 MkW which promotes sanmenxia, nanyang, and xinyang wind power station to be speedily built.

Biomass power generation is an extraordinary part of power generation to curb levels of greenhouse gas emissions. Henan has a large number of biomass resources such as straw, corn, bush, and forest stock. In 2005, national government implemented 'Renewable Resources Law of the People's Republic of China' to accelerate the development of renewable industry, therewith, provincial government has also approved 19 biomass projects which total installed electricity generation reached 0.4 MkW in 2008, As a result, biomass power generation in Henan will become more and more prominent in power industry during 11th Five Year Plan (FYP) or more years.

Solar photovoltaic power generation is now accepted as one of the clean energy sources which have already obtained development in recent years. The solar radiation in Henan is between 4600~5000 MJ/m^2 which is the second adequate radiation province in China.

2.2 Analysis of Power Generation Efficiency

There are many indicators to evaluate power generating efficiency status (Yao et al., 2010), which mainly includes coal consumption of power generation, coal consumption of power supply, coal consumption of heat supply, heat efficiency, and comprehensive power thermal efficiency et al. In this article, we analyzed two indicators which were coal consumption of power supply and comprehensive power thermal efficiency respectively. Table 1 provides coal consumption of power supply and a historic context for understanding the trends from 2002 to 2008 in Henan province. In 2008, the coal consumption of power supply reached 343.50 grams of coal equivalent/kWh (gce/kWh), which was less than that of China (349gce/kWh).

Table 1. Coal consumption of power supply in Henan, 2002-2008

year	coal consumption of power supply (gce/kWh)
2002	408
2003	409
2004	411
2005	390.19
2006	377.19
2007	360.73
2008	343.50

Comprehensive thermal efficiency of power generation is calculated specifically for heat equivalent of power generation and heat consumption of power generation which principle calculation is described by formulate (1):

$$Comprehensive\ thermal\ efficiency(\%) = \frac{power\ generation(kWh) * 3600\left(\frac{kJ}{kWh}\right) * 100\%}{coal\ \ consumption\ of\ power\ generation(kg) * 29308\left(\frac{kJ}{kgh}\right)} \quad (1)$$

Table 2 displays average comprehensive power thermal efficiency and average GHGs emission efficiency in China's power industrial, 2000. It can be observed that the power efficiency of hydro (70%) is higher than that of any other fuels with coal (40%), natural gas (50%), and oil (47%). Whereas the GHGs emission efficiency of coal (1.11 kg CO_2/kWh) is higher than that of any other fuels such as natural gas (0.47 kg CO_2/kW) and oil (0.71 kg CO_2/kW).

Table 2. Average comprehensive power thermal efficiency and average GHGs emission efficiency in China's power industrial, 2000

Fuel	Average comprehensive power thermal efficiency %	Average GHGs emission efficiency kg CO_2/kWh
Coal	35-45	1.11
Nature gas	40-58	0.47
Oil	45-50	0.71
Hydro	60-80	
Nuclear	25-35	
Wind	10-20	
Other renewable	5-15	

2.3 Analysis of Electricity Sector Policy Status

National and provincial energy conservation and GHGs mitigation policies have always regarded as a major factor in macro effect for Henan's electricity, inter alia, GHGs emission target. Thus, it is necessary to evaluate energy conservation and GHGs mitigation policies. The central and provincial government from unit scale, coal consumption of power generation, hydro consumption, auxiliary power rate, power transmission losses rate, SO_2 emissions, and differential power prices, promulgate and implement a series of policies to vigorously develop electricity sector.

In 2007, National Development and Reform Commission (hereafter named NDRC) promulgated and implemented the 11th FYP energy development plan, setting the targets for power industry during the 11th FYP, all these indicators such as thermal power generation reduce 15 gce/kWh, auxiliary power rate decrease 1.4%, the rate of waste water attain 100% (NDRC, 2007), soot and SO_2 emissions drop to 1.2g and 2.7g, respectively. Shortly after, the provincial government also proposed some targets in the Henan's 11th FYP energy development plan. These targets are following: total installed power generation surpass 45 MkW, the proportion of single unit more than 0.3 MkW reach 55%, and the average coal consumption of thermal power supply below 370 gce/kWh.

Chinese government has promulgated the Renewable Energy Law in 2005. The exploration and utilization of renewable resource as a priority to R&D of relevant technologies in high-tech industries and has brings into national science and technology development plan and high-tech industrial plan. It has earmarked special funds to support R&D of relevant technologies, pilot project, decrease cost production, and improve the quality of production.

In 2007, China's state council announced a comprehensive working plan to accelerate the closing of small thermal power generation (state council, 2007). The policy determined whether the outdated capacity that main includes single unit installed electricity capacity of thermal power 50MW or below, coal consumption of power supply more than the average level of 10% in this province (area, city) or national level of 15%, and phasing out coal-fired plants on the basis of relevant laws et al. It has determined to build more efficient power system (the proportion of single unit installed electricity capacity of thermal power 300 MW, 0.6 MkW and 1 MkW achieved 80%, 70%, and 60%, respectively) replaced inefficient plants. The target of the small thermal power generation closures reached 5 0000 MW. During this time, Henan's government has published and implemented the medium and long term special plan for energy conservation to response central government request. In addition, it has promulgated a series of relevant policies (such as optimal dispatching of generation and generation rights trading) to accelerate the closures of small thermal power generation. To be on track, the amount of capacity closures reached 60060 MW, resulting in savings 69 Mtce and 139 $MtCO_2$ in China (NDRC, 2009). From 2006 through 2009, the cumulative closures were 3140 MW, 14380 MW, 16690 MW, and 26170 MW, respectively. The closures of Henan's power industrial reached 24 MW, 1543 MW, and 2406.25 MW during 2006, 2007, and 2008, respectively (NDRC,2009). Overall, it appears that this program exceed their target.

3. Overview of LEAP-Henan Model

Long-range Energy Alternative Planning System (LEAP), a comprehensive energy-environment analysis tool, is a bottom-up model, providing a platform for structuring data, developing energy balances, projecting demand and supply scenarios, to estimate associated emissions and evaluating alternative policies (Yophy et al., 2010; Jianyi et al., 2010). Ernst Worrell, Tobias Fleiter, and Koopmans provided an excellent discussion of the advantages and limitations of bottom-up models (Ernst et al., 2004; Tobias et al., 2011; Koopmans et al., 2001). In this study, we combine the LEAP model with Henan's electricity sector to successfully construct the "LEAP-Henan Model". In the model, the time span of the analysis was 2009-2020, including the "12th FYP and 13th FYP". The calculation of energy consumption & GHG emissions were emulated by the method of JianyiLin (Jianyi et al., 2010). The historical data, from 2005 to 2008 used in trend forecasting, were derived from the survey cooperated with Henan Provincial Development and Reform Commission. The year 2009 is set as the baseline year due to data constraints. The greenhouse gas emission factors were taken from the "IPCC Guidelines for National Greenhouse Gas Inventories". The greenhouse gas emissions of Henan's electricity sector under each scenario could be attained through setting the generation proportion of specific fuel type, linked with the energy intensity and emission factor. The mitigation potential of Henan's electricity sector can be achieved through comparing the emissions under three scenarios.

The power demand was assumed to be same in all scenarios and was predicted independently from LEAP-Henan model. It could avoid the uncertainty in power generation prediction. In order to demonstrate the future greenhouse gas mitigation potential, this study employs three scenarios to simulate the different development paths in the electricity sector: the baseline scenario, the technology priority scenario and energy structure optimization scenario. These scenarios are primarily driven by three factors: power demand, generating efficiency and power energy structure. Lastly, it gives a projection on electricity sector emission through scenario comparison and the mitigation potential could be acquired.

3.1 Power Demand

According to the economic development plan and historical development trends of Henan Province from 2000 to 2020, the power demand is predicted based on the trend analysis of economic development of central and provincial levels. The average annual growth rate of Henan's power demand was 8.9% from 1978 to 2008 and it was 13.4% from 2000 to 2008. The growth rate of Henan's power demand was below 10% in 2008 as a result of the global financial crisis. Based on the state macro-control, the average annual growth rate of Henan's power demand keeps 10% from 2009 to 2020 which is predicted through simulation of growth trend. The power demand from 2010 to 2020 is shown as following, refer to Table 3.

Table 3. Henan's power demand prediction

	2005	2008	2010	2015	2020
Power demand (10000 kWh)	13818115	19719754	23000000	43200000	60000000
Average annual rate			8.02%	13.4%	6.8%

3.2 Scenario Structure and Assumptions

3.2.1 Baseline Scenario Analysis

Baseline scenario is the most conservative scenario, which assumes that the past trends continue in the future and national macro-control for energy saving and emission reduction will be taken in to consideration.

In LEAP model, there are two factors – process efficiency and maximum availability which are related with generating efficiency. Table 4 provides process efficiency and maximum availability data for 2005 through 2020. The process efficiency is the percentage ratio of energy outputs to feedstock energy inputs in each process. We use 100% efficiency for hydropower and renewable electricity generation systems. The maximum availability of a process is the ratio of the maximum energy produced to what would have been produced if the process ran at full capacity for a given period (expressed as a percentage). The process efficiency in baseline scenario is in line with the fact of Henan province and it is the lowest comparing with the other scenarios. The process efficiency of new built coal-fired power units is 50% and that of existing coal-fired power units is 30%.

Table 4. Generating efficiency setting in the baseline scenario

Type	Baseline scenario	
	Process efficiency	Maximum availability
New built coal-fired power units	50%	85%
Existing coal-fired power units	30%	60%
Natural gas	28%	80%
Wind power	80%	70%
Hydropower	100%	70%
Nuclear power	100%	50%
Biomass power	80%	80%
Solar power	100%	30%

In the baseline scenario, it remains the tendency until the year 2009, which does not take new plans into consideration. Table 5 shows the result of the power energy structure up to 2005 and forecast figures from 2009 to 2020. To the year 2020, the coal-fired power generation percent will be 86.35% and the hydropower percent will be 6.05%.

Table 5. Power energy structure in baseline scenario

	2005	2010	2015	2020
Coal-fired power units				
Existing small scale	0.460	0.243	0.0848	0.0555
New built large scale	0.451	0.651	0.838	0.808
Natural gas	0	0.0297	0.0271	0.0258
Hydropower	0.0882	0.0717	0.0452	0.0605
Nuclear power				0.0413
Other renewable energy	0	0.00428	0.00463	0.00868
Wind power		0.00143	0.00116	0.00165
Biomass		0.00285	0.00289	0.00619
Solar			0.000579	0.000826

3.2.2 Technology Priority Scenario

In the technology priority scenario, the advanced generating technologies are the key development target. Installed capacities of current power plants have been enlarged and small-scale equipment's have been phased out of the market. The technology level is high than in baseline scenario.

Table 6 provides a detailed data in the technology priority scenario. With the rapid development of society, advanced generation technologies have been widely introduced, such as integrated gasification combined cycle (IGCC) and Natural gas combined cycle (NGCC).

Table 6. Generating efficiency setting in the technology priority scenario

Type	Technology priority scenario	
	Process efficiency	Maximum availability
New built coal-fired power units	51%	85%
Existing coal-fired power units	30.5%	60%
Natural gas	28%	80%
Wind power	80%	70%
Hydropower	100%	70%
Nuclear power	100%	50%
Biomass power	80%	80%
Solar power	100%	30%

In order to compare the mitigation potential brought by advanced technologies, the power energy structure in technology priority scenario is assumed the same to that in baseline scenario.

3.2.3 Energy Structure Optimization Scenario

In the energy structure optimization scenario, the power energy structure adjustment will be put in the first place. The clean energy and renewable energy power plants such as hydropower, nuclear, wind and solar will have a larger generation ratio.

To compare the mitigation potential brought by energy structure optimization, the generating efficiency in energy structure optimization scenario is assumed the same to that in baseline scenario.

The proportion of renewable energy in power energy structure will be improved greatly (see table 7). The hydropower in Henan province is limited and has been nearly exploited to the maximum. Henan is rich in biomass energy and possesses unique advantage to develop biomass power projects. The objective in "11th five-year Plan" has been realized. The installed capacity of wind power and biomass power will achieve 500000 KW in 2010.

Table 7. Power energy structure in energy structure optimization scenario

	Energy structure optimization scenario			
	2005	2010	2015	2020
Coal-fired power units				
Existing small scale	0.460	0.241	0.0755	0.0427
New built large scale	0.451	0.651	0.838	0.808
Natural gas	0	0.0297	0.0271	0.0258
Hydropower	0.0882	0.0717	0.0452	0.0605
Nuclear power				0.0413
Other renewable energy	0	0.00571	0.0139	0.0215
Wind power	0	0.00190	0.00289	0.00331
Biomass	0	0.00381	0.00985	0.0165
Solar	0	0	0.00116	0.00165

4. Simulation Results and Discussion

4.1 Greenhouse Gas Emission and Emission Reduction Potential

Figure 3 illustrates the greenhouse gas emissions from different scenarios. 2005 is the base year. It can be seen that the greenhouse gas emission continues to increase from 2010 to 2020 in all scenarios. Baseline scenario represents the most conservative greenhouse gas emission projection. In the baseline scenario, the key assumption is that no measures will be implemented during the scenario period; therefore, the baseline scenario provides a reference vision of how energy demand and GHG emissions in Henan Province would evolve if the provincial government does nothing to influence long-term trends. The model indicates that if keeping the development tendency, from 2005 to 2020, there is likely to be 383.9 Mt or more CO_2eq emitting from Henan's electricity sector every year.

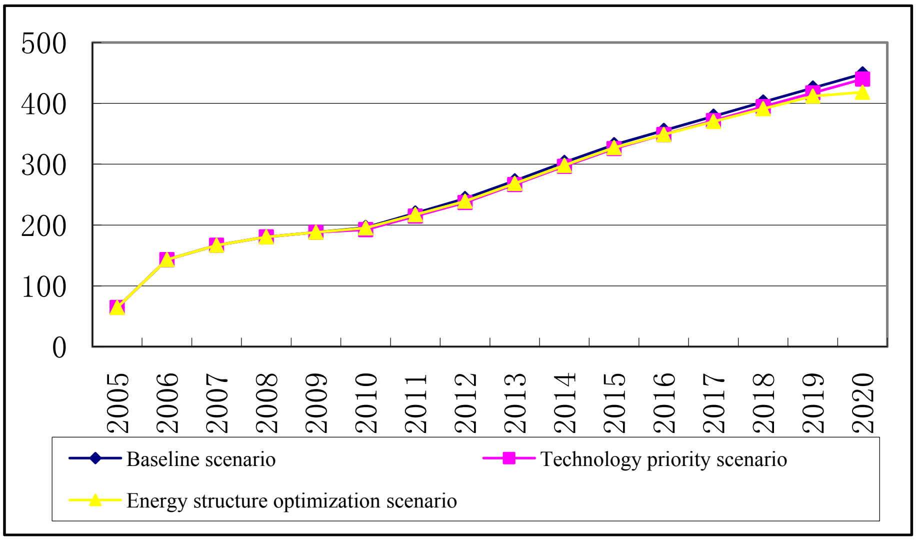

Figure 3. The greenhouse gas emission in different scenarios

Technology priority scenario, which considers the advanced generating technologies, can achieve emissions of 4397 Mt CO_2eq. The greenhouse gas emissions of technology priority scenario are 8.7 Mt CO_2eq more than that of baseline scenario. Therefore, it is very necessary to improve the generating efficiency by advanced generation technologies.

Energy structure optimization scenario, characterized by its aggressive renewable energy generation, will emit 4181 MtCO_2eq in 2020, which is 30.3 MtCO_2eq less than baseline scenario and 21.6 MtCO_2eq less than technology priority scenario.

Comparing the emissions of technology priority scenario and energy structure optimization scenario, the emission of technology priority scenario is lower than that of energy structure optimization scenario before the year 2015. It implies that the advanced generated technologies will be employed to reduce the greenhouse gas emissions greatly before 2015 and in the long term, renewable energy and energy structure adjustment will play the dominant role in reducing the greenhouse gas emissions.

4.2 Greenhouse Gas Emission Intensity

Table 8presentsclearly the results for greenhouse gas emission intensity. With the development of electricity sector, the greenhouse gas emission intensity in each scenario will decrease from 2005 to 2020. It is because of the energy-saving policies implement and advanced technologies employment. When comparing three scenarios, we find that the greenhouse gas emission intensity decreases more rapidly in the other two scenarios than baseline scenario. In technology priority scenario, it can realize 16.1% reduction in 2020 compare with 2005. In energy structure optimization scenario, it can realize 19.1% reduction in 2020 than 2005.

Table 8. Greenhouse gas emission intensity in different scenarios (kg CO_2/kWh)

	2006-2010	2011-2015	2016-2020
Baseline scenario	0.89	0.806	0.763
Technology priority scenario	0.874	0.781	0.734
Energy structure optimization scenario	0.888	0.8002	0.72

This paper presents the greenhouse gas mitigation potential in Henan's electricity sector up to 2020 under three scenarios. The mitigation potential is very huge and we should adopt corresponding reducing measures in different development phase. It is also appears that it could contribute to somewhere between approximately 9% and 13% of the savings required to support Henan Province's efforts to meet their targets. It is in line with the previous research in this field. Some papers which assessed the cost of mitigation measures concluded that the renovation of conventional thermal power plants was prior to use to realize emission reduction, followed by the renewable energy power generation whose cost was more highly (Zhang et al., 2007). Limited by the generating efficiency and power generation of different units from 2005 to 2008, we have to employ the estimated value taken from the literatures.

5. Conclusion

This paper conducted a study about different scenarios of greenhouse gas emissions in the power industry in Henan Province; the LEAP-Henan model was designed when we grasp the power industry in Henan repository, then, through the reasonable and strict hypotheses, we forecast the power industry GHGs mitigation in Henan in different scenarios. The main conclusions are summarized as follows:

There is huge potential of GHG emission reduction in Henan's electricity sector. in terms of emissions, that of technical priority scenario in 2020 is 8.7 MtCO_2eq less than the baseline scenario , and that of energy structure optimization scenarios is 30.3 MtCO_2eq less than the baseline scenario. In terms of the emission intensity of electricity generation, the technology priorities and energy structure optimization scenarios are significantly lower than that of the baseline scenario. It decreased by 14.27% from 2005 to 2020 in the baseline scenario, 16.02% in the technology priority scenario and 18.92% in the energy structure optimization scenario; therefore, the power industry in Henan Province has great potential to reduce GHGs mitigation.

By comparing the technical priority and energy structure optimization scenarios, we can obtain the technical priority GHGs scenarios emissions less than energy structure optimization scenarios in 2016, after that, the situation is just opposite. These shows that power generation, in the near future, to adopt advanced technology can achieve better emission reduction, however, renewable energy development and energy structure adjustment will fundamentally change the greenhouse gas emissions in the long term. Therefore, in order to achieve the theoretical scenarios emission reduction, the power industry in Henan should focus on promoting the power industry restructuring, strengthening and improving power generation scheduling approach, focusing on the development of high parameters, high-capacity, high efficiency thermal power, and speed up the shutdown coal consumption, heavy pollution of small thermal power units, at the same time, the traditional power plant must increase competitiveness through upgrading, the development of clean coal technology should promoting actively and accelerate wind power, straw power generation ,nuclear power development.

Henan need to develop the carbon tax and renewable energy "Clean Development Mechanism" (CDM) projects, reuse of methane generation CDM project (landfill gas power generation, coal bed methane power generation, and coke oven gas power generation), and the pressure of waste gas or heat power generation project. For the highly cost and undeveloped technology in local areas, we can use CDM projects to achieve local sustainable development.

References

B. J. H. W. Wetzalaer, N. H. van der Linden, H. Groenenberg, et al. (2007). GHG marginal abatement cost curves for the non-annex I region. Retrieved from http://www.ecn.nl/docs/library/report/2006/e06060.pdf

Carl C. Koopmans, & Dirk Willem te Velde. (2001). Bridging the energy efficiency gap: using bottom-up information in a top-down energy demand model. *Energy Economics, 23*, 57-75. http://dx.doi.org/10.1016/S0140-9883(00)00054-2

Carolien Kroeze, Jaklien Vlasblom, Joyeeta Gupta, et al. (2004). The power sector in China and India: greenhouse gas emissions reduction potential and scenarios for 1990-2020. *Energy Policy*, 55-76. http://dx.doi.org/10.1016/S0301-4215(02)00251-3

Edgard Gnansounou, Jun Dong, & Denis Bedniaguine. (2004). The strategic technology options for mitigating CO2 emissions in Power sector: assessment of Shanghai electricity-generating system. *Ecological Economics, 50*(1-2), 117~133. http://dx.doi.org/10.1016/j.ecolecon.2004.03.028

Ernst Worrell, Stephan Ramesohl, & Gale Bord. (2004). Advances in energy forecasting models based on engineering economics. *Annu. REV. Environ. Resource, 29*, 345-381. http://dx.doi.org/10.1146/annurev.energy.29.062403.102042

Huang Yophy, Bor Yunchang Jeffrey, & Peng Chieh-Yu. (2011). The long-term forecast of Taiwan's energy supply and demand: LEAP model application. *EnergyPolicy, 39*(11), 6790-6803.

http://dx.doi.org/10.1016/j.enpol.2010.10.023

IEA (International Energy Agency). (2004). World Energy Outlook. OECD Code: 612004251P1

Jianyi Lin, BinCao, ShenghuiCui, WeiWang, & XuemeiBai. (2010). Evaluating the effectiveness of urban energy conservation and GHG mitigation measures: The case of Xiamen city, China. *Energy Policy, 38,* 5123-5132. http://dx.doi.org/10.1016/j.enpol.2010.04.042

Nag, B., & Parikh, J. K. (2005). Carbon emission coefficient of power consumption in India: baseline determination from the demand side. *Energy Policy, 33*(6), 777-786. http://dx.doi.org/10.1016/j.enpol.2003.10.002

National Bureau of Statistics. (2000-2009). Henan Statistical Yearbook. NBS, Beijing.

National Development and Reform Commission (NDRC). (2009). Announcement of the thermal power plant closures in 2009. Retrieved from http://www.gov.cn/zwgk/2009-03/13/content_1258402.htm

National Development and Reform Commission (NDRC). (2010). the electricity consumption sharply increase and clean energy vigorously development in 2009. Retrieved from http://nyj.ndrc.gov.cn/ggtz/t20100106_323322.htm

Passakorn Phananiramai, Jay, M. Rosenberger, Victoria, C. P. Chen, Seoung Bum Kim, & Melanie L. Sattler. (2011). A mathematical optimization technique for managing selective catalytic reduction for coal-fired power plants. *Energy Systems*,171-188. http://dx.doi.org/10.1007/s12667-011-0030-0

Paul A. Steenhof. (2007). Decomposition for emission baseline setting in China's electricity sector. *Energy Policy*, 280-294. http://dx.doi.org/10.1016/j.enpol.2005.11.024

Qiang Wang, & Yong Chen. (2010). Status and Outlook of China's free-carbon electricity. *Renewable and Sustainable. Energy Reviews*, 1014-1025. http://dx.doi.org/10.1016/j.rser.2009.10.012

Qingyu Zhang, Tian Weili, Wei Yumei, et al. (2007). External costs from electricity generation of China up to 2030 in energy and abatement scenarios. *Energy Policy, 3*, 4295-4304. http://dx.doi.org/10.1016/j.enpol.2006.12.026

Shresrha, R. M, & Timilsina, G. R. (1996). Facrors affecting CO_2 intensities of power sector in Asia: a Divisia decomposition analysis. *Energy Economics, 18*(4), 283-293. http://dx.doi.org/10.1016/S0140-9883(96)00019-9

Steenhof, P. A. (2007). Decomposition for emission baseline setting in China's electricity sector. *Energy Policy, 35*(1), 280-294. http://dx.doi.org/10.1016/j.enpol.2005.11.024

Tobias Fleiter, Ernst Worrell, Wolfgang Eichhammer. (2011). Barriers to energy efficiency in industrial bottom-up energy demand models—A review. *Renewable and Sustainable Energy Reviews, 15*, 3099-3111. http://dx.doi.org/10.1016/j.rser.2011.03.025

Wei Yiming, Liu Lancui, Fan Ying, et al. (2008). China Energy Outlook 2008: Carbon emission Research. (In Chinese)

WenjiaCai, Can Wang, & Jining Chen. (2010). Revisiting CO_2 mitigation potential and costs in China's electricity sector. *Energy Policy*, 4209-4213. http://dx.doi.org/10.1016/j.enpol.2010.03.048

WenjiaCai, Can Wang, Ke Wang, et al. (2007). Scenario analysis on CO_2 emissions reduction potential in China's electricity sector. *Energy Policy*, 6445-6456. http://dx.doi.org/10.1016/j.enpol.2007.08.026

Wetzelaer, B., et al. (2007). GHG mitigation abatement cost curves for the Non-Annex I region. Retrieved from http://www.Ecn.nl/publications/PdfFetch.aspx?nf=ECN-E-06-060

XuGuoquan, & Jiang Zhaohua. (2006). Decomposition model and case analysis for carbon emission in China. *China population, resources and environment*, 158-161. (In Chinese)

Yao Xiaoyan, Li Yuan, & Wen Qi. (2010). Low-carbon Economy Eval uation Index System of Thermal Power Industry. *Journal of Ningxia University (Natural Science Edition), 31*(4), 389-392. (In Chinese)

Zhang Ying, Wang Can, Wang Ke, et al. (2007). CO_2 emission scenario analysis for China's electricity sector based on LEAP software. *Tsinghua University*, 365-368. (In Chinese)