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Can Beijing fight with haze? Lessons can be learned from London and Los Angeles

Ke Wang[1] · Yingnan Liu

1. Current situation of haze in China

Recently, Chinese Academy of Social Sciences published Green paper on climate change: a report on fighting climate change 2013 (Wang and Zheng 2013), which points out that the problem of haze and fog in China was hitting the record-level, and China is currently suffering the worst air pollution problem since 1961. In Fig. 1, the record of 299 observation stations distributed around the country shows that the problem of haze rapidly rose up in the 21th century (Gao 2008). Additionally, a satellite map from NASA points out the severity: from a global perspective, Eastern China suffered the highest average PM 2.5[2] concentration in the air from 2001 to 2006, which is even worse than the situation in Saharan Desert (Voiland 2009). Especially from 2011, the frequently occurring haze weather in the spring and the winter began to draw a wide public attention. Geographically, the severity of the haze problem is increasing progressively from the east to the west, which can be found in Fig. 2. Although blue sky shows up more frequently in the southwest, heavy layers of haze and fog are hovering over Eastern China (Zhang 2013). Especially in some southeastern regions, the annual average haze days have crossed 100 days. Fig. 3 shows the situation of haze days in Beijing and Shanghai during last winter.

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[2] PM 2.5, one of the main air pollution sources, is particulate matters with diameter smaller than 2.5 micrometers. PM 2.5 tends to penetrate into human lung, and cause series of diseases.

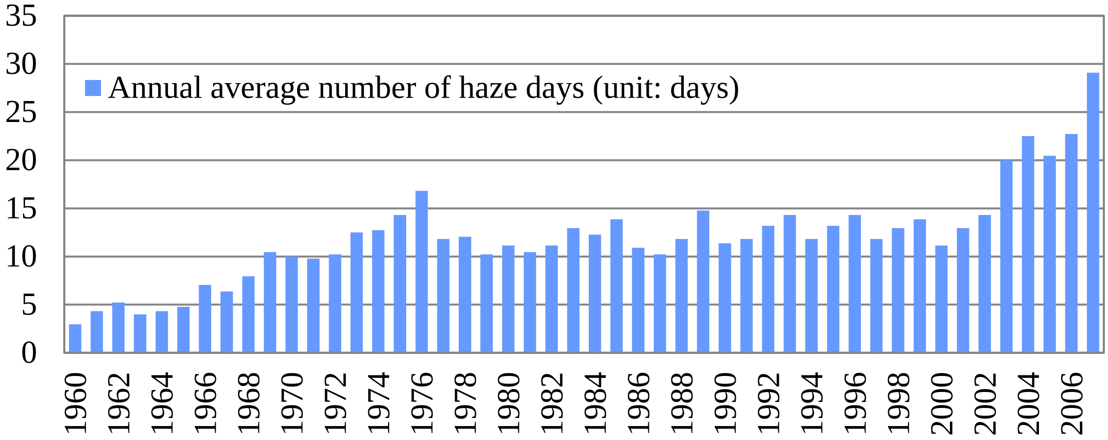

Fig. 1 Annual average number of haze days from 299 observation stations in China from 1960 to 2007 (Data source: National Bureau of Statistics of China)

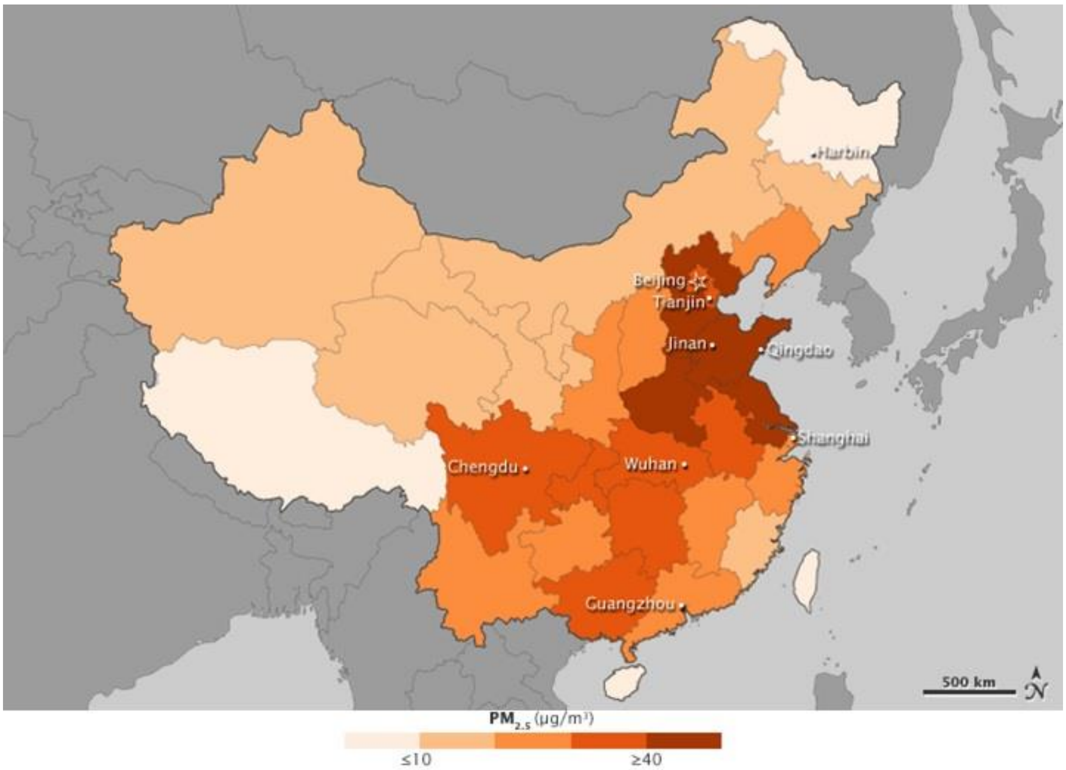

Fig. 2 Distribution of average PM 2.5 concentration in China from 2008 to 2010 (NASA)

Fig. 3 Left: A hazy day of the financial district, Pudong, Shanghai (Aly Song, Reuters); Right: Blue sky shown on a screen in the haze, Tiananmen Square, Beijing (Feng Li, Getty Images)

During each winter, cities in Northern China gradually activate their central heating systems after temperature drops below zero degrees centigrade, and coal and coal gas are the main sources of energy consumption in these central heating systems. Together with the specific climate conditions, the increasing pollutants from fossil fuel combustion of the central heating systems intensify the haze in Northern China. In December 2013, the double orange alert[3] of both fog and haze has been issued continuously for 7 days in large areas of Northern and Eastern China. People in big cities have to wait for northerly wind to take the grey breath away. Fig. 4 shows a satellite image (right) from NASA which captures the heavy layers of haze and fog during that time.

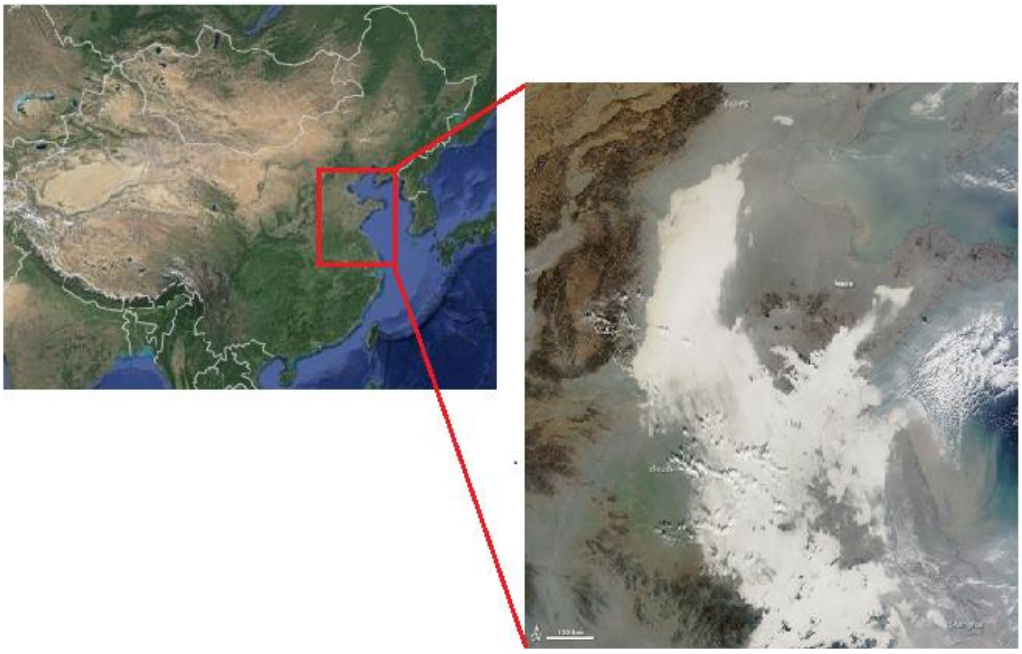

Fig. 4 Haze and fog in Eastern China captured by NASA's Terra satellite, December 7, 2013 (NASA)

2. Contributing factors for the haze in Beijing

[3] Three level alerts for fog and haze are yellow, orange and red associate with increasing severity.

In Beijing, the capital city of China, the haze problem in winter can be traced back to over 600 years. Specific geographical conditions and particular climatic situation led to chronic hazy winters. However, the immediate causes of the haze problem in recent years is the rapid increase of fossil fuel consumption which is associated with the rapid development of industries in Beijing and surrounding provinces (Chen 2013). In general, the grey sky in Beijing is mainly due to coal burning, vehicle exhaust, climate and geographical environment and other factors, such as crop stubble burning and fireworks.

2.1. Coal burning

Coal is the primary source of thermal electric generation in China. In order to meet the strategic goals of energy saving and increasing the proportion of renewable energy, China is reducing the proportion of thermal electricity generation. However, by the end of 2012, coal-fired electricity generation still contributed 78.6% of the national electricity generation. Although the situation in Beijing is better than the national average, a large proportion of electricity in Beijing is imported from surrounding provinces (e.g., Shanxi, Hebei and Inner Mongolia), the local coal-fired electricity generation of Beijing still is approximately 30% of its demand. The specific components of electricity generation are given in Fig. 5.

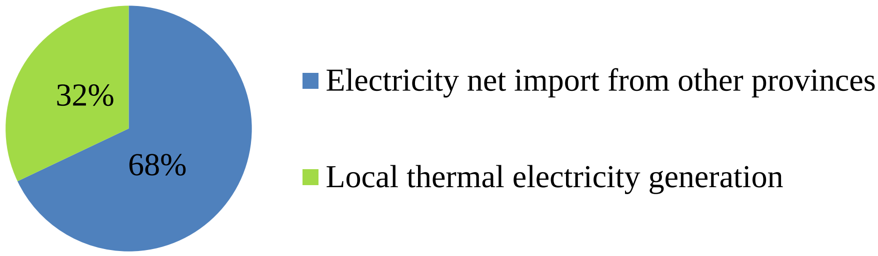

Fig. 5 Electricity consumption in Beijing in 2011 (Data source: National Development and Reform Commission of China)

Fig. 6 reflects consumptions of coal in Beijing and surrounding provinces. At present, coal and coal gas are the primary sources for the central heating system, and the sudden increase of coal consumption for this system in each winter worsens the air quality in Beijing and other Northern China cities. In 2013, for instance, the central heating system was activated on November 15th in Beijing, Tianjin, Jinan and Shijiazhuang, and on November 31st in Taiyuan. Just after that, a serious haze occurred and lasted for more than one week in the beginning of December in Beijing and Northern China.

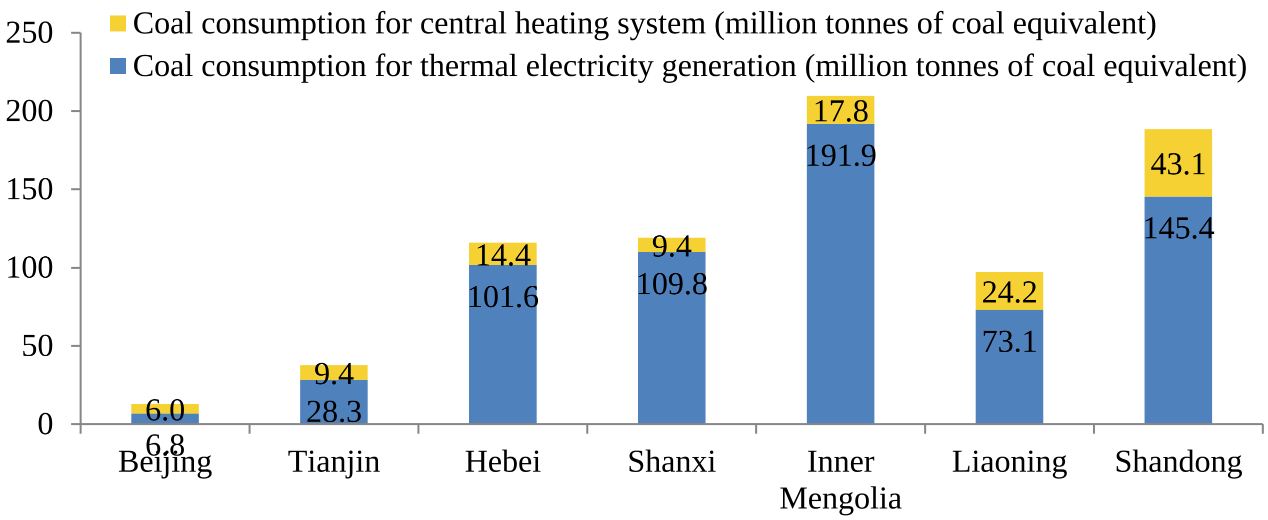

Fig. 6 Coal consumption for thermal electricity generation and the central heating system in Beijing and surrounding provinces for the year 2011(Data source: National Development and Reform Commission of China).

Thermal electricity generation and the central heating system are not the only sources of coal consumption, but heavy industry also takes a large proportion. The haze distribution in China shows a strong correlation with the heavy industry distribution. It can be seen from Fig. 7 that the 25 cities where the air quality index hit the maximum value[4] (representing the worst case) in December 2013 were also located in the areas of heavy industries. In 2013, seven out of the top ten most air polluted cities in China are located in Hebei which is the closest surrounding province to Beijing (CNEMC 2013). In addition and more specifically, there are at least 50 large iron and steel plants in Hebei and most of them operate all year long, and the air pollutants from these surrounding industries keep on impacting the air quality of Beijing. When climatic condition in Beijing is stable, heavy pollution is trapped by the west and north mountain ranges in Beijing (Wang 2014). Therefore, haze cannot fade away until strong airflow occurs in the region. Fig. 8 shows an iron and steel factory in Hebei and a thermal electricity generation station in Beijing.

[4] The maximum value of air quality index is 500 which indicates the worst air quality.

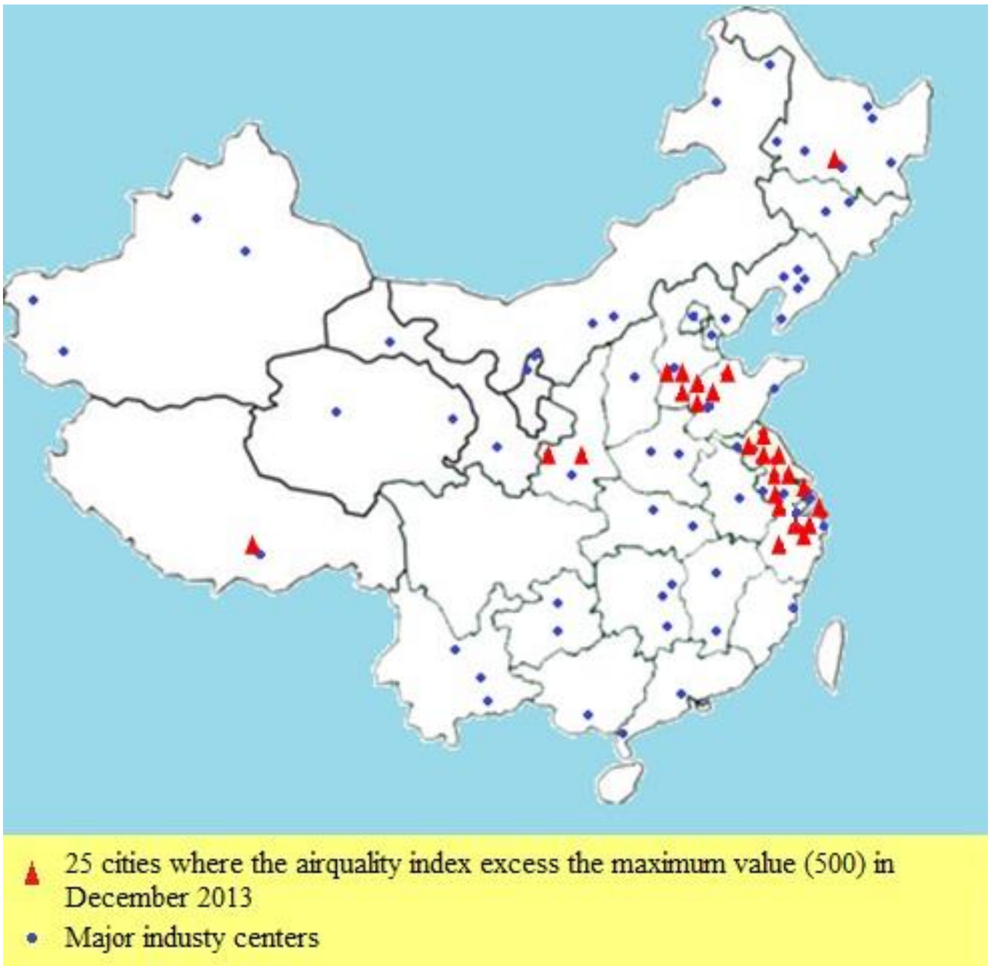

Fig. 7 Distribution of major industry centers in China and 25 cities that suffered heavy haze in December 2013

Fig. 8 Left: Pollution from a steel factory in Yutian County, Hebei, 100km from Beijing (Yunxiao Shang, Oriental outlook); Right: Pollution from a thermal power station in Beijing (Jason Lee, Reuters).

2.2. Vehicle exhaust

Pollutants from vehicles contribute to more than 22.5% of PM 2.5 in Beijing (Wang 2014), and the vehicles with large engine capacity are more numerous than the vehicles with small engine capacity. By the year 2010, civil automobiles in Beijing exceeded 800,000 compact car category and 12,000 subcompact car category[5], leading to heavy traffic. On an average, citizens in Beijing spend 52 minutes on their daily commute to work, including a 14 minute wait in the traffic grid lock (Niu 2012) allowing engines to emit pollutants continuously. Although the government is taking serious steps to solve the traffic problems, there are an additional 200,000 new vehicles on the roads each year. The increasing number of vehicles is shown in Fig. 9. More vehicle possessions cause longer congestion duration resulting in heavier air pollution.

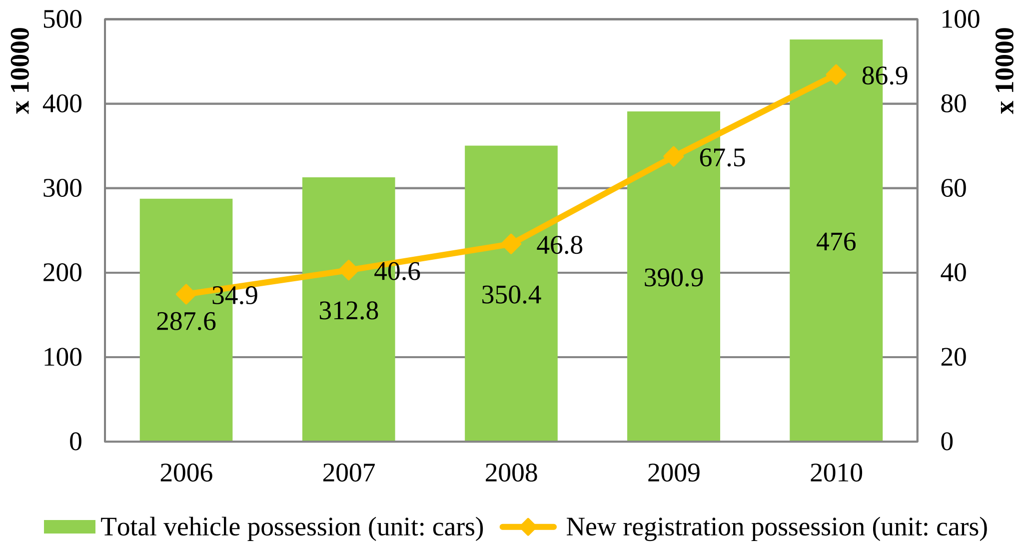

Fig. 9 Statistics on possession of civil motor vehicles in Beijing from 2006 to 2010 (Source: National Bureau of Statistics of China).

2.3. Climatic and geographical conditions

In winter, the temperate continental climate in Beijing leads to high air pressure and rainless days. As a result, pollutants suspended in the air and low speed airflow exacerbates the haze problem. Geographically, the mountain ranges surround Beijing on three sides leading to poor air circulation. Due to a given humidity, intensity of sunlight, and low clouds, haze is trapped in the low temperature layer of the inversion formed by Aleutian low (Ma et al 2013).

[5] Subcompact vehicles are vehicles with engine capacity of 0.8L, 1.0L, 1.0T or 1.2L.

2.4. Other factors

Some other activities may also cause haze as shown in Fig. 10. In rural areas, crop stubble burning is a frequently-used method to deal with agricultural waste. Large portions of crop residues are used as biomass fuels that are approximately 40% in Hebei and Inner Mongolia, 55% in Liaoning and Heilongjiang, and 70% in Beijing and Tianjin respectively (Tian et al 2011). In urban areas, fireworks increase the PM 2.5 concentrations. For example, during the Chinese Spring Festival of 2012, fireworks increased the level of PM 2.5 by 80 times (Li 2012). Although fireworks consumption was reduced by 40% due to the recommendation of the local government, there are still approximately 260,000 cases of fireworks used during the Chinese Spring Festival of 2013 (Lu 2013). Additionally, roadside barbecues and construction creates dust, intensify PM 2.5 concentration in the air (BMPG 2013).

Fig. 10 Upper left: Dust in a construction site (Shidong Li, China Environmental News); Upper right: Roadside barbecue (Xianglu Li, Beijing Evening News); Lower left: Fireworks during the Chinese Spring Festival of 2013 (Xiaoguang Luo, Xinhuanet); Lower right: Crop stubble burning in the field of Weixian, Hebei (Jiqian Ma, China news).

3. Comparison between Beijing, London and Los Angeles

Haze problem has come up due to industrialization in many cities. For instance, Los Angeles has spent more than fifty years towards cleaning the air starting in 1940s. The Great Smog in London which killed at least 4,000 people in 1952 and the following few years is still in people's memory. These cases in London and Los Angeles may provide useful lessons for Beijing.

3.1. London

In December 1952, a severe pollution event named The Great Smog affected metropolitan London. A thick layer of haze and fog hung over the city for a week and caused serious health problems to the citizens for at least five years after that (Davis et al 2002). The haze disaster was caused by pollutants from fuel burning. At that time, the consumption of coal, diesel fuel and other solid fuels were used. Also, the coal-fired power stations in the Great London area intensified air pollution. During winters, people used coal to keep their houses warm. Thus, the inversion layer trapped the air pollutants in the absence of strong winds (Hughes and Mason 2001, GLACH 2002). In general, there are similarities between The Great Smog of London and the haze in Beijing, which are shown in Table 1.

Table 1 Similar pollution sources in London in The Great Smog and Beijing at present

Similar factors	London 1950s	Beijing (2011-present)
Heating in winter	275 Petajoules[6] house coal-burning per year	6 million tonnes of coal equivalent (180 Petajoules) for central heating system per year
Electricity generation	Coal-fired power was the major source of electricity generation	Coal-fired power is the major source of electricity generation
Vehicle exhaust	Exhaust from diesel-fuelled buses intensified pollutants concentration	Vehicles contribute to more than 50% of PM 2.5
Economic development	Postwar industrial growth with 2.5% annual growth on GDP in the U.K. (ONS 2010)	Booming economy with around 8% annual growth on GDP in China

3.2. Los Angeles

Smog started to occur in Los Angeles in the 1940s when the regional industries increased dramatically due to the requirement of the Second World War. Motor vehicle fleet grew rapidly and the pollution made the air visibility decline rapidly (Atwood and Kelly 1997). After the government has taken control during the past 50 years, the air became clearer, but Los Angeles still suffers from smog. Although the bright sunlight in California makes its beaches famous tourist attractions, it also raises photochemical smog. Moreover, human made factors also contribute significantly to the smog situation. Nitrogen oxides pollution is the main source of smog in Los Angeles, and this is brought by vehicle exhaust for 55% and construction for 21%, with additional contributions from factories and power plants of reactive organic gases (Vandersteen 2012). Mountain ranges surrounding Los Angeles also create an inversion layer (Medina 2007), thus contributing to smog. At present, the haze problem in Beijing caused by automobiles is similar to the situation in Los Angeles as shown in Table 2.

Table 2 Similarities between Los Angeles and Beijing.

Similar factors	Los Angeles	Beijing
Vehicle exhaust	55% of the nitrogen oxides pollution from vehicle exhaust	50% of PM 2.5 from vehicle exhaust

[6] One Petajoule equals to 10^{15} joules.

Industrial processes	50% of the reactive organic gases and 22% of the nitrogen oxides from industrial processes	More than 50 large iron and steel factories in the closest surrounding Hebei province bring heavy air pollution (nitrogen oxides and sulphur oxides)
Geographical condition	Located in the basin and surrounded by maintain ranges on three sides	Located in the plain and surrounded by maintain ranges on three sides

4. Lessons Beijing can learn

Bothe London and Los Angeles have been struggling with the haze problem for over 50 years. They both controlled the haze in two ways: control the air pollution and clean the fuel. Beijing may find out particular strategies to deal with its current haze problem according to the experiences of London and Los Angeles.

In London, the smog was mainly caused by sulphur dioxide emitted from burning unclean coal and diesel fuel. The Clean Air Act in 1956 focused on the problem and gave specific regulation on fuel quality. By taking control in two parts: 'integrated pollution control' and 'local air pollution control', London minimized industrial pollution through advanced techniques. Changing fuel types has apparent effect on reducing sulphur dioxide. Coal used in houses reached to 275 Petajoules in the year 1950, and reduced prominently speed after 1955. On the contrary, the consumption of cleaner fuels like gas, petrol and electricity grew quickly after 1960. The Annual average sulphur dioxide concentration dropped from 400mg/m^3 in 1950 to around 75mg/m^3 in 1980, while the annual average smog concentration dropped from 275mg/m^3 to 25mg/m^3. In 1999, the Mayor's Air Quality Strategy advised on traffic, construction, and the industry. While it is hard to reduce the quantity of vehicles, the government suggested reducing pollution from vehicle in short term and increasing cleaner vehicles and technologies in long term. In order to reduce the pollution caused by warming houses and buildings and heavier industries were moved out from urban area.

In Los Angeles, the smog problem at present is mainly concerned with vehicles. Regulation on vehicle emission was first introduced in California Motor Vehicle Pollution Control Board in 1959. Starting from 1963, many new cars were equipped with devices to reduce hydrocarbon emissions from engine crankcases. From 1975, the requirement of catalytic converter on vehicles and trucks significantly alleviated the problem of smog. Moreover, the fundamental challenge is to clean up fuels. In 1960s, motor vehicle fuel was regulated by the amount of highly photochemical reactive olefins in gasoline. Later on, methanol and natural gas was advocated to replace gasoline from 1970s. In the last decade of the 20th century, Low Emission/Zero Emission Vehicle program required manufacturers to develop electric cars with zero emission.

In 2008, Beijing enforced the surrounding factories to stop emitting waste for the Olympic Games, but the air quality deteriorated badly in several months after that. Forcible regulation on emission reduction does not work well in long term and London and Los Angeles both used it for short term. The fundamental way to solve the problem is to develop new technique to control the emission of pollutants, and change fossil fuel to clean fuel. Several practicable means are given below.

- Regulating the quality of gasoline and coal. Clean the fuel in manufacturing and transportation sectors to reduce PM 2.5 emission from factory and on road, and other pollutants emissions from coal-burning and fuel combustion.
- Gradually replacing coal with cleaner fuel. Lower the proportion of coal usage in heavy industry and electricity generation.

- Encouraging buying cars with higher energy efficiency or new energy automobiles.
- Constructing sustainable buildings to relieve the pressure on heating supply from the central heating system in Northern China.

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