Study on air pollution control under the influence of energy policy in Shanxi Province

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Abstract. At present, China's resource constraints are becoming tighter and environmental problems are serious. Shanxi province's energy policies implementation has a huge impact on the ecological environment. This paper focuses on the emission of air pollutants from coal-fired power generation, coal chemical industry, biomass power generation, coal bed methane power generation, as well as the impact of emission reduction measures such as "coal to electricity" and "coal to gas" on the atmospheric environment in Shanxi Province. In 2015, coal power, coal chemical and other energy-related industries in Shanxi province emitted 429,800 tons of sulfur dioxide, 348,000 tons of nitrogen oxides and 364,400 tons of dust, accounting for 38%, 37% and 25% of the province's industrial emissions respectively. After the strict implementation of energy policies, the emissions of air pollutants SO\(_2\), NO\(_x\) and dust from energy-related industries should be 121,500 tons, 236,100 tons and 19,300 tons respectively in 2020. Emission of air pollutants SO\(_2\), NO\(_x\) and dust from energy-related industries should be reduced by 72%, 32% and 95% respectively in 2020 compared with that of 2015. However, we need to improve environmental access, tighten standards, strengthen environmental protection requirements in the energy industry, and continue to optimize the energy consumption structure.

1. Introduction

Studies have shown that the impact of energy policy itself on the atmospheric environment is crucial [1, 2]. As an energy province, the implementation of energy planning and policies has a greater impact on air pollution prevention and control in Shanxi Province [3]. In order to speed up the improvement of the environment air quality, the State Council issued the “Three-year Action Plan to Win the Blue Sky Defence War”(hereinafter referred to as the "Action Plan")[4]. "Action Plan" points out that the Taiyuan, Yangquan, Jincheng, Linfen cities are the surrounding areas of Beijing-Tianjin-Hebei region; Luliang, Jinzhong, Linfen, Yuncheng cities are the Fenwei plain area. All of them (most of Shanxi Province) are key areas and will continue to carry out air pollution prevention and control campaigns to achieve multi-win environmental, economic and social benefits.

2. Regional overview

Shanxi Province is located in the western part of North China, at the east of the Loess Plateau. It neighbors Hebei, Henan, Shaanxi and Inner Mongolia. The geographic coordinates are 38°34′-40°43′N, 110°14′-114°33′E, showing a parallelogram from northeast to southwest. It is about 380 kilometers wide from east to west, 682 kilometers long from north to south, and covers a total area of about 156,000 square kilometers. Shanxi province currently has jurisdiction over 11 prefecture-level cities, including Taiyuan, Datong, Yangquan, Changzhi, Jincheng, Linfen cities are the surrounding areas of Beijing-Tianjin-Hebei region; Luliang, Jinzhong, Linfen, Yuncheng cities are the Fenwei plain area. All of them (most of Shanxi Province) are key areas and will continue to carry out air pollution prevention and control campaigns to achieve multi-win environmental, economic and social benefits.
districts, 12 county-level cities and 83 counties). Shanxi is a major resource development and utilization province. The reserves of 32 mineral resources such as coal, coal bed methane, and bauxite rank among the top ten in the country. Among them, coal reserves account for 17.3% of China’s total reserves.

3. Current situation of pollutant discharge
According to "The 13th Five-Year Comprehensive Energy Development Plan of Shanxi Province"[5], the total production capacity of all kinds of coal mines in Shanxi province is 1.46 billion tons in 2015; The installed capacity is 69.66 million kilowatts, of which coal power generation capacity is 55.17 million kilowatts, accounting for 79.2% of the province's installed capacity, the new energy installed grid-connected capacity reaches 14.49 million kilowatts, accounting for 21% of the province's total generating capacity; The province's coal-bed methane (coal mine gas) extraction volume is 10.13 billion cubic meters, the utilization was 5.73 billion cubic meters; There are 253 coal chemical enterprises in the province, with the main product capacity reaching 24 million tons/year.

According to the data of environmental statistics, in 2015, coal power, coal chemical and other energy-related industries in the province annually discharged 435,300 tons of sulfur dioxide, 375,600 tons of nitrogen oxides and 367,200 tons of dust, accounting for 38%, 37% and 25% of the province's industrial emissions respectively (Table 1). In general, the total amount of air pollutants discharged from energy-related industries is large, and the overall environmental air quality of the whole province is poor, the phenomenon of exceeding the environmental standards is prominent, which is the main environmental restriction factor for the energy development in Shanxi Province.

| Industry Output | Emissions Ten thousand tons/year |
|----------------|---------------------------------|
|                | SO₂  | NOₓ  | Dust and smoke |
| Coal power     | 55.17 million kw                 | 35.81 | 29.24 | 28.95 |
| Biomass power generation | 35 million kw                     | 0.067 | 0.14  | 0.008 |
| Coal bed methane power generation | 38.8 million kw                | 0.0014 | 0.43 | 0.0022 |
| Coking         | 80.40 million tons               | 0.55  | 2.76  | 0.28  |
| Methanol: 5.5 million t/a; PVC: 1 million t/a; Crude benzene refining: 700,000 t/a; coal tar processing: 2.77 million t/a; Synthetic oil from coal: 310,000 t/a |
| Coal chemistry | Total | 43.53 | 37.56 | 36.72 |

4. Pollutant emissions under the influence of energy planning
Focuses on the emission of air pollutants from coal-fired power generation, coal chemical industry (coking and new coal chemical industry), biomass power generation, coal bed methane power generation, as well as the impact of emission reduction measures such as "coal to electricity" and "coal to gas" on the atmospheric environment.

4.1. Coal-fired power generation industry
At present, all coal-fired power plants can achieve ultra-low emissions according to the "Action Plan". The emission standard limit is nitrogen oxides ≤50mg/Nm³, sulfur dioxide ≤35mg/Nm³ and dust ≤5mg/Nm³ for traditional generator. The emission standard limit of low calorific value coal generator is nitrogen oxides ≤50mg/Nm³, sulfur dioxide ≤35mg/Nm³ and dust ≤10mg/Nm³.
According to “The 13th Five-Year Comprehensive Energy Development Plan of Shanxi Province”, the province's installed coal-fired power capacity will be expected to reach 72 million kilowatt-hours in 2020. Referring to the emission coefficient of the waste gas volume of the thermal power industry in the Manual of the Generation and Discharge Coefficient of Industrial Sources in the First National Survey of Pollution Sources, the emission of SO$_2$, NO$_x$ and dust is 83,100 t/a, 118,800 t/a and 11,900 t/a respectively.

4.2. Coking industry
At present, all enterprises have completed the transformation of special emission limits according to the "Action Plan". The province's coke production capacity will reach 90 million tons in 2020 according to "Coking Industry Layout Opinions in Shanxi Province". Referring to the discharge coefficient of industrial waste gas of coking industry in the Manual of Generation and Discharge Coefficient of Industrial Source in the First National Survey of Pollution Sources, the emission of air pollutants was estimated according to table 2 and the capacity utilization rate based on the value of 54% (data in 2015), the emission of SO$_2$, NO$_x$ and dust were 600 thousand tons, 29,800 tons and 300 thousand tons respectively, which decreased by 91%, 40% and 95% compared with that in 2015.

| Number | Emissions link                          | PM  | SO$_2$ | NO$_x$ |
|--------|----------------------------------------|-----|--------|--------|
| 1      | Cleaning coal crushing, crushing screening and transport | 15  | -      | -      |
| 2      | Loading coal                           | 30  | 70     | -      |
| 3      | Pushing coke                           | 30  | 30     | -      |
| 4      | Coke oven chimney                      | 15  | 30     | 150    |
| 5      | Dry coke quenching                     | 30  | 80     |        |
| 6      | Crude benzene tubular furnace          | 15  | 30     | 150    |

4.3. Integrating project of oil, electricity and heat for clean utilization of high sulfur coal
According to Environmental impact statement, SO$_2$, NO$_x$, and dust emissions of this project are 18,500 t/a, 13,500 t/a and 12,300 t/a respectively.

4.4. Coalbed methane power generation industry
Five million kilowatts coal bed methane power generation base will be built according to “The 13th Five-Year Comprehensive Energy Development Plan of Shanxi Province”. Referring to the emission coefficient of the waste gas volume of the thermal power industry (the raw material is natural gas and the control measures adopt low nitrogen combustion technology) in the Manual of the Generation and Discharge Coefficient of Industrial Sources in the First National Survey of Pollution Sources, and the special emission limits of gas-fired boilers in the "Emission Standards of Air Pollutants for Boilers (GB13271-2014)”, SO$_2$, NO$_x$ and dust emissions are respectively 25000 t/a, 75,000 t/a and 10,000 t/a.

4.5. Biomass power generation industry
Installed capacity of biomass power generation (including waste power generation) shall strive to reach 750,000 kilowatts according to “The 13th Five-Year Comprehensive Energy Development Plan of Shanxi Province”. Referring to the emission coefficient of the waste gas volume of the thermal power industry (the raw material is garbage and the control measures adopt low nitrogen combustion technology) in the Manual of the Generation and Discharge Coefficient of Industrial Sources in the First National Survey of Pollution Sources, and the 24h emission limit in "Standard for Pollution
Control of Domestic Waste Incineration (GB18485-2014), SO₂, NOₓ and dust emissions are respectively 400 t/a, 1,300 t/a and 12300 t/a.

4.6. The "coal to electricity" and "coal to gas" emissions reduction plan
According to “13th Five-Year Comprehensive Energy Development Plan of Shanxi Province”, by 2020, the proportion of coal consumption in primary energy consumption will be reduced to 80%, small coal-fired boilers will be completely phased out through central heating and clean energy replacement. According to “The 13th Five-Year New Energy Development Plan of Shanxi Province”, the province will promote coal bed methane power generation and civilian use, involves 12 million people. The material balance algorithm was used to calculate the emissions of sulfur dioxide and dust, and the emission coefficient method was used to calculate the emissions of nitrogen oxides (Coal consumption per capita is 0.1t/a, table 3), the calculated result is that SO₂, NOₓ and dust will be reduced by 11,500 t/a, 2,300 t/a and 18,000 t/a respectively.

Table 3. Main calculation parameters

| Class                      | Name                                    | Value  |
|----------------------------|-----------------------------------------|--------|
| Coal quality               | sulfur content                          | 1.2%   |
|                            | ash content                             | 15%    |
|                            | net caloric value of as-received basis(MJ/kg) | 21     |
| The combustion process     | heat loss due to incomplete combustion  | 20%    |
|                            | the fraction of sulfur in a fuel oxidized to SO₂ during combustion | 80%    |
|                            | the fraction of ash content              | 10%    |
| The end of processing      | desulfurization rate                    | 0      |
|                            | dust removal coefficient                 | 0      |
| Other                      | NOₓ emission coefficient (kg/t coal)    | 1.88   |

In 2020, the emission of SO₂, NOₓ and dust from energy-related industries will be 121,700 tons, 237,200 tons and 19,400 tons respectively. Through emission reduction measures such as the “coal to electricity” and “coal to gas”, SO₂, NOₓ and dust will be reduced by 11,500 t/a, 2,300 t/a and 18,000 t/a respectively. Under the premise of full implementation of the plan, the emissions of air pollutants SO₂, NOₓ and soot from energy-related industries in 2020 will be reduced by 72%, 37% and 95% respectively compared with 2015 (Table 4), and the quality of the air environment will be improved accordingly.

Table 4. Emission statistics of air pollutants from energy-related industries in 2015

| Industry                        | Year | Output                  | SO₂       | NOₓ       | Dust and smoke |
|---------------------------------|------|-------------------------|-----------|-----------|----------------|
| Coal power                      | 2015 | 55.17 million kw        | 35.81     | 29.24     | 28.95          |
|                                 | 2020 | 72 million kw           | 8.31      | 11.88     | 1.19           |
| Biomass power generation        | 2015 | 35 million kw           | 0.067     | 0.14      | 0.008          |
|                                 | 2020 | 75 million kw           | 0.04      | 0.13      | 0.01           |
| Coal bed methane power generation | 2015 | 38.8 million kw        | 0.0014    | 0.43      | 0.0022         |
|                                 | 2020 | 50 million kw           | 2.50      | 7.50      | 1.00           |
| Coking                          | 2015 | 80.40 million tons      | 0.55      | 2.76      | 0.28           |
|                                 | 2020 | 90 million tons         | 0.62      | 3.09      | 0.31           |
| Coal chemistry                  | 2015 | 24 million t/a (chemical fertilizer:12 million t/a; Methanol:5.5 million t/a; PVC: 1 million t/a; Crude benzene refining :700,000 t/a; coal tar processing: 2.77 million t/a; Synthetic oil from coal:310,000 t/a) | 7.10      | 4.99      | 7.48           |
|                                 | 2020 | Integrating project of oil, electricity and heat for clean utilization of high sulfur coal | 1.85      | 1.35      | 1.23           |
5. Air pollution control measures

5.1. Coal-fired power generation industry
Restrict the construction of supercritical units, prohibit the construction of subcritical units, and eliminate ordinary high-temperature and high-pressure units; It is not allowed to enter coal-fired power plants whose pollutant emission does not reach the standard limit or the relevant requirements of total pollutant emission control. Make sure that all coal-fired boilers above 65 tons of steam per hour in the province completed ultra-low emission transformation. Monitor all pollutant emission concentrations online, strengthen the control of non-point sources in power plants, and build fully enclosed coal storage. Through overall planning and reasonable deployment, power generation projects shall provide central heating to neighboring counties, surrounding industrial enterprises and residents as much as possible.

5.2. Coking industry
Strictly implement the overall requirements of the state "to determine coke with steel". Tamping coke oven chamber must reach 6 meters and above and the scale of production ≥ 1 million tons. It is strictly prohibited to build new heat recovery coke oven. The height of the carbonizing chamber of the top coke oven must be 6.98 m or above. All coking enterprises must meet the special emission concentration limit requirements of air pollutants.

5.3. Coalbed methane power generation industry
Accelerate the popularization of coal and gas co-mining technology, reduce methane emissions from the source of coal mining. Make sure that pollutant discharge meets the gas standard requirements in "Boiler Air Pollutant Emission Standard (GB13271-2014)".

6. Conclusion
Our findings demonstrate that sustainable energy policies are particular effective on reducing air pollution. If we strictly implement the energy polices, emission of air pollutants SO2, NOx, and dust from energy-related industries should be reduced by 72%, 32% and 95% respectively in 2020 compared with that of 2015. But we need to improve access, tighten standards, and implement the requirements of the ecological environment access list, so as to force the energy industry to upgrade and transform its environmental protection. In addition, we should optimize the energy consumption structure and build a clean, low-carbon and efficient energy system.

Acknowledgments
Supported by Scientific and Technological Innovation Programs of Higher Education Institutions in Shanxi (2020L0728) and Science Foundation of Shanxi Institute of Energy (ZB-2018002).

References:
[1] Chen, X.Y., Li, F., Zhang, J.D., Zhou, W., Wang, X.Y., Fu, H.J. (2020) Spatiotemporal mapping and multiple driving forces identifying of PM2.5 variation and its joint management strategies across China. J. Clean. Prod. 250: 119534.1-119534.11.
[2] Li, F., Zhang, J., Liu, C., et al. (2018) Distribution, bioavailability and probabilistic integrated ecological risk assessment of heavy metals in sediments from Honghu Lake, China. Process Saf. Environ. Protect., 116:169-179.
[3] Donatella Baiardi. (2020) Do sustainable energy policies matter for reducing air pollution? Energy Policy, 140.

[4] The State Council. (2018) Circular of the State Council on Printing and Issuing the Three-year Action Plan to Win the Blue Sky battle. http://www.gov.cn/zhengce/content/2018-07/03/content_5303158.htm.

[5] People's Government of Shanxi Province. (2016) The 13th Five-Year Comprehensive Energy Development Plan of Shanxi Province. http://www.shanxi.gov.cn/sxszfxxgk/sxsrmzfzcmbm/sxszfbg/fjig_7203/szfgfwj_7205/201612/t20161226_272758.shtml.