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Response Measures to the Beijing Smog:

Assessment of Current Policies and Options for Improvement

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ABSTRACT OF THESIS submitted by:
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It has been three years since the heavy smog that now regularly attacks Beijing started to make major headlines. The government passed the Beijing 2013-2017 Clean Air Act with accompanying Regulations of Control of Air Pollution of Beijing to improve air quality. London and Los Angeles have experienced similar problems decades ago. This research aims at identifying and analyzing policy responses to air pollution in Beijing, London and Los Angeles, and exploring whether these responses and their results offer opportunities for learning across the different cities, with particular attention to Beijing. The main lessons revealed by the analysis where opportunities for learning exist include: limiting population growth in the metropolitan area; establishing a scientifically credible evidence base for the lay out for the city; establishing a sound and comprehensive legal system; improving the quality of gasoline used; investing in research on Near Zero Emission and clean energy technologies; and taking advantage of other high technologies relevant for controlling air pollution.

Keywords: environment; policy; assessment; air pollution; smog; China

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Table of Contents

List of Tables

List of Figures

List of Abbreviations

AQI	air quality index
AQMD	Air Quality Management Districts
CARB	California Air Resource Board
DPSIR	drivers-pressure-state-impact-response
EC	elemental carbon
EC Directive	European Commission Directive
EPA	Environmental Protect Agency
LA	Los Angeles
NH^{4+}	ammonium salt
NO^{3-}	nitrate
NO_x	nitrogen oxide
OM	organic matter
PM	particular matter
PM2.5	particulate matter ≤ 2.5 pm in aerodynamic diameter
PM10	particulate matter ≤ 10 pm in aerodynamic diameter
PSD	Prevention of Significant Deterioration
SO_4^{2-}	sulphate
UK	United Kingdom
US	United States
VOC	volatile organic compound
WHO	World Health Organization

Chapter 1 Introduction

In this thesis, I will discuss the current response measures in Beijing to deal with the city's severe smog, and assess if these solutions can be effective in solving the problem. Two additional cases, London and Los Angeles will also be analysed, to explore whether their strategies and experience with regard to air pollution offers lessons to Beijing. Based on the analysis, recommendations for both policies and actions to increase the effectiveness of Beijing's air quality measures and to reduce the impact of smog will be discussed. The reason I compare London and Los Angeles with Beijing is that both of them are major cities with some similar characteristics to Beijing, such as large population and large number of motor vehicles. While this research is looking at air pollution, megacities of the world have many other common sustainability problems, such as traffic, where similar opportunities for learning may occur. Despite the many potential similarities between the cities, there are also many rather fundamental differences. This applies not only to the biophysical aspects of a city, its different geography, climate or urban form, but also its governance, policies and institutions, the technologies used, the economic rules and not the least the culture and habits of the population. These differences also make comparisons and transferring lessons from one context to another challenging.

1.1 Background

China is a fast-developing country, as the GDP is growing at the pace of around 10% each year (Netease 2015a). The industrialization of China also increases the demand of coal consumption (Fang et al. 2014). Thus the environment is suffering from problems due to the high speed of development. As the capital of China, Beijing has higher rates of industrialization than average and as a result, it shows more problems than other cities. Smog, or fog and haze, have become a serious problem in China, especially in Beijing in recent

years. Particular matter smaller than 2.5 micrometres (PM2.5) is the major component of Beijing's smog. While smog events in Beijing go back many years, the public began to be seriously concerned of smog at the start of 2013 when heavy smog attacked Beijing. 25 out of 31 days in January 2013 people suffered from heavy smog, and $PM_{2.5}$ concentration in Beijing passed 1000 $\mu g/m^3$, which is 40 times higher than the WHO (World Health Organization) permissible level (Luo 2013; Guan *et al*. 2014). The number of hospitalizations also increased during these smog days, because PM in smog (along with other pollutants) has a strong impact on the human respiratory system (Zhao 2013). From 2013 January data (Fig 1) one can see that on the days with the worst air quality PM2.5 was the main pollutant. As these data show, reducing PM2.5 is the most important. However, other pollutants are also of concern, especially because the concept of PM2.5 was only introduced in 2011 in China it, which means there is no PM2.5 monitoring data before 2011. Therefore, for longitudinal analysis, this research has to rely on other pollutants statistics (Yang 2012).

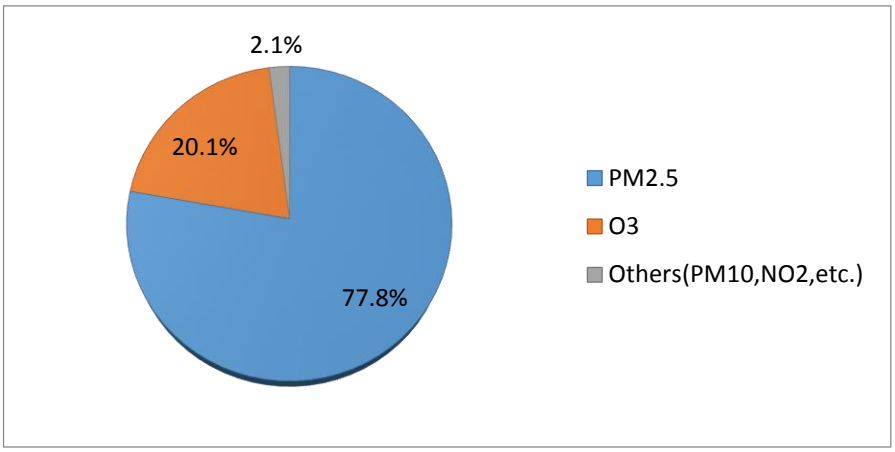

Fig 1. Proportion of pollutants in smog on the most polluted days of January 2013 (Source: Beijing Evening 2104 Jan 02)

Historical records show that Beijing has suffered from smog for around 700 years (Yun 1999). However, at that time people did not have the tools to assess how heavy the smog is, thus more detailed information is not available. Only in recent years did people start to know the word "smog" and begin to be concerned about it. While air quality immediately before

and during the 2008 Olympic Games in Beijing was rated as good (Zeng *et al.* 2010), good air quality did not last. By January 2013 the problem attracted everyone's attention, and PM2.5 became a popular word in daily life for every Chinese.

The Beijing Municipal Environmental Protection Bureau released information on the source of PM2.5 in Beijing's air. In any given year, PM2.5 coming from other regions takes up 28-36%, while local emissions contribute 64-72%. In local emission, traffic takes up 31.1%, coal burning 22.4%, industry 18.1%, dust 14.3%, and other sources 14.1%, including cooking oil, vehicle repair, livestock breeding, and architectural painting.

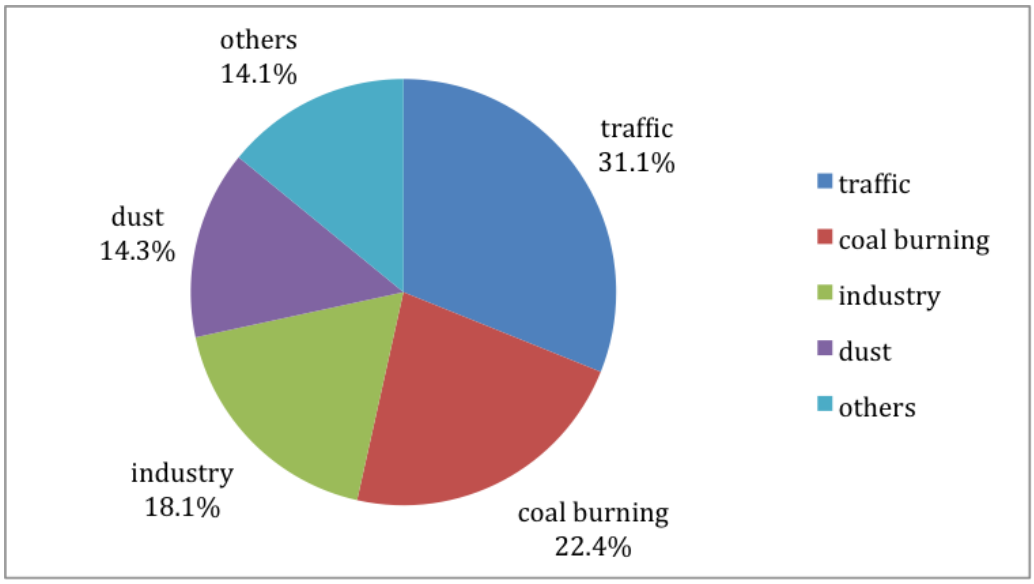

Fig 2. The source of Beijing $PM_{2.5}$

(Source: Beijing Municipal Environmental Protection Bureau)

As for the components of PM2.5, the main components are organic matter (OM), nitrate (NO^{3-}), sulphate (SO_4^{2-}), crust derived matter and ammonium salt (NH^{4+}), the percentages are 26%, 17%, 16%, 12%, and 11%. Apart from these factors, there are also elemental carbon (EC), trace elements and some other components (Beijing Municipal Environmental Protection Bureau 2014). Figure 3 shows that organic matter and nitrates take up the largest portion in PM2.5.

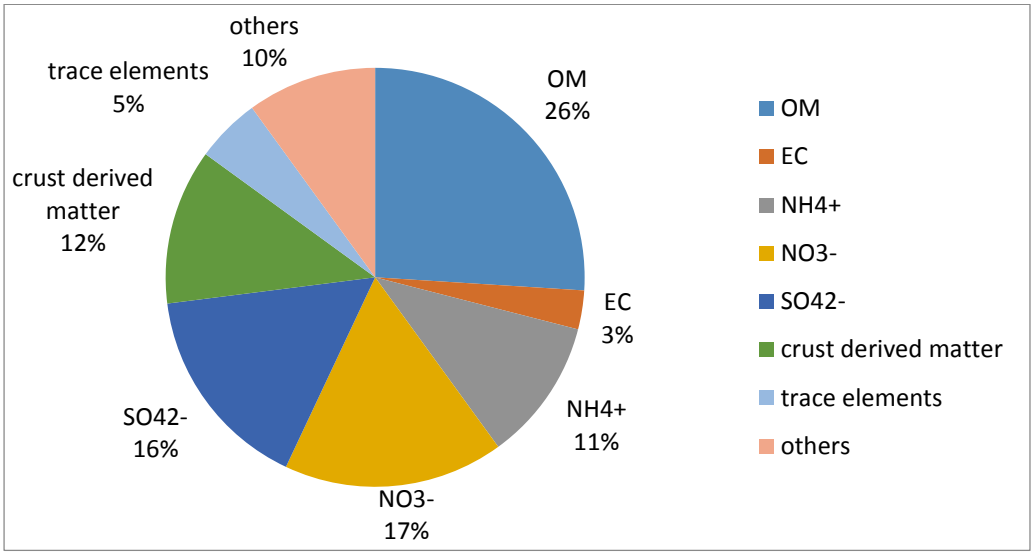

Fig 3. The components of Beijing $PM_{2.5}$

(Source: Beijing Municipal Environmental Protection Bureau)

Dust, sulphuric acid and heavy metal often accompany smog. When people breathe in these substances, they will get into human's respiratory system, which is very harmful and extended exposure may even cause death (Jiang and Wang 2014). Zhou's research shows that smog has a significant association with mortality (Zhou *et al.* 2015). But that is not the only social impact of smog. Apart from influence on human health, smog also causes a variety of other problems to society. For example, last year, on October 26th, due to smog, many flights had trouble with landing in Beijing or taking off. Apart from such problems, the smog may also reduce the intensity of ultraviolet radiation reaching the surface and thus acting as a disinfectant, thus increasing the survival of pathogens that can cause infectious diseases (Sun and Huang 2014).

Besides biophysical factors, policy is also an important factor in smog. One of the main problems is that China's environmental laws have many vague details. For example, the 29th provision of *Environmental Protection Law* states that enterprises that heavily pollute the environment need to put in place treatment measures on specified time lines. However, there

is no definition for 'heavily polluted' in the law, thus making it difficult for law enforcement agencies to carry out their work (Chen 2015). Besides, the latest revision of the *Environmental Protection Law* was in 2000, which means during the past 15 years environment did not develop with the economy. The law is outdated and can no longer meet current environmental protection needs (Han 2013).

1.2 Thesis Objectives

The main objective for this thesis is looking at how air pollution as an increasingly significant problem of urban growth, and what cities in different stages of development and different stages of dealing with their air pollution issues can learn from each other. Beijing will be the subject to discuss in this thesis, as with two cases of London and Los Angeles. Beijing citizens are not satisfied with the air quality, and their numbers are growing year by year (Du 2013). As the current situation is approaching crisis proportions, there is no doubt that improvements need to be made. Since the Beijing Municipal Environmental Protection Bureau has already identified the main pollutants and pollution sources, the targets for strategy development and implementation and achieving improvement are known.

I am interested in identifying and analysing policy responses to air pollution, and whether these responses offer opportunities for learning across the different cities or within a particular city like Beijing itself. The Beijing government announced a clean air act to improve the air quality in 2013. It is very detailed but consequences are not obvious so far, so a coarse-scale assessment will be made in this thesis about the Act, and recommendations will be given to improve it. The cases of London and Los Angeles will be reviewed to see if their experience with air pollution policies may also be applicable to Beijing. Given some structural similarities between the cities, such as the prevalence of transport in both Beijing's

and London, learning from others' experience may help make the problem easier to solve (Zhang *et al.* 2014).

So in this thesis the following questions will be addressed:

- What are the main physical sources of Beijing's smog?
- What does Beijing do to solve the problem? Is Beijing's current effort working so far?
- What are the similarities and differences between the air pollution problems of Beijing on the one hand and London and Los Angele on the other?
- How did London and LA solve the problem? Is there anything in their experience that can be adapted to Beijing?
- What can be done in the future for Beijing to reduce the smog problem?

At last, a summary of all the question will be how a city like Beijing can learn from its own successes or mistakes and combine its own lessons with what it can learnt from abroad.

1.3 Outline

In Chapter 1 I have provided the background and objectives for this thesis. Chapter 2 describes my methodology. Chapter 3 will be a section to introduce conceptual approaches to air pollution. Chapter 4 discusses the Beijing 2013-2017 Clean Air Act. I will translate and discuss some key points of the act first and then review how it works actually. Chapter 5 is the two cases of London and LA, I will summarise their replies to the air pollution problem. Chapter 6 is the assessment of Beijing current policies and actions, it will contain both government and public, and economy, industry and traffic will be the mainly topics. Chapter 7 is the summary to respond the questions of this thesis objectives.

Chapter 2 Methodology

In this chapter I will describes the approaches I use in my thesis and the limitations I meet to do the research.

2.1 Research approach

My research is basically based on literature reviews, in accordance with some informal interviews and a further exploration of a documentary. I started my research with an extensive literature review of Beijing's current smog problem. Besides, I also find out the source of the pollution, which I think will be great helpful to my thesis as I have a clear target. And then I did literature review on the London and LA cases. From my literature review I found that they have some useful experience such as how they improve their legislation system that might be helpful for Beijing, and I also found that traffic is a main pollution source for both cases, thus many solutions can be adapted to Beijing's issue. Later on, I read through the Beijing 2013-2017 Clean Air Act, which looks reasonable and wholesome. However, the situation of heavy smog does not really be improved so much. So I continue my research with discussion on the clean air act. Apart from this, there is a very important documentary *Under the Dome* appears in China. It was made by a famous Chinese journalist Jing Chai, whose daughter got cancer at birth. She thought it was the smog to blame, so she made this documentary movie to appeal for more attention on smog (Chai 2015). It has many useful ideas that have great inspiration to my thesis. So I follow the track of the documentary to figure out what is the real problem in the smog problem. After that, I combined all the resources I have to summarize the possible improvement for the Beijing smog, and write this thesis.

I also use a simplified version of the drivers-pressure-state-impact-response (DPSIR) framework to do my research. Drivers refer to human activates and economic sectors explain that why this problem needs to be settled; pressure refers to the production and consumption activities that lead to emissions; state refers to the air quality, which is represented by the concentration of key pollutants in ambient air; impact is related to impact on human health, but also economic impact, such as cost, and impact on Beijing's natural environment; and responses stands for policy responses, which is the most interested part for my thesis (Kristensen 2004; Jäger *et al.* 2007).

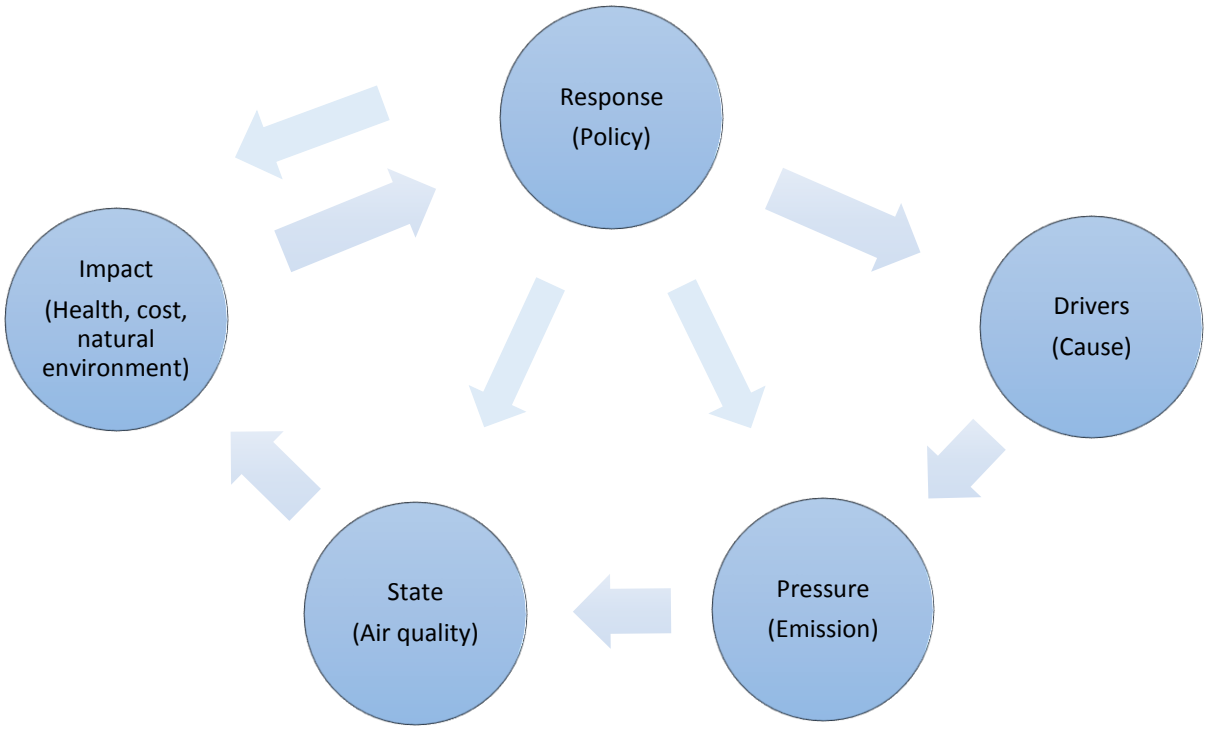

Fig 4. DPSIR framework

2.2 Limitation

Due to the time scale I do not get the chance to talk to policy makers in Beijing, thus some of my suggestions might be too idealization and not possible to be carried out. Besides, it is not possible for me to collect the primary data in a short period, so all the data in my thesis are

taken from other researches. Though I tried to use the most data from official source, however I cannot guarantee the data is neutral.

2.3 Analytic framework

As I have mentioned in the approaches section, my analytic framework is DPSIR. The smog problem relates with many aspects, so the discussion will includes various people and areas. Traffic, industry, public and dust are the main four sectors to discuss in the pollution source. It is a little different from the Figure 2, because coal burning can be classified into industry and public. Policy, economy and environment are three indivisible factors. So when I consider whether a policy is feasible, smog is not the only thing I will take into consideration but also economy, such as the cost. Apart from this, when talking about the London and LA cases, I will clearly identify several questions as follows:

- What is each strategy targeting at?
- What is the type of measures be used?
- How are the measures backed up by their legislation?How do they report on progress and adjust policies in light of changing conditions?
- What enforcement mechanisms do they use to make sure everything going under control?
- What is the role of public and stakeholder in participation?

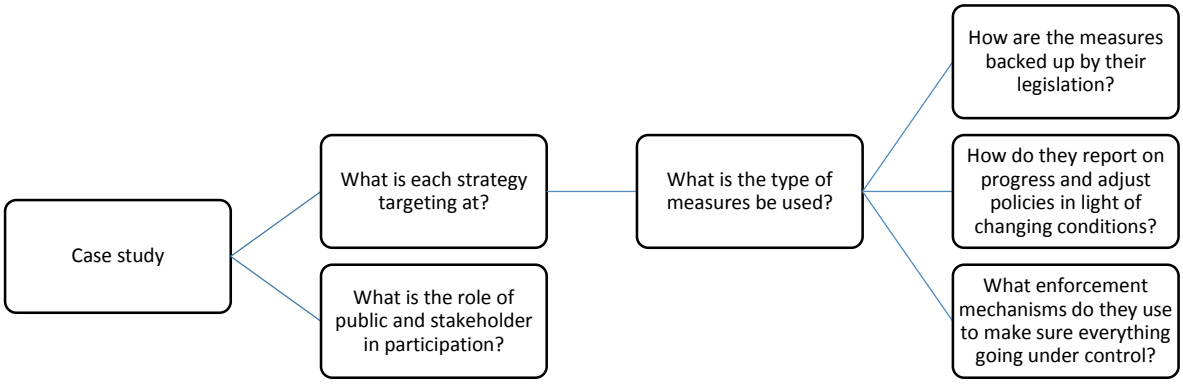

Fig 5. Analytic framework

Figure 5 shows how to analyze responses in this research. Then when assess the Beijing's situation, these questions will also be addressed and thus we can have a clear conclusion of what is the difference between Beijing and these two cities, and focusing on the difference I will give some recommendation to improve the situation.

Chapter 3 Conceptual approaches to air pollution

Air pollution is a long-term social problem. The cause can be various, and the components can be different. But no matter what kind of air pollution, they all have the similarity that they have impact on human's life (Vallero 2014). In this chapter, I will summarize the conceptual approaches to air pollution.

3.1 Air quality data

Study shows that large cities have many similarities in air quality data. In general, common pollutants include SO_2, NO_2, PM and ground-level ozone. The worldwide statistics indicate that SO_2 is no longer a problem for large cities. Most cities have the WHO standard level of NO_2 except Beijing, which is approximately three times higher than the standard. PM is a major problem for all Asian countries except Japan, while ground-level ozone is a global problem (Baldasano *et al.* 2003).

The gaseous pollutants, including SO_2, NO_2 and ground-level ozone, come from power plants, domestic heating, industry, vehicle and biofuel. Desulfurization, low-NO_x combustion, improving the coal quality, and cleaner industrial facilities can help to reduce the emissions. The PM emissions are from combustion soot, industrial dust and fugitive dust (Chan and Yao 2008).

3.2 Conceptual approaches

Air quality interventions can reduce different sources of PM, and the intervention scale can be large to nation or small to the specific local area. Air quality interventions often last for a long period. It may affect environment, transport, energy and health. The process might take long time and the outcome cannot often be seen immediately (Burns *et al.* 2014).

Air quality interventions are response measures for the government, while for the residents "energy ladder" is a method to reduce air pollution. Figure 6 shows an example of energy ladder. The more developed of a family, the more cleanliness, energy efficiency and cost is the fuel. Therefore, moving up the ladder can reduce the pollutant emissions (Kirk *et al.* 1994).

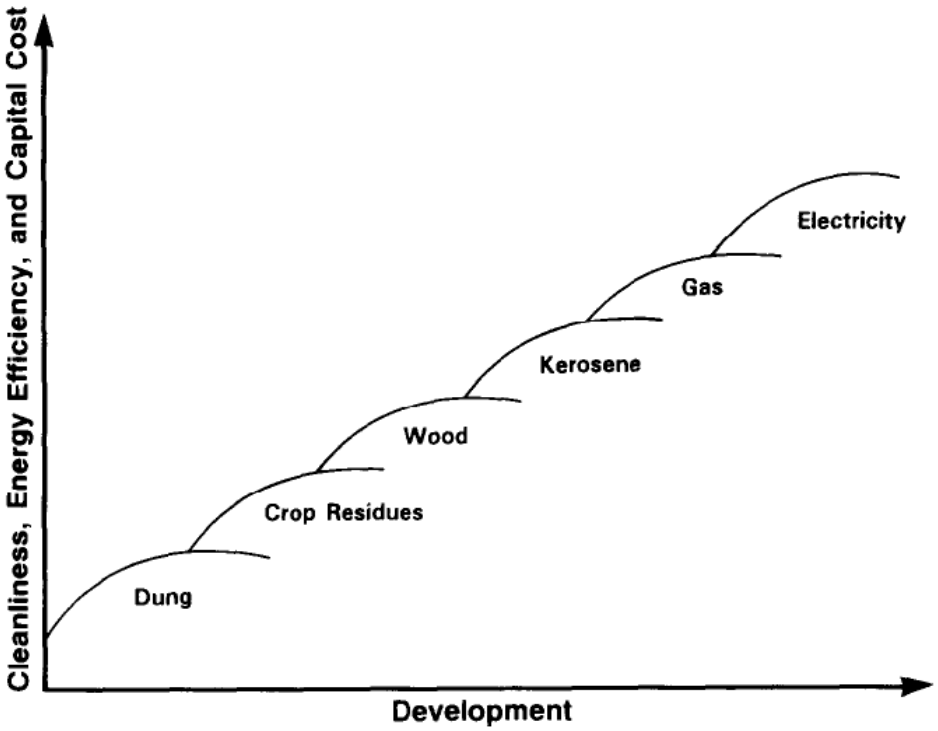

Fig 6. Household energy ladder typical in South Asia

(Source: Air pollution and the energy ladder in asian cities, 1994)

Reducing demand for activities that may cause pollution is also a possible method to control air pollution. For example, congestion charge is a way to control the vehicle number so as to reduce emissions from vehicles. Researches have shown that this method has benefit on air quality (Beevers and Carslaw 2005; Tonne *et al.* 2008; Eliasson *et al.* 2009).

Though it may sound corny, greening is an effective method to improve air quality as trees can remove many kinds of pollutants (Nowak et al. 2006). There is not much available space

for big cities to build a forest, thus new ideas are in demand to enlarge the greening area. Research has shown that green roof is a potential method, as it can remove quantity of air pollutants (Yang *et al.* 2008).

Chapter 4 Beijing 2013-2017 Clean Air Act

Beijing 2013-2017 Clean Air Act was carried out in 2013 to respond to the call of a national plan-Air Pollution Prevention Plan. Because Beijing suffers from heavy smog and the air quality is far from the national new standard, this clean air act aims to improve the air quality to a higher standard in five years. In this chapter, I will go through the act, and focus on some key points to discuss.

4.1 Aim and objective of the act

The clean air act aims at reducing the pollutant emission and improving the air quality, especially focusing on PM2.5 pollution. It tries to adjust the energy and industry structure, and to achieve a result to develop environment and economy at the same time. The objective is to reduce PM2.5 by 25% and control it under 60 μg/m^3 in 2017. However, it is still on a high level compared to the safe range provided by WHO, which is 25μg/m^3 (WHO 2006). From this point of view, the standard of the clean air act might be not high enough. Apart from this, by this standard, the average reduction should be 5% each year, but the Beijing Environment Protection Bureau showed that the reduction rate is 4% in 2014 compared to 2013, so whether the aim can be achieved by 2017 is doubtable (Beijing Municipal Environmental Protection Bureau 2015e).

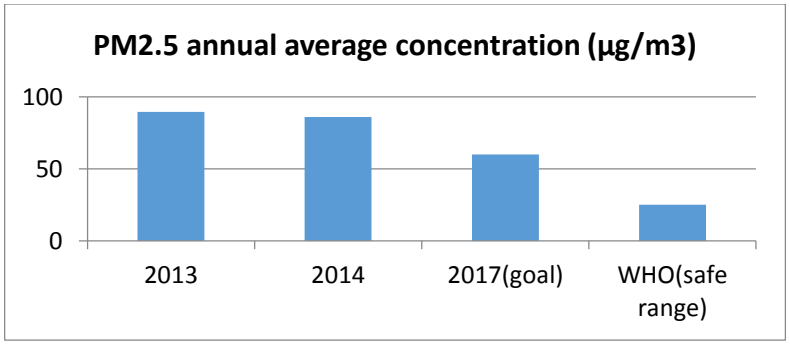

Fig 7. PM2.5 concentration trend and goal

(Source: Beijing Municipal Environmental Protection Bureau)

4.2 Emission reduction plan

The clean air act contains eight aspects of emission reduction, including source pollutant emission control, adjusting energy structure, adjusting traffic structure, improving industrial structure, pollution abatement, urban refined management, eco-environment construction, and heavy air pollution emergency plan.

(1) Source pollutant emission control

Four sub plans are mentioned in this plan, of which optimization of urban functions and spatial layout is a long-term project and impossible to be done within 5 years, so it will not be discussed in this thesis. Apart from this, controlling the population scale is a good recommendation. There is no doubt Beijing has too many people and the population needs to be controlled, however, as the capital of China, how to control the population is quite a hard question. In this act it only mentions refine of resources distribution, which is far from solving the problem. Controlling the vehicle number is also mentioned in the act. The aim is to control the number within 6,000,000 at the end of 2017, while the number at the end of 2013 is 5,437,000 (Beijing Traffic Management Bureau 2014). The last sub plan is the control of high-polluted industries, such as steel and cement. The way to control them is strictly forbidden to build related factories in Beijing.

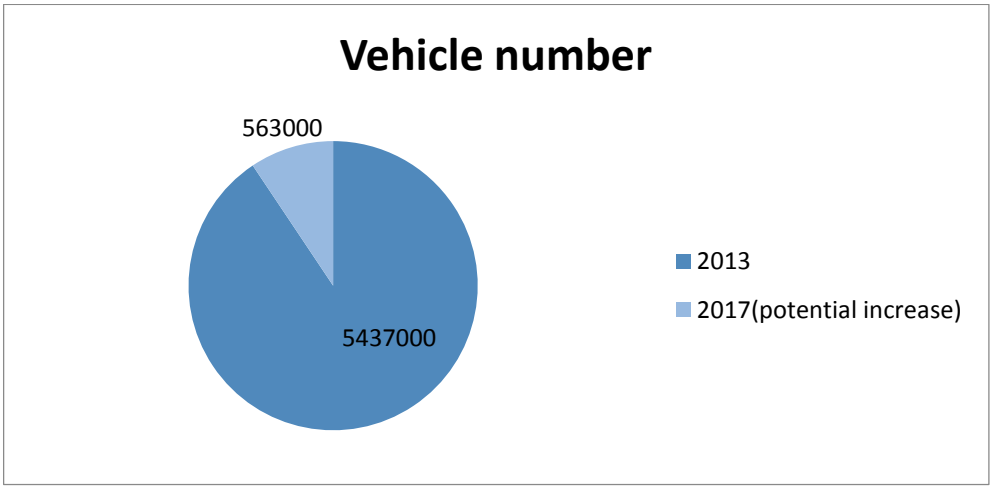

Fig 8. Control of vehicle number

(2) Adjusting energy structure

Clean energy and renewable energy are considered to be used to replace coal. The act aims to cut down coal consumption 13,000,000 ton till 2017 compared to 2012, the final goal is to control the coal consumption within 10,000,000 ton and takes up less than 10% in the whole energy system. In general, the main point is to replace coal with electricity and natural gas, or replace low quality coal with high quality coal. By 2017, the urban citizens do not use coal and the rural citizens do not use low quality coal. Besides, the act also emphasizes enhancing the energy consumption efficiency. It mainly relates with using efficient energy system in new building.

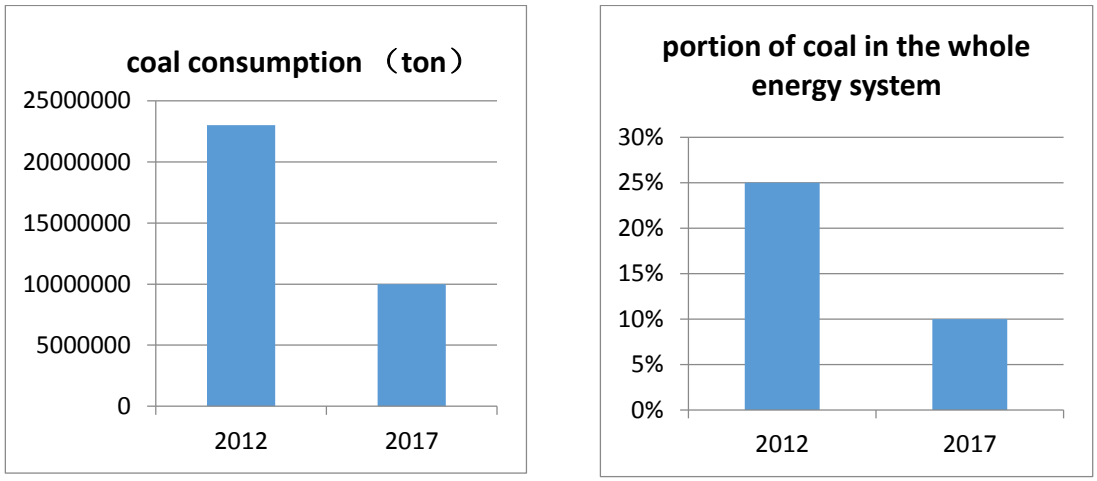

Fig 9. Coal changes in energy structure

(Source: Beijing government)

(3) Adjusting traffic structure

Adjusting traffic structure includes two parts: one is the vehicle; the other one is the energy for the vehicle. Improving the public traffic network is recommanded in the act. Though the public traffic tickets have been raised at the end of 2014, but data has shown that it does not lead to an increase of private cars use (Cao and Zhang 2015). For the past *Qingming* Festive, which is a three-day vacation for people to visit graves, the Beijing Public Transport increases its capacity and adds 14 routes for visiting graves (Beijing Public Transport 2015). It seems

that this plan is working in Beijing now. As to the energy for the vehicle, the act proposes that relative department should encourage people to buy and use new energy vehicles. However, there is no policy to encourage people to buy new energy vehicles so far. Besides, the quality of diesel and gasoline is also stressed in the act, which will be discussed later in chapter 6.

(4) Improving industrial structure

The act announces that Beijing has decided to use higher standard than the national's to manage the industry. It achieves the goal that eliminates outdated and high-polluted industry in 2014, one year before the national Twelfth Five-year Plan. Small polluting enterprises will be shut down till the end of 2016. Eco-industrial Park will be built and all the industries are required to develop new clean technology.

(5) Pollution abatement

As to pollution abatement, the act claims that Beijing will have higher standard of waste emission than before, and will complete a system of air pollutants emission standard. Nitrogen oxide, dust and volatile organic compound (VOC) are three main pollutants that are focused on in the act. By the end of 2014, all the cement factories in the urban area will complete denitration process. And by the end of 2015, the rural area will also accomplish the goal. The thermal power plants must upgrade their skills and facilities in order to decrease the amount of dust they released. Besides, during the transportation and storage period, they also need to guarantee an enclosed space in case the dust flow with the wind. The goal for the management of VOC emission is a reduction of 50% till 2017 compared with 2012.

(6) Urban refined management

The aim of urban refined management is reducing fugitive dust quantity. Construction dust, waste spilled out on road, outdoors barbecues and vehicle emissions are mentioned in this

plan. The goal is reducing 20% fugitive dust till 2017 compared with 2012. In order to manage the fugitive dust, Beijing decides to use recycle water to wash main roads every day starting from 2015. Till 2017, the washing methods will spread to rural area, and hopefully the recycle water consumption can reach an amount of 300,000 m^3. As to the household garbage, the goal for 2015 is that the processing capacity increases 18,000 ton every day. And the garbage transport will be done fully enclosed, preventing spilling out waste on road. The outdoor barbecues now face with more strict rules. Some regions are divided in which this activity is forbidden. Besides, incinerating waste or straw to do barbecues is strictly forbidden. The environmental protection department will strengthen supervision on cooking oil fume as well.

(7) Eco-environment construction

Three actions are proposed to construct eco-environment. The first action is improving the greening coverage. By 2017, the rate of woody plant cover can reach 60% in the whole city. In the plain area, the Millions Acres Afforestation Project will be done by 2016. While in the mountain area, Beijing and Tianjin Sandstorm Source Control Project, Taihang Mountains Afforestation Project and Forest Health Management Project are kept carrying forward. The second action is expanding water area. Yongding River, Chaobai River and Beiyun River will get comprehensive control and management so as to expanding water area. The goal for 2017 is a 1000 hectare cumulative increase, of which contains 10 wetland parks and 10 wetland protection areas. The third action is implementing ecological restoration. Abandoned mine and wasteland in suburbs will get ecological restoration, and the environment has a substantial improvement by 2017.

(8) Heavy air pollution emergency plan

The act suggests that heavy air pollution emergency should be brought into the city emergency management system. The relative regulation should also be revised, including traffic restriction, polluting factory shutdown temporary, outdoors construction shutdown, primary and middle school suspend classes, and available meteorological intervention. Besides, the act also advance that Beijing should have a linkage mechanism with surrounding cities to deal with heavy air pollution.

4.3 Compliance and enforcement mechanism

Six actions consist of compliance and enforcement mechanism, so as to guarantee the clean air act will be applied with valid support.

(1) Perfecting regulation system

Perfecting the air pollution regulation system in Beijing is the main goal for next step, as well as positively promoting legislation for *the regulations for the control of air pollution of Beijing*.

(2) Innovating economic policy

Four economic policies are raised to limit the air pollution. The first one is taking the advantage of resource and price leverage, following the rule of "using more paying more" and "more emission more burdens". A sound price system of resource and environment can reduce much unreasonable waste. New energy saving and emission reduction mechanisms should be positively promoting. For example, the whole city will uniform the heating price gradually, and encourage people to use clean energy for heating by promoting same price for bottled gas. Besides, the government also decides to encourage rural area to use electricity instead of coal by a discount of electricity price. The second policy is making full use of tax

adjustment. Renewing the price for SO_2 and NO_x emission and starting to impose fees on VOC, construction dust and business cooking oil fume are two targets for the following steps. Besides, traffic jam fee is also being considered to reduce the vehicle quantity in city center. The third policy is developing the restriction function of financial instruments. The Beijing Municipal Environmental Protection Bureau needs cooperate with Beijing Municipal Bureau of Finance to accelerate emission trading, green credit and green securities. Collecting enterprise information into bank credit reporting system, so as to restrict enterprise that has illegal environmental record to get loan or financing from the stock market. The fourth policy is giving full scope to the guiding function of finance. Allowance or subsidy will be given to support clean energy transformation and eliminating polluted enterprise. Good model, which has higher standard for energy efficiency and pollution control, will be given financial support by the government.

(3) Strengthening the support of science and technology

The prevention of air pollution will be concerned as the main content of *Science and Technology Beijing* strategy. Beijing Municipal Environmental Protection Bureau and Beijing Science and Technology Commission will take the advantage of science and technology resource in the capital. For example, they can organize scientific research institutions, colleges and universities, enterprise and other relative institutions to develop a further study of the cause of air pollution formation, transport law, analysis of pollutant source, treatment technology, impact to human health, and long-term forecasting for air quality. Apart from this, strengthening the cooperation and communication with foreign countries is also stressed, to learn the advanced concept for the control of air pollution and technology.

(4) Strengthening organizational leadership

The act suggests to found Beijing Atmospheric Pollution Comprehensive Treatment Leading Group, which is responsible for organizing research of atmospheric pollution prevention policy and actions. Every district should have a branch group and make sure all the work can be put into effect.

(5) Delimiting and carrying out the responsibility

The government will delimit the responsibility of this act, and sign goal responsibility with branch governments, relative departments and enterprises. Besides, the government will draw up annual clean air act plan, which has detailed goals, missions and measures. By 2015, a mid-stage assessment will be made and the act will be adjusted.

(6) Establishing strict evaluation and accountability mechanism

A strict evaluation and accountability mechanism will be designed by the government. At the start of each year, district governments, relative departments and enterprises must report their task achievement and get assessment, and then the result will be announced to the public. Department or person that fails the assessment will get punishment.

4.4 Public participation

Preventing air pollution is a common responsibility for the whole society. The government should carry forward the concept of ecological civilization, and accelerate the foundation of capital environmental culture. Knowledge popularization, education and guidance, public presentation and public service advertising are practical methods to raise public awareness.

(1) Enterprise self-discipline pollution control

On the one hand, enterprises should obey the environmental regulations, making sure that pollution treatment apparatuses work well and the emission meet the standard. On the other hand, the government should encourage enterprises developing environmental protection management.

Table 1. Enterprise self-discipline pollution control

Enterprise type	Actions
Industrial enterprise	a) Taking in advanced pollution treatment experience from the same kind of industry at home and abroad to strengthen pollution control. b) Highly polluting enterprises such as building material and chemical industries need to reduce capacity, transforming and upgrading to a high technological new path of industrialization with less resource consumption and waste emission. c) Enterprises like cement and thermal power need to develop efficient denitration measures. d) Enterprises like petrochemicals and printing need to strengthen VOC pollution treatment, reducing energy consumption and waste emission.
Construction enterprise	a) The enterprise must meet the Green Construction Management Requirements to make sure the construction site road got harden and covered and the transport vehicles washed clearly before working. b) Construction waste and dust must be collected in closed container or package. c) When the construction work begins, the enterprise should

	spilling water to prevent dust pollution at the same time. d) Enterprise should choose low emission vehicles, adopt new technology, and use environmentally friendly painting.
Transportation enterprise	a) The concept of green transportation should be spread actively. b) Enterprise should buy and use low emission and new energy vehicles on their own initiative. c) Vehicles should be maintained regularly. d) Fuel-efficient driving, emission on standard and avoiding spilling out waste on road are the basic goals.
Environmental protection enterprise	a) New technology of road sweeping and cleaning will be adopted, including advocating washing the road with recycle water. b) Burning leaves or waste in the open air is regarded as illegal behavior and must be strictly forbidden.
Catering enterprise	a) Enterprise should use clean energy on its own initiative, and stop using coal. Besides, outdoor barbeques should also be avoided. b) Enterprise also had better to install cooking oil fume purification facilities, as well as strengthen regular maintenance to make sure the emission meets the standard.
Other service industry enterprise	Shopping mall, supermarket, hotel and entertainment should carry out wall and roof greening, energy conservation transformation, electricity conservation transformation for evening lighting, and clean energy transformation for heating apparatus.

(2) Public self-conscious pollution reduction

Public is the direct practitioner for protecting atmospheric environment and improving air quality. The government should lead the public to build a green environment. First, the government should advocate green consumption, including health diet, not using too much oil to cook food, avoiding outdoor barbeques, choosing energy-efficient furnishing and environmentally friendly painting, not using coal, turning off lights when leaving and opening windows instead of using air conditioner in summer. Second, the government should encourage green travel, such as travelling by bike or on foot. Third, the government should promote environmental protection education. Fourth, the government should organize public benefit activities.

(3) Social supervision pollution prevention

Social supervision is a good way to find those problems that government cannot realize easily. It can be a powerful tool in the process of solving Beijing smog. So the government should strengthen information disclosure, such as releasing the air quality of each district through Internet or TV. Besides, the government should make sure the supervision channels are unblocked. Several hotlines will be perfected and citizens are encouraged to report illegal air pollution activities through them. What's more, the government should also encourage media to take part into the supervision.

Chapter 5 Two cases: London and LA

London and Los Angeles suffered from severe air pollution in history. They used to represent cities falling into air pollution trouble. However, after decades of endeavour, the air quality of these two cities has improved to a much better level. In this chapter, I will deeply study on these two cases, trying to find out their successful policies and actions.

5.1 London case

The world known killer smog happened in London from December 5th to 9th in 1952, during which around 12,000 people died because of the smog (Dooley 2002). Research found that the dominated part for the smog pollutants is soot, while a number of other particulars such as smelter spheres, fly ash, gypsum and sodium chloride particles were discernible as well (Whittaker *et al.* 2004). So the London government made many efforts to reduce coal consumption after the Great Smog, and a rapid decline showed within 5 years (Zhang *et al.* 2014). When it came into 1970s, traffic pollution took the place of industry pollution and became the biggest pollutant source (Yang and Zhang 2014). Series of actions were made to improve the air quality. In general, air quality is much better in London now than it used to be in 1952. The mean annual PM10 level was 300 μg/m^3 in 1952, and approximately 3000 μg/m^3 during the Great Smog days, but in 2002 it decreased to 30 μg/m^3 (Davis *et al.* 2002). Though it took London a long time to fight with the smog, and some strategies might not be perfect, we can still learn some useful experience from the London case as they have made significant breakthroughs.

5.1.1 Clean Air Act

In order to respond to London's Great Smog of 1952, the Parliament of the United Kingdom passed the Clean Air Act 1956. It focused on the smoke pollution, which is London-type

smog actually, and created smoke-free zone so as to reduce the major pollutant from burning of coal for heating (Zhang and Samet 2015). It is clearly that this clean air act has a very specific target. The aim is to reduce the emission of dark smoke, and all the content is about it. All the coal burning power station must be shut down in the city area, and they can only be rebuilt in suburb area if it is really needed. Besides, smoke free zones are set in London, and traditional family used stoves are also get renovated (Yang and Zhang 2014). Research showed that the clean air act had great effect on the smoke control-a steady reduction of the smoke concentration after the Clean Air Act put into practice is great evidence (Auliciems and Burton 1967).

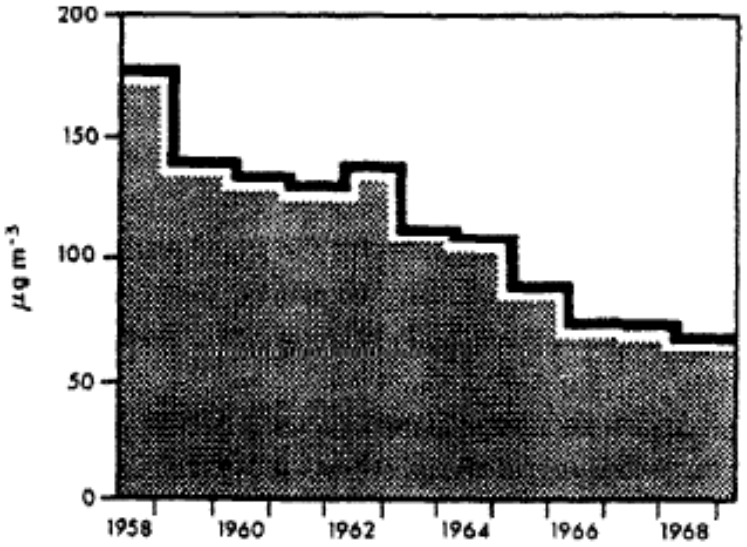

Fig 10. Average smoke concentration near ground level in the UK 1958-1968

(Source: Royal Commission on Environmental Pollution, 1971, first report, p.17)

The Clean Air Act was revised in 1968, and the key change was that Clean Air Act 1968 introduced the use of tall chimneys to disperse air pollution for industries burning coal, liquid or gaseous fuel. Though there is no available data to show the consequence of such new method whether really improved the air quality or not, the UK government is still requiring the height of chimneys in the latest policies (GOV.UK 2014). Later in 1993, the Clean Air Act 1993 was carried out, which is a consolidation of the earlier acts (Beattie *et al.* 2001).

5.1.2 Back up legislation and enforcement mechanism

The UK government also carried out a series of legislation after the Clean Air Act to perfect and back up its air pollution policy system. After 1970s, the smoke pollution was no longer the main problem for London, while traffic pollution became a big problem (Yang and Zhang 2014). So there are a lot of new regulations focusing on traffic in the following policies.

Table 2. Other air pollution acts applied in the UK

(Source: History of Air Pollution in the UK, Air Pollution website)

Year	Act	Key point
1970	EC Directive 70/220/EEC	Set requirement for positive ignition engines of motor vehicles, such as limiting emissions of CO and hydrocarbons from petrol engines.
1972	EC Directive 72/306/EEC	Set requirement for diesel engines of motor vehicles, such as limiting black smoke emissions from heavy-duty vehicles.
1974	Control of Pollution Act	Allow for the regulation of the composition of motor fuels. Also limit the amount of sulphur in fuel oil. Public can complain or give advice to the government if they have any thought about the environment.
1975	EC Directive 75/441/EEC	Set up a procedure for exchanging air quality information between Member States.
1975	EC Directive 75/716/EEC	Sulphur content of certain liquid fuels is the main concern. Define two types of gas oil, which are diesel and heating oil, and set sulphur limits for these fuels.

1978	EC Directive 78/611/EEC	Set requirement for the lead content of petrol, and limit the maximum permissible lead content of petrol to 0.4g/L.
1979	International Convention on Long Range Transboundary Pollution	Introduce to control the transboundary effects of acid rain and limit emission of acidifying pollutants.
1980	EC Directive 80/779/EEC	Set air quality limit values and guide values for SO_2 and suspended particles.
1981	The Motor Fuel (Lead content of Petrol) Regulation	Limit the maximum amount of lead in petrol to 0.4g/L.
1982	EC Directive 82/884/EEC	Limit value for lead in the air.
1984	Directive 84/360/EEC	Establish a common framework intend to fighting with pollution from industrial plants throughout the community.
1985	EC Directive 85/210/EEC	Allow for the introduction of unleaded petrol.
1987	EC Directive 88/77/EC	Measures respond to the emission of gaseous pollutants from vehicles diesel engines. Control emissions from heavy-duty vehicles.
1988	EC Directive 88/609/EEC	Limit emissions of SO_2, NOx, and PM from power stations and other large combustion plants.
1989	EC Directive 89/427/EEC	Set limit values and guide values of air quality for SO_2 and suspended particulates. Unified the method of measurement.
1989	The Air Quality Standards Regulations	The EC limit and guide values for SO_2, suspended particulates, lead and NO_2 are brought into UK law.
1989	EC Directive 89/429/EEC	Focus on air pollution from existing waste

		incinerators and set limits on new waste incinerators.
1990	Environmental Protection Act	The first time bring many smaller emission sources under air pollution control by local authorities and establish a system of integrated pollution control for the most potentially polluting industrial processes.
1991	The Road Vehicles Regulations	Set standards for emissions of carbon monoxide and hydrocarbons for petrol cars and light goods vehicles.
1992	EC Directive 92/72/EEC	Concern about ozone type air pollution. Establish a procedure for monitoring, exchange of information and warnings to the public about ozone pollution.
1995	The Environment Act	Provide a new framework for local air quality management with the back up of law. Require publication of a National Strategy, which will set air quality standards and targets for the pollutants of most concern.
1996	EC Directive 96/62/EC	Set controlling levels of SO_2, NO_x, PM, lead and ozone, benzene, carbon monoxide, and other hydrocarbons.
1997	The National Air Quality Strategy	The final version of the National Air Quality Strategy responds to The Environment Act. Commit to achieve new air quality objectives throughout the UK by 2005.
2000	The Air Quality Strategy for England, Scotland, Wales and Northern Ireland	The second National Air Quality Strategy, which sets new air quality objectives for local authorities.

As to the enforcement mechanism, almost every act has its own provisions or chapter of enforcement. For example, in the Clean Air Act 1956, the 29th provision is *enforcement*, and it claims the local authority to enforce the provisions of the Act (*Clean Air Act 1956* 1956).

5.1.3 Information disclosure and Public participation

The information disclosure regulation did not come out very early in UK. It was until 1992 that the Environmental Information Regulations first showed specific information disclosure mechanism. The regulation clearly stipulated that public institutes who have environmental information have the obligation to provide the information to the public (*Environmental Information Regulations 1992* 1992). Later on in 2000, the Freedom of Information Act 2000 began to implement, and it required that public institutions cannot refuse to give environmental protection related information to citizens (*Freedom of Information Act 2000* 2000). The public participation helps to improve the effect of environmental protection (Yang and Zhang 2014).

5.1.4 Summary of London case

The London Great Smog happened in 1952. The Clean Air Act helped to solve the smog problem. The strategy is to reduce the smoke emission, basically on three sources-factories, traffic and home heating. So measures can be classified as three types. The result was outstanding, and till 1970s the main pollution source was no longer from industry. Instead, traffic emission became the first pollutant source. In order to continue controlling the air pollution, UK adjusted its strategy and turned its focus on traffic emission. For all the years, UK carried out a series of legislation to back up its action to reduce the emission. The public participation was backed up by legislation after 1990s and showed its helpful effect.

5.2 LA case

The air quality in California became bad since the 1940s. Photochemical smog first appeared in Los Angeles in 1943. People suffered from eye and throat irritation, and related patients in hospital became more and more (Brienes 1976). So the government started to be aware of the significance to control the smog. In most industrial areas, it turned out to be easy to solve the problem. What they did was just installing two kinds of devices, one to make the fuel burned completely and the other to remove the large particles. With such changes, the wind could help the area to disperse the rest pollutants in the air. Such cases were successful for cities like St. Louis and Pittsburgh. However, Los Angeles case was not that simple, as it was not only polluted by industry. The cause of the smog in LA was complicated, including topography, climate, meteorology, industrial installations and fuels, settlement pattern and something else (Reith 1951). From this perspective, the LA case has similarity with Beijing and the experience might be adapted to Beijing.

5.2.1 Clean Air Act

The US government did not pay much attention on the air problem until 1955. Air Pollution Control Act was the first legislation concerning about air pollution in US, and it was a response option to the Donora PA episode and LA smog. The former case got solved because the cause of pollution was simple as already stated in previous section, while the LA air quality did not show any evidence of getting better but worse and worse (Stern 1982). This act was just "an act to provide research and technical assistance relating to air pollution control" without any other practical help to the air pollution, so it is easy to understand why it did no help to the LA smog (Air Pollution Control Act 1955).

In 1963, the United States carried out their first real legislation that aimed to solve the air pollution problem, which was the Clean Air Act. This act is much more detailed than the Air Pollution Control Act. It raised clear purposes and was defined as "an act to improve,

strengthen, and accelerate programs for the prevention and abatement of air pollution" (Clean Air Act 1963). Like the UK Clean Air Act, the US act also got several times amendments. Major ones were happened in 1970, 1977 and 1990. The 1970 act had made great progress, which leaded to a major shift in the government's role in air pollution control. It gave right to the federal and state to limit emissions from both stationary (industrial) sources and mobile sources (EPA 2013).

However, this national act was broad enough and cannot include all the aspects. Thus, later in 1968, California Air Resource Board (CARB) was formed. And in 1976, the regional Air Quality Management Districts (AQMD) was founded. In 1988, the California Clean Air Act, which was specific for the Californian state, became law, and authorized CARB and AQMD their responsibilities (Van Vorst 1997). The result was optimistic, as almost all the pollutants emission showed decrease trends after 1970s except PM10.

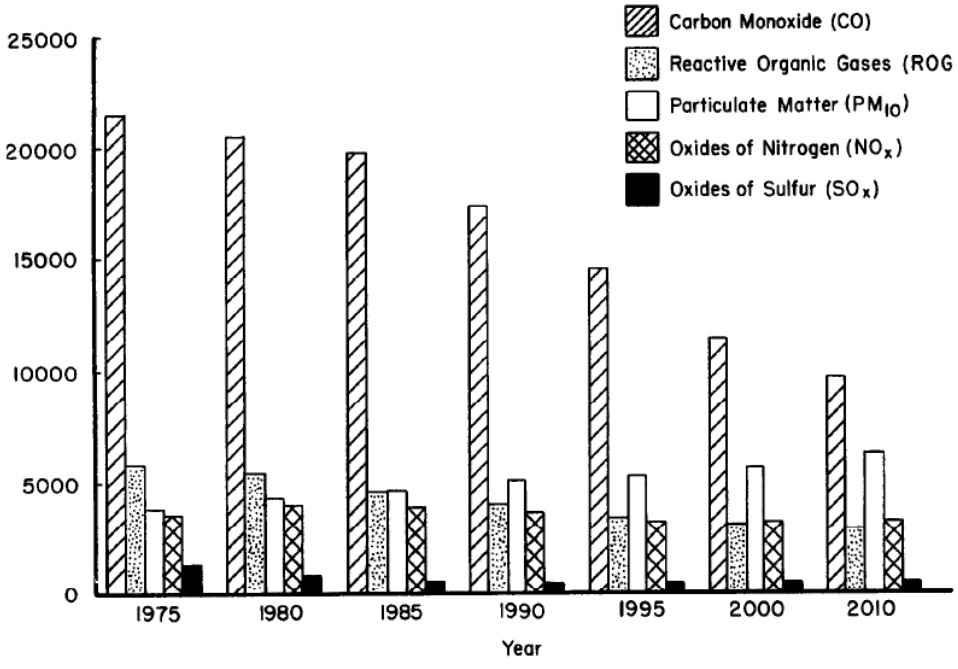

Fig 11. California statewide emission trend

(Source: Impact of the California Clean Air Act, 1997)

It is worth to notice that US put much effort on the research and technology of air pollution and they were the main roles in the early acts. Besides, US did not show a quick answer to the

air pollution problem and the legislations were carried out too late that makes the problem solved for such a long period.

5.2.2 Back up legislation and enforcement mechanism

Los Angeles set up an Air Pollution Control District in 1947. As the state of California thought its main pollution source was the vehicle emission, most of the legislations and actions were meant to reducing emission from vehicles and fuels. In 1959, APCD Rule 63 was adopted, which had a limit for the allowed amount of olefins in gasoline. And then in 1971, the California State Legislature set limit values for both olefins and fuel volatility in the South Coast Basin (Chass 1972). National legislation also provided support for the LA case, such as the Motor Vehicle Air Pollution Control Act and the Air Quality Act.

Table 3. US air pollution control legislation from 1955 to 1990

(Source: History of Air Pollution Legislation in the United States, 2012; Air Quality Management in the United States, 2004)

Year	Act	Key point
1955	**Air Pollution Control Act**	a) This act began to inform the public about the hazards of air pollution and detailed new emissions standards. b) Provided funds to local and state agencies for research and training.
1959	**Air Pollution Control Act, Extension**	Extended research funding for four years.
1960	**The Motor Vehicle Exhaust Study Act of 1960**	Authorized the Public Health Service to study automotive emissions and health.
1962	**Air Pollution Control**	a) Enforced the principle provisions of the original act. b) Called for research to be done by the Surgeon General. c) Required Public Health Service to include auto emissions in their program.

1963	**The Clean Air Act of 1963**	a) Raise the problem to federal level. b) First legislation truly concerned about control the pollution.
1965	**The Motor Vehicle Air Pollution Control Act**	a) First federally mandated emission standards on light-duty vehicles. b) Coordinated pollution control with Canada and Mexico.
1966	**The Clean Air Act Amendments of 1966**	Authorized grants to air pollution control agencies for maintenance of air pollution control programs.
1967	**The Air Quality Act of 1967**	a) Mandated enforcement of interstate air pollution standards. b) Authorized ambient monitoring studies and stationary source inspections.
1970	**The Clean Air Act Amendments of 1970**	Authorized the development of comprehensive federal and state regulations to limit emissions from both stationary sources and mobile sources.
1974	**Energy Supply and Environmental Coordination Act of 1974**	Plant or installation must comply with the air pollution requirements or they will not get the EPA certification.
1977	**The Clean Air Act Amendments of 1977**	a) State permits that Prevention of Significant Deterioration (PSD) studies. b) Primarily concerned provisions for the PSD of air quality in areas attaining the NAAQS.
1990	**The Clean Air Act Amendments of 1990**	a) Increased the authority and responsibility of the federal government. b) New regulatory programs concerning about acid rain were authorized.

As to the enforcement mechanism, the Clean Air Act has certain provision about it. For example, it required automakers to produce cars with less pollution or none pollution by the

year 1975 (Chernow 1974). Besides, the congress authorized the federal government to set up the Environmental Protect Agency (EPA), which had significant powers, to take the responsibility of the implementation of Clean Air Act (Pinter *et al.* 2014; Zheng and Tian 2013). Before the 1960s, the LA forbad the factories from releasing black smoke and also forbad residents from burning household garbage. The government also arranged "smog police" to track vehicles that release black smoke on highway. Later on, the whole LA area carried out a wide range of factories inspection on their pollutants discharge license. If the factory was found having illegal performance, it might be fined and even face with civil penalty (Mazmanian 2006).

5.2.3 Information disclosure and Public participation

The public participation in the LA smog was successful and important for the process of air pollution control. The LA government carried out a series of public environmental education since 1960s, which encouraged more people to take part in solving the air pollution problem and promoted public participation (Mazmanian 2006). In April 22nd 1970, around 20 million people hold a demonstration all over the US to call on environment protection. And it was this demonstration that made the government to be aware of the urgency of environment protection. The public effort accelerated the Clean Air Act amendments in 1970, which showed great importance in changing the air quality in LA later on (Xue 2014). The public also charged EPA in 1984 because it passed a plan which stated that the south LA coast zone needed at least 20 years to meet the national ozone concentration standard (Hou and Wang 2014).

Though there is no detailed provision in the Clean Air Act to stress the information disclosure mechanism, we can see that the government dealt with it properly and public participation

was quite frequent. Nowadays, the LA 24 hours live air pollution monitoring data is available online and public can check it anytime.

5.2.4 Summary of LA case

The LA smog was caused mainly by vehicles emission. It took the city a long period to improve the air quality. The process was slow, which took almost 30 years. The legislations were focused on academic research of air pollution at the beginning, which was helpful for the later actions as the research figured out the main pollution source was vehicle emission rather than industry. So the main strategy for LA was reducing emission from vehicles. The public participation in LA was impressive, it pushed the government to solve air pollution problem and accelerated some legislations accomplishment. However, the LA did not have a good way to control its population. Its population rise three times in the 60 years after World War II, as well as the vehicle amount rise from 2,300,000 to 10,000,000 (Mazmanian 2006). These factors had great impact on the air quality and slowed down the speed of the pollution control process. After 1980s, the strict legislations of air regulations to local industries leaded to a good direction for development.

Chapter 6 Assessment of current policies and actions in Beijing

It has been two years since the Beijing smog burst out, and in the past two years the government has already done many things to improve the situation. In this chapter, we will go through the related policies, legislations and actions, and assess them to see if they can improve air quality efficiently.

6.1 Back up legislation

Though the Beijing Clean Air Act is comprehensive and includes almost all the aspects that may have influence to the air quality, it is still not enough to guarantee everything going under control, as it lacks detailed strategy and solution. So back up legislation is necessary to put the act into practice. The Regulations of Control of Air Pollution of Beijing is the main legislation made by the National People's Congress-the highest legislative institution in China-to fight with the smog. This regulation is necessary because the last time of the national air pollution control law revised was ten years ago (Tao 2015). As Beijing has great changed in the past ten years, the outdated law can no longer fit the current situation and that is part of the reason for the cause of smog. Compared to outdated law, the most significant feature of new regulation is that it increases the punishment scope and strengthens the penalties (Han and Li 2014).

The regulation clearly illustrates the penalties for industries, vehicle emissions, and other aspects such as restaurants. For those enterprise whose facilities do not meet the standard and cause air pollution will get at most 500,000 Yuan penalty. For those vehicles whose emission do not meet the standard will get a 3,000 Yuan fine, which is 30 times than before. And the regulation stresses again that heavy industries like coal, concrete, steel are forbidden to built or expand in Beijing. Besides, the regulation also requires all the restaurants to install devices

treating oil fume and smell, or they will be fined 50,000 Yuan if their emission polluted the air. As to the outdoor barbeque, the regulation specifies that any institution or person is not allowed to barbeque outdoor in forbidden area, and the fine can be as much as 20,000 Yuan.

The Regulations of Control of Air Pollution of Beijing seems comprehensive and fits for the current situation. It came out very quickly, only four months after the Clean Air Act (Li 2014). The powerful means of punishment will eliminate many illegal phenomena, and thus it can be a strong back up for the Clean Air Act. From the perspective of legislation, what Beijing has done is satisfying. What's more important is that whether this regulation can be really implemented. Besides, air pollution is not a separate area problem, as air pollutants have the feature of mobility. Other cities surrounding Beijing do not use the same regulation, which will decrease the pollution control efficiency (Tao 2015). For the next step, Beijing needs to cooperate with the surrounding cities to unify the legislation.

6.2 Vehicle emission

In chapter 1 the pollutant source analyze has already been shown, and we can see that traffic emission takes up the most portion compared to other sources. Therefore, it has to be an important aspect to solve for Beijing. The standard yellow cars are those with high pollution emission, including gasoline car under National Stage I Emission Standards and diesel car under National Stage III Emission Standards (Shang 2009). In 2014, Beijing became the first city in China to solve the standard yellow cars problem. Only in 2014, 450,000 old cars were eliminated. And from 2011 to the end of 2014, 1,390,000 old cars were eliminated and that caused a 4% reduction of nitrogen oxide emission per year (Beijing Municipal Environmental Protection Bureau 2015a).

Vehicle emission does not only affect by the car itself, but also by the fuel it uses. In the documentary *Under the Dome*, it also mentioned that China's oil quality is not as good as developed countries (Chai 2015). From my literature review, it is real that China's oil quality standard is lower than EU, and in 2013 the sulphur content in oil equals that in EU and US ten yeas ago (Netease 2015b). In the Table 4, we can have a direct look at the difference of the oil quality (Zhou 2013).

Table 4. Comparison of China and EU's single car emission (g/km)

***Consider the car in the same condition and the only difference is the oil quality**

SO_2			
	China (National Stage III Emission Standards)	EU (European Stage V Emission Standards)	
Items	Sulfur content (μg/g)	Sulfur content (μg/g)	Emission multiple
Gasoline oil	150	10	15
Automotive diesel oil	350	10	35
NO_x			
	China (National Stage III Emission Standards)	EU (European Stage V Emission Standards)	
Items	NO_x emission	NO_x emission	Emission multiple
Gasoline oil	0.35	0.16	2.2
Automotive diesel oil	0.56	0.23	2.4
CO			
	China (National Stage III	EU (European Stage V	

	Emission Standards)	Emission Standards)	
Items	CO emission	CO emission	Emission multiple
Gasoline oil	2.3	1.0	2.3
Automotive diesel oil	0.64	0.5	1.3
PM			
	China (National Stage III Emission Standards)	EU (European Stage V Emission Standards)	
Items	PM emission	PM emission	Emission multiple
Gasoline oil	0.05	0.005	10
Automotive diesel oil	0.05	0.005	10

Though the oil quality seems not promising at present, the petroleum industry is making effort to improve it, and the oil quality upgrade in China is at the path of three years one time, which is very quick compared to other countries (Yu 2015). Once the oil quality upgrades, the cars also need upgrade to fit for the oil, so these two industries need more cooperation in the future.

6.3 Coal burning emission

As a kind of important traditional energy, coal is always the crime for air pollution. Thus no coal strategy is a popular way for big cities to deal with air pollution (He 2014). Beijing has carried out three measures to reduce its coal consumption. First, the first large coal-fired power plant was shut down in July 2014. And a new heating and power center, which is the largest and takes highest cost in Beijing, was built and began to work at the same year. Second, the reconstruction for boiler from coal burning to gas burning accomplished very optimistic. In 2013, the reconstruction amount was 3428 steam quantity per hour (He 2014).

And in 2014, it raised to 6595 steam quantity per hour, which was higher than the expectation of 5400 steam quantity per hour (Beijing Municipal Environmental Protection Bureau 2015b). Third, a combination of reduction and exchange method was used to promote domestic coal management. In 2014, the city area had 17,000 families changed their fuel from coal to electricity, while 24,000 families in rural area changed their fuel from coal to gas. These three measures have reduced more than 2,800,000 tons of coal in total (Beijing Municipal Environmental Protection Bureau 2015b).

Though it looks like everything is going well for the coal burning exchange, a cost problem comes with it gradually. The energy structure in China is rich in coal but lack in oil and gas. The gas cost is high and the supply is not sufficient, so replace coal with gas to generate electricity will lead to the cost going up for power generation enterprises. Even though there is subsidy from government, the funds cannot always be distributed in time let alone the amount is not enough for enterprises. Under this circumstance, some enterprises come up with the concept of Near Zero Emission, which still uses coal as the fuel but does much effort on treating the emission (Editorial department of China Power Enterprise Management 2014). From this point, it is not a long-term strategy if the government cannot find out a solution to balance the cost and energy.

6.4 Information disclosure and public supervision

From the two cases study we know that the information disclosure is an effective way to get public supervision and makes the process of air pollution control more efficient. The Beijing Municipal Environmental Protection Bureau has set up an air quality monitoring network, which uses the world's advanced technology. The monitoring center has 35 branches, and they can detect pollution information including PM2.5, SO_2, NO_2, inhalable particles, CO, and ozone. The center integrates the data and releases air quality index (AQI), air quality

forecast, and health influence and prevention information, and updated every hour. As to the access, the center spreads information through radio, TV program, website, weibo, wechat and cell phone app. Almost every popular platform is used for information disclosure. Besides, the center has an open day every week so that public can go to the center to understand how the center works. What's more, the center also provides scientific monitoring data to each big websites for free, to reduce the misunderstanding caused by irregular data (Beijing Municipal Environmental Protection Bureau 2015c).

The public supervision is also working well. The Beijing Municipal Environmental Protection Bureau website has access to many information, such as vehicle exhaust emission and project environmental impact assessment. The government also sets a hotline 12369 for public to report illegal behavior that has impact on environment. It is proved in the documentary *Under the Dome* that this hotline works efficiently and can really help to solve the problem (Chai 2015). After the Regulations of Control of Air Pollution of Beijing released, in two month, the Beijing Municipal Environmental Protection Bureau got 1191 reports from public, in which 970 reports had relation with air pollution, and these issues were all solved by legal operation department (Han 2014).

Compared to the two case studies, it is clearly that Beijing shows great concerns on the information disclosure and public supervision. Facts show that this mechanism is operating well and actually does help in improving the air quality.

6.5 Public participation

Public participation in Beijing smog is broadly, most citizens showed their passion for helping to reduce air pollution. Generally, fireworks were very popular in China during the Spring Festival, as it is considered as a tradition. But fireworks have huge impact on the air

quality, because they might release SO_2, CO_2, CO and several kinds of metals, which not only influence people's health but also increase the PM (Wang *et al.* 2007). Since 2013, some people began to stop set off fireworks on their own. The fireworks sales in 2014 got a 27.3% reduction compared to 2013. As a result, the PM concentration during Spring Festival is decreasing these years. 2014 is 24.1% lower than 2013, while 2015 is 13% lower than 2014 (Beijing Municipal Environmental Protection Bureau 2015d). Apart from this, many other activities also show the public participation passion, including volunteer activities, environmental cultural week, environmental education, and a series of environmental theme activities. The government has done enough for the public awareness on Beijing smog. The effect seems great and the public participation is satisfying.

Chapter 7 Recommendation and Conclusion

As the results of this research have shown, the smog problem of Beijing is slowly moving in a positive direction. Current legislations provide a solid basis for solving the problem. Legislation would need to be accompanied by strong enforcement mechanisms to guarantee that all the policies or actions are implement without hindrance and delay. Broad public participation would also help speed up the implementation process. The research identified several challenges that would need to be tackled in order to solve the problem more efficiently. A summary of what was learnt from the case of Beijing is as follows, which may also be of help to other megacities as they fight their air pollution problem.

(1) Managing Beijing's rapidly growing population is a tough policy dilemma. Although the Beijing Clean Air Act refers to rearranging the city's layout so as to disperse the population, there has been no follow policies or action to deal with this issue. While addressing these issues is both technically and policy-wise hard, the government should have already started to do research on it and gradually improve this situation.

(2) Establishing a sound and comprehensive legal framework is the basis for government to control air pollution effectively. There has to be a specific government department or agency in charge of air pollution, so that responsibilities could be distributed fairly without conflict of interest. Supervision, especially on the part of the public, should be of most concern as it is a highly efficient way to identify shortcomings in the process of air pollution control. An update of the legislation is also necessary, and adjustment should be made in accordance with the changing air pollution situation.

(3) Beijing's gasoline standards for the transport sector are not strict enough. As traffic-related pollution makes up a higher percentage than any other pollution source, emissions from vehicles should be addressed. Beijing has already made progress in eliminating the most heavily polluting old cars. As a next step, it should target improving gasoline quality. Once gasoline quality has been improved, vehicle engine standards can raise again. Such virtuous circle will soon bring cars and oil quality to higher levels.

(4) The use of coal as a fuel source requires further research. Replacing coal with gas is not possible on the long-run, as the cost is too high and enterprises cannot afford it. Research on Near Zero Emission coal should be conducted, and more broadly research on how to increase the share of clean energy in Beijing's energy supply. Finding the best way to balance economy, energy and environment is the key point for answering this question.

(5) Beijing should take advantage of advanced technology as much as possible. Research and technology are always the possible solutions to balance the development of economy and environment.

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