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Analysis of Heating Systems in the Coal-to-Electric Power Process in Hebei Province, China

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ABSTRACT

Smog has become the most serious climate problem in North China in recent years. Coal burning has been found as the key factor to generate smog. Hebei province has started to stop coal burning in winter, however, there should be an efficient warming way for the millions of people in the cold North China. Heat pump is a high energy-saving technique and could be a good solution for Hebei warming. This paper compared different heating systems, and the result shows that heat pumps can bring the obvious energy-saving as well as the smog-reducing.

Keywords: Air Source Heat Pump, Coal-to-Electric Power, smog-reducing, energy-saving

1. SMOG IN NORTH CHINA AND THE INFLUENCE OF COAL BURNING

China experienced smog affecting about 600 million people in 17 provinces in 2013, which is almost a fourth of the China's territory[1]. Where does the smog come from? There are 5 main factors: car, coal, industry, combination, and accumulation [2]. China burned 4.1 billion metric tons of coal in 2014. The extremely large amount of chemicals emitted from coal burning and other meteorological factors have triggered the haze [3].

From some statistical figures in relevant reports, it can be concluded that the coal burning is the No.1 factor for smog generation. As shown in Figure 1 a), the sum of the coal burning relevant ratios is 41.5% (= 24.5% + 17%); and in b) the number is 31% (= 18% + 14%), keeping the biggest contribution to the smog.

Table 1 Primary Energy Consumption and its Composition in Hebei

Year	Total Energy Consumption (10000 tons of SCE)	As Percentage of Primary Energy Production (%)			
		Coal	Petroleum	Natual Gas	Primary Electricity
2008	24321.87	92.31	6.67	0.94	0.08
2009	25418.79	92.51	6.21	1.21	0.07
2010	26201.41	89.98	7.75	1.51	0.76
2011	28075.03	89.09	8.12	1.66	1.13
2012	28762.47	88.86	7.48	2.04	1.62
2013	29664.38	88.69	7.22	2.23	1.86
2014	29320.21	88.46	6.98	2.54	2.02

As shown in Table 1, from the Statistical Yearbook for Hebei Economics 2015 [5], the coal consumption is always the No.1 item in all its energy consumption, at least in recent 7 years.

Table 2 Overall Energy Balance Sheet

(10000 tons of SCE)

Item	2005	2010	2013	2014
Total Energy Consumption	**19836**	**26201**	**29664**	**29320**
Consumption by Usage				
Farming, Forestry, Animal Husbandry, Fishery Conservancy	532	713	574	625
Industry	15852	20563	23389	22785
Construction	203	319	265	253
Transport, Storage and Post	710	971	1162	1109
Wholesale, Ratail Trade and Hotel, Restaurants	205	304	565	639
Others	465	716	829	911

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Residential Consumption	1870	2615	2881	2997

And as shown in Table 2, the residential consumption in Hebei Province is almost the 10% of the whole consumption. Compared to the other provinces, Hebei is a high energy consumption province, which has 70.34 million people, 5.27% of the whole country, and an increasing of 6.4% per year for its energy consumption (2005~2009) [6].

Pollutant discharge level of coal burning can be calculated roughly with relevant estimation formulas, separately for dust, SO_2, CO, NO_X [8]. Considering 1 ton coal burning, the dust-catching rate taken as 85%, the dust pollutant discharge will be 1.5kg, SO_2 discharge will be around 24kg, NO_X discharge will be around 7.6kg [9].Then, the total energy consumption of 293.2 million ton for Hebei province in 2014, can generate 439.8 million kg dust, 7.037 billion kg SO_2, and 2.228 billion kg NO_X. These are the most contributors to the heavy smog in Hebei province.

So recently, Hebei province has started to stop coal burning in winter. The policy so-called coal-to-electric power has been executed firmly in Hebei. And in this process, instead of using air conditioning, the heat pump has attracted more attention owing to its energy-saving ability.

2. COMPARISON OF ASHP, GHPS, AIR CONDITIONING AND BOILER HEATING

Boiler heating is the most traditional heating way in north China in winter. And the main consumption for this way is coal. Air conditioning has started to be popular because it can be used either in winter or in summer. Heat pump is coming into people's view recently though in fact it had been developed a century ago. The most popular heat pumps have 2 common types: air source heat pumps (ASHP) and geothermal heat pumps (GHPs) [10].

2.1 ASHP

ASHP can deliver 1.5 to 3 times more heat energy to a home compared to the electrical energy it consumes, because it moves the heat rather than converting is from a fuel[10]. And ASHP will use half the energy to provide the same amount of cooling, cutting air-conditioning costs in half.

Compared to GHPs, ASHP is more widely used mainly due to its lower installation costs [11]. But when considering the outcome of the energy and exergy flow, a simulation analysis revealed that GHPs is better than ASHP or conventional heating system [12]. GHPs has roughly 25% less demand of absolute primary energy and exergy whereas about 50% high overall primary coefficient of performance (COP) and overall primary exergy efficiency than base case (conventional system).

2.2 Air conditioning and Boiler

There are many state-of-the-art work on the calculation of boiler [13][14][15], as well as the air conditioning [16][17][18][19].

For the heating calculation of air conditioning, there is a simple formula:

$$Q = 0.0036 T_a N Q_a \frac{t_i - t_a}{t_i - t_o} \quad (1)$$

Q: heat value (GJ); T_a: daily run hours (h); N: days for running; Q_a: designed load (kW); t_i: temperature indoors (℃); t_a: average temperature outdoors (℃); t_o: temperature outdoors in winter (℃).

2.3 Comparison Calculation

there is the calculation of coefficients of heating, real specific consumption of heating, exergy coefficient of heating, of 3 classical heating systems, boiler, GHPs, and air conditioning[20].

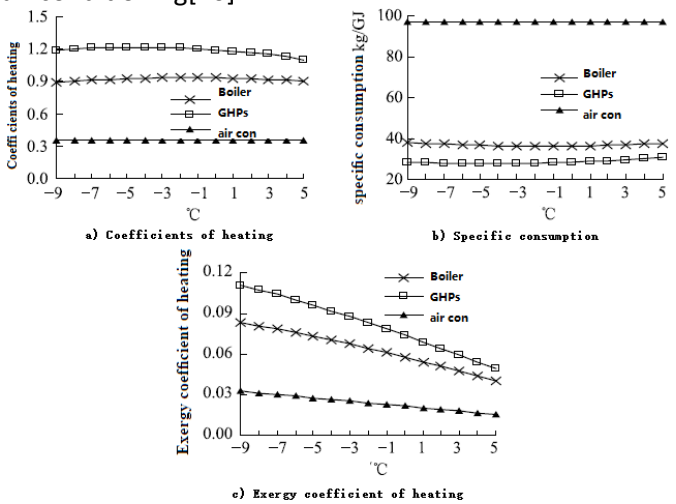

Figure 1 Comparison of coefficients for boiler, GHPs, air conditioning

Seen from Figure 1, it is obvious that for GHPs, the energy related coefficients are all the highest, while its consumption is the lowest. And air conditioning is the worst, while boiler is in the middle.

And it is clear in Table 3, that the operation cost of ASHP is 84% cheaper than diesel, 75% cheaper than electric heater, 56% cheaper than gas, and 28% cheaper than coal.

Table 3 Comparison table for heating ways

Heating Way	Boiler of oil	Electric heater	Boiler of Gas	Boiler of Coal	ASHP
Type of Energy	Diesel	Electric	Gas	Coal	Electric +air
Polution figue	High	No	Middle	High	No
Safety	Dangerous	Dangerous	Dangerous	Dangerous	Safe
Efficent rate	86%	100%	86%	65%	437%
Cost (RMB)	7.4/L	0.5/kwh	2.38/m3	850/t	85014
1kW heat cost (RMB)	0.72	0.5	0.28	0.16	0.114
1 ton hot water cost (RMB)	25.06	17.44	9.77	5.6	3.99
Life of equipment (year)	10	8	5	15	15

3. *CONCLUSIONS*

Hebei province is the biggest area in the centre of north China and contributes the most share of the smog owing to its huge industry and residential population using coal burning popularly. The coal-to-electric power policy has been executed to reduce the smog. In this process, heat pumps should be widely used owing to its obvious good performance in energy-saving.

It can be concluded that if using heat pumps to replace all of the boilers, the whole province will reduce 439.8 million kg dust, 7.037 billion kg SO_2, and 2.228 billion kg NO_X. And compared to air conditioning, the heat pump systems will save 25%~50% power energy, and get more 50% COP.

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