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Haze in Beijing (2008-2018): Control Measures, Thinking and Living in Haze

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Master's thesis in Global Environmental History

Abstract

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This thesis analyses the formation of haze by taking the case of severer haze in Beijing in the winter of 2015, which was caused by the collective effect of human activities, topography and meteorological. Among these causes, anthropogenic emissions contributed most, such as coal-fired emissions and vehicle emissions. The haze not only brings direct harm to health, but also slowly changes the way people live in the haze. Beijing has issued the Clean Air Action Plan to mitigate haze. Additionally, a series of stringent control measures were adopted during Beijing Olympics and APEC summit. These measures, such as vehicle emissions reduction and coal-free programme effectively reduced the PM concentration but failed to reduce GHG emissions. Hence, the causes for the lack of sustainability of air pollution control measures are included in thesis.

Keywords: Haze, Beijing, $PM_{2.5}$, Coal-free, Living in haze

Master’s thesis in Global Environmental History (45 credits)

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Contents

Acronyms

APEC	Asia-Pacific Economic Cooperation Summit
AQI	Air Quality Index
BMBS	Beijing Municipal Bureau of Statistics
BMCT	Beijing Municipal Commission of Transport
BMEP	Beijing Municipal Environmental Protection Bureau
BTH	Beijing-Tianjin-Hebei
CCTV	China Central Television
CEC	China Electricity Council
CGV	Conventional gasoline/diesel vehicles
EPA	United States Environmental Protection Agency
GDP	Gross Domestic Product
GHG	Greenhouse gases emissions
IEA	The International Energy Agency
LDGV	Light-duty gasoline vehicles
MEE	Ministry of Ecology and Environment of the People's Republic of China
MITT	Ministry of Industry and Information Technology
MOF	Ministry of Finance of the People's Republic of China
NASA	National Aeronautics and Space Administration
NEVs	New energy vehicles
NDRC	National Development and Reform Commission of the People's Republic of China
PM	Particle matter
RCC	Residential coal combustion
SDGs	Sustainable Development Goals
WHO	World Health Organization

1. Introduction

On 14th, Oct 2016, my flight from Munich to Beijing was delayed, landing 40 minutes late due to the extreme low visibility and my connecting flight was cancelled. It was the second time that my flight trip was disturbed by haze weather in 2016. During the waiting time for new flight, I considered that haze was no longer new part of the lives of almost all people in China and it had indeed changed peoples' life in China.

In fact, not only Beijing, the whole China, especially the densely populated cities are suffering from the haze problem. In the report *Toward an Environmentally Sustainable Future* produced by the Asian Development Bank in 2013, it is estimated that less than 1% of the 500 largest cities in China meet the air quality standards of World Health Organization (WHO) and seven cities among them are ranked in the 10 most polluted cities in the world (Asian Development Bank 2012: xvii). As the capital of China, the position of Beijing is critical, politically and economically. Its dilemma, such as how to guarantee Gross Domestic Product (GDP) growth while also protect environment, reflects the development dilemma of the whole of China, all regions are confronting similar problems. Since 2008, Beijing and the region around Beijing has formulated a number of policy measures to mitigate the haze problem. Thus, a historical study of these policy measures and their effects both in mitigating haze but also in terms of other effects, and social consequences is of interest. Hence, the history of measures of haze mitigation adopted in Beijing can be studied and understood as a possible blueprint for future mitigation of similar problems in other cities.

1.1 Aims and research questions

This thesis will seek to understand where the haze problem comes from how Beijing mitigates it and how haze affects people's everyday life in Beijing. By analysing the effects, disadvantages and people's reactions and sentiments to Beijing's haze control, this thesis will discuss whether haze control measures in Beijing are sustainable and discuss what actions could possibly be taken in the future. The thesis will focus on haze control measures during 2008 and 2018. I choose this period because 2008 and 2018 mark two important milestones in China when it comes to the haze problem. However, the thesis also looks at the longer history of environmental policy in Beijing and China as a broader background. It will generally describe the environmental condition from the founding of the People's Republic of China (1949) to the beginning of modern environmental management (1973). The history of Chinese air pollution control will be tracked to present a more comprehensive story and background to the Beijing haze problem.

2018 was the 40 years anniversary of the implementation of the reform and opening-up policy. From 1978 to 2018, China's average annual GDP growth was 9.3%. The proportion of China's GDP in the world's GDP rose from 1.8% in 1978 to 18% in 2017. The rapid growth of China's economy has enabled China's many improvements in the fields of energy, transportation, telecommunications, science, education, culture and health, and infrastructure construction (Zhang and Shen 2018). However, the price of 40 years rapid economic and industrial development is that China's environmental problems are one of the most severe, in the countries of the world (Diamond 2005: 358). In 2008, Beijing hosted the 29th Summer Olympic Games. When Beijing won the bid in 2001, Beijing promised to spend 12 billion US dollars to achieve the goal of 'Green Olympics' (Stone 2008). Many measures have been implemented since 2001 including increasing access to new energy, converting coal-burning stoves to cleaner energy and enforcing more emission standards for vehicles (BOCOG 2004 in Streets *et al* 2007). The unprecedented pollution intervention successfully decreased all measured air pollutants except ozone during the Olympic Games, but the air pollutants came back after Olympic Games because of the relaxation of pollution control measures (Rich *et al* 2012). A similar situation was reproduced during the 21st Asia-Pacific Economic Cooperation Summit (APEC) held on November the 10th and 11th in Beijing, 2014 when a number of actions to mitigate haze were undertaken one week before the summit. The measured produced a clear blue sky, called the *APEC blue*, the presence of which was symbolic in many ways as it made Beijing residents consider the importance of and how to keep good air quality over long-term. Some regulations such as restriction on the number of on-road vehicles, have continued after Olympic Games and *APEC blue*. However, Beijing experienced extreme air pollution event in following years. The 'Red Alter[1]' for highest level of air pollution alarm turned on in 2015 winter.

1.2 Theory and methodology

I will use sustainable development as theoretical framework of this thesis. The debate of sustainable development is about our relationship with natural world and about the character of development (Baker 2015: 1-5), which covers various aspects such as material, energy consumption, climate change, biodiversity, health lifestyle and many others. Challenging conventional development model, which focus on economy growth, urbanization, transformation of nature (such as clearing forests for agriculture farming) and results in environmental degradation, sustainable development seeks a ecological society that lives harmonious with nature (Baker 2015:6-7). Guided by the general principle of sustainable development in the Agenda 21, which was raised by United Nations, human's development should not undermine the integrity and stability of the natural system (UN 1992). Thereafter, UN has set the 17 Sustainable Development Goals (SDGs) to divide sustainability into more details and in SDG 13, we should take urgent actions to combat climate change (UN 2015). Considering the overlaps between haze mitigation and responding to global climate change, such as reducing carbon emissions, saving energy and optimizing industrial structures, the theory of sustainable development has provided the standards to evaluate whether the measures of haze control in Beijing are sustainable. Can they reduce greenhouse gases emissions (GHG)? Can they improve people's living environment? Can they be promoted to other cities? Can they be effective in the long run? What are the benefits and risks with a very centralised system imposing mitigation measures? What can we learn from the Beijing measures in terms of the importance of citizenship involvement?

This thesis is mainly based on the review of academic literatures, policies, government reports and analyses of public debates (including news and social media opinions). I have combined these methods with fieldwork interviewing a few residents and visitors to Beijing in semi-structured format. Interviews has been carried out to reflect the very personal experience of living with haze in China and raises just a few examples, and the interviewees have been traced using social media and blogs on the haze problem in China. The China Air Quality Standard will be used as important reference and standards to judge the air quality. The data mainly

[1] Red Alert refers to the highest alarm for air pollution. Start Red Alert when forecast daily average AQI (see Table-1) is above 200 and will last longer than 96 hours or, above 300 and will last longer than 48 hours, or above 500 (BMEP, 2018).

come from China air quality online monitoring and analysis platform: Real-time Air Quality Index (AQI), China Yearbook of Statistics Bureau, BP Statistical Review of World Energy and Beijing Municipal Environmental Monitoring Centre.

1.3 Organisation

The thesis is divided into seven chapters. The first three chapters presents a general background to the haze problem and explaining definitions and concepts (Chapter 2). Chapter 3 will explore the causes of haze in Beijing. The severe haze in 2015 will be used as a case to analysis the multiple effects of meteorological, geographical elements and industry development. Chapter 4 provides a short history of Chinese environmental law and national air pollution control action. I will also describe here the process of China's environmental protection and some of its related problems. China's carbon emissions goal related to Paris Agreement will be included in this Chapter as well. In Chapter 5 I will discuss the response measures for haze mitigation, which is the focus of this thesis. I have chosen three measures which are very close to daily life. They are vehicle control, coal-free programme and shared bike promotion. I will use the sustainable development as the theoretical frame and critically reflect on different measures that whether they have met the standard of sustainability, including their influence, disadvantages and prospects. Additionally, the Beijing Olympic Games and APEC summit will be discussed separately. In both events, the Chinese government took unconventional measures to quickly improve air quality. However, these measures lacked legality and violated the spirit of the rule of law. In forth part (Chapter 6), the interviewing for local people, migrant workers and foreign visitors will be adopted to describe a life-closed Beijing. Their narratives can demonstrate the interaction between environment and human in some degree. In the last part (Chapter 7), I will discuss the findings and also relate back to my overall research questions asking what we can learn from the history of haze mitigation in the Beijing area and how does China's command-and-control model in environmental management impact haze mitigation.

2. Background: haze in Beijing

2.1 ‘Under the Dome’, haze and PM

In February 2015, a 104 minutes environmental documentary titled ‘Under the Dome’ drew public attention to the problem of air pollution and the state of environment of China. It is a self-financed documentary film produced by former China Central Television (CCTV) journalist, Chai Jing. The film investigated an inescapable problem: air pollution in China. The film boosted abundant debates about haze on the internet and social media. The film collected over 147 million times views on Chinses video site Tencent within three days of its release (Tiezzi 2015). This film tackled the politics dilemma that the officials of the Ministry of Environmental Protection were powerless to enforce antipollution laws on large state-owned enterprises among oil and gas businesses, as well as private steel producers and automakers (Huang 2015a). The film was taken down from the China mainland internet after six days but is still available on YouTube. The film was criticized by some audiences for being politically insensitive, for exaggerating data and for spreading panic. However, ‘Under the Dome’ is a science popularization rather than a haze mitigation plan, because it not only uses data about health and cancer risk to shock the public, but also tells a story about the cause of haze: what is haze and where does it come from. It raised the public attention to the problem that haze is not only a temporary meteorological phenomenon, but dangerous because as it is the result of a catastrophic air pollution. In the film Chai Jing directly and very personally expresses her worries about haze from the perspective of a common citizen and received huge resonance from the Chinese public.

To avoid the confusion between terms of ‘haze’ and ‘smog’, which are both used in various academic papers to describe the air polluted condition in Beijing, I first need to explain the definitions of these two terms. According to Britiannica Academic (2019), smog can be divided into two types: sulphurous smog (also called London Smog) and photochemical smog (also called Los Angeles Smog). Sulphurous smog results from the high concentration of sulphur oxides in the air and is caused by the burning of sulphur-bearing fossil fuels. Photochemical smog is caused by the chemical reaction of nitrogen oxides with hydrocarbon vapours through the presence of sunlight. The reactants of sulphurous smog are mainly linked to large automobile emission. On the other hand, the Oxford Dictionary of Environment and Conservation (Park and Allaby 2017) defines haze as “*A reduction in visibility…, that is caused by the absorption and scattering of sunlight by particles of dust and other aerosols*”. Both smog and haze can describe the low air visibility and atmospheric phenomenon in Beijing, but here I will continue to use ‘haze’ in thesis, as this is the more common phrase used in newspapers and public debates in China.

Haze as a meteorological phenomenon refers to high particle mass concentrations and low visibility (Zhang Ziyin *et al* 2017). Particle matter (PM) is the main component of haze, which is the mixture of solid particles and liquid droplets in air (EPA 2018). PM has been shown the major air pollutant in Beijing when daily monitor on air pollutant became available since 1999 (Cao 2014). Particle pollution includes particles in the size range of PM_{10} (with diameters between 2.5 μm and 10 μm) and $PM_{2.5}$ (with diameters smaller than 2.5 μm). PM_{10} is mainly produced by mechanical processes such as construction and $PM_{2.5}$ primarily comes from combustion sources, such as fossil fuel and biomass combustion (WHO 2005). Most particles come from the results of complex reactions of various pollutants emitted from industries and automobiles (EPA 2018). The microorganisms in PM have direct link to the various allergies and the spreading of respiratory diseases (Cao 2014). The health effects of PM have been well documented in Pope and Dockery's (2006) research. They have pointed out that fine particles can pose a great threat to human health. They are more toxic because their surfaces include sulphates, nitrates, acids, metals, and particles with various chemicals adsorb bed onto their surfaces. Additionally, $PM_{2.5}$ with a smaller particle size, can penetrate deeper into the lungs. Fine particles also have a longer transmission distance (Pope and Dockery 2006). Staying indoors cannot protect you from the harm of air pollutants. The outdoor air pollutants can penetrate the indoor and result in significant health risks (Ji and Zhao 2015 in Zhang Ziyin *et al* 2017). WHO estimates that there are seven million deaths each year due to exposure to fine particles (WHO 2018). Therefore, considering the direct impact on human health, people and medias gradually use $PM_{2.5}$ concentration to represent the air condition. Guidelines about PM concentration (figure 1) have been provided by WHO. The guidelines provide the threshold value that people health will be at lowest risk in long-term exposures.

Guidelines

$PM_{2.5}$:	**10 μg/m³ annual mean**
	25 μg/m³ 24-hour mean
PM_{10}:	**20 μg/m³ annual mean**
	50 μg/m³ 24-hour mean

Figure 1: WHO Air quality guidelines for particulate matter (WHO 2005)

Many countries have issued national air quality standards. However, measurement standards in different countries and organization are not the same. In this thesis, I will refer to the China Air Quality Standard (2012). The AQI system in China includes six indicators: SO_2, NO_2, CO, PM_{10} and $PM_{2.5}$. AQI is calculated according to the formulas in Technical Regulation on Ambient Air Quality Index (MEE 2012). I have translated China Air Quality Standard into English (Table 1). The AQI values, has provided people a standard for evaluating the air quality. The higher the AQI, the more serious the air pollution is. The corresponding six air pollution levels are classified according to AQI. For example, AQI between 0 and 50 refers to good air quality and people can perform normal activities. When AQI is between 151 and 200, the air quality is Moderately polluted. Children, elders and patients with respiratory diseases should avoid long-term exposure to polluted air. When the AQI is above 300, the most serious pollution level has been reached. Most people are advised to stop outdoor activities and stay indoors.

Table 1. Air Quality Index Scale and Colour Legend[2]

AQI	Air Pollution Level/Colour Legend	Health Implication	Cautionary Statement
0~50	Good	Air quality is considered satisfactory, and almost no air pollution.	Normal activities can be done.
51~100	Moderate	Air quality is acceptable. However, for some pollutants there may be a moderate health concern for a very small number of sensitive people.	A very small number of hypersensitive groups should reduce the outdoor activities.
101~150	Lightly Polluted	Symptom of vulnerable groups may slightly aggravate. Irritation occurs on general public.	Children, elders, cardiac patients and people with respiratory diseases should reduce prolonged and high intensity outdoor exercise.
151~200	Moderately Polluted	Symptom of vulnerable groups will further aggravate. The heart and respiratory system of healthy groups may be affected.	Children, elders, cardiac patients and people with respiratory diseases should avoid prolonged and high intensity outdoor exercise. General public should reduce outdoor exercise.
201~300	Heavily Polluted	Symptom of cardiac patients and lung disease patients significantly aggravate. Their exercise tolerance reduces. Healthy groups will be generally affected.	Children, elders, cardiac and lung disease patients should stop outdoor exercise and remain indoor. general public should reduce outdoor activities.
＞300	Severely Polluted	The exercise tolerance of healthy groups reduces. The obvious and intense symptoms occur. Some diseases may be triggered.	Children, elders and sick should remain indoor and avoid physical output. General public should avoid outdoor activities.

Table 2: Beijing AQI record.[3]

Date	AQI	Air Pollution Level	$PM_{2.5}$	PM_{10}	SO_2,	CO	NO_2
2015-12-07	230	Heavily Polluted	180	199	36	3.5	93
2015-12-08	295	Heavily Polluted	245	246	20	4.3	92
2015-12-09	294	Heavily Polluted	244	10	32	3.6	94
2015-12-19	168	Moderately Polluted	127	155	29	3	87
2015-12-20	249	Heavily Polluted	199	194	27	3.6	101
2015-12-21	280	Heavily Polluted	230	284	23	4.1	104
2015-12-22	347	Severely Polluted	297	427	29	5.3	103
2015-12-23	305	Severely Polluted	255	298	21	4.7	104
2015-12-24	209	Heavily Polluted	159	275	18	2.7	82
2015-12-25	485	Severely Polluted	477	510	12	7.3	141

Units of measure: $\mu g/m^3$ (CO: mg/m^3)

[2] Translated by the author from the Technical Regulation on Ambient Air Quality Index (MEE 2012)
[3] Data cited from China air quality online monitoring and analysis platform. Table 2 is generated by the author.

2.2 Beijing haze event in winter 2015

In the recent years, Beijing has suffered from hazard haze which frequently occur in autumn and winter. Here I will take the particularly severe haze event in the winter of 2015 as an example to explore the dynamics of the haze problem in Beijing and why it takes place.

On December 7th, 2015, Beijing declared a haze Red Alert for three days. The Red Alert was the highest level of alarm according to the Beijing Air Pollution Emergency Plan (BMEP 2018a). I have taken the data of two heavily polluted period (7 to 9 and 19 to 25 December, 2015) from China air quality online monitoring and analysis platform (hereinafter called AQI monitoring platform) and organized them into table 2 (AQI monitoring platform 2019).The AQI in the days from December the 7th, the 8th and the 9th respectively were 230, 295 and 294, which means the air condition is heavy polluted over three days. During the period of the Red Alert, temporary restrictions were enforced: schools were required to close; automobiles could only drive under the odd-and-even of license plate number (e.g. the vehicle with the license plate tail number 0,2,4,8 can be allowed on road in even date and uneven numbers on dates with uneven numbers), fireworks and outdoor barbecues were banned and 30% of the government automobiles were not allowed to be used (Huang 2015b).

An even more serious Red Alert was issued by Beijing on the second on December 18th, 2015 for four days. Forecasting experts said pollution levels reached more than 20 times the safe limit at that day (VOA 2015). The AQI monitoring platform provides more details on pollutant indicators and the $PM_{2.5}$ is the primary pollutant (see Table 2). Overall, the air quality of Beijing was extremely low in the whole December 2015. According to the data (AQI monitoring platform 2019), there were only two days in AQI ‘good’ level and seven days in ‘moderate’ level. The peak $PM_{2.5}$ concentration had reached 477 $\mu g/m^3$ on December 25th which was very dangerous to human health. The conditions in November 2015 and January 2016 were still not optimistic, with 16 polluted days and 10 polluted days respectively. What caused the severe haze in Beijing? I will explore it in chapter below.

3. The causes of Haze in Beijing

The severe haze pollution in 2015 gained much attention but, in fact, Beijing has been long-term plagued by haze, especially in winter. Haze is the result of the collective effect of human activities, topography and meteorological (Shao *et al* 2017). I will analyse each factor separately.

3.1 Landscape: topography and meteorological conditions

Beijing can be regarded as a prisoner of geography. The city locates in the northwest edge of North China Plain, where is surrounded by mountains in North, Northwest and Southwest (Taihang Mountains and Yanshan Mountains). The geographical features make Beijing like a 'pool' and block the air pollutants from flowing out of the city (Zhang *et al* 2015; Shao *et al* 2017).

Meteorological conditions also lead the severe haze build-up in autumn and winter. Meteorology impacts air pollutant accumulation spread and regional transport. Meteorology has very close linkage to the formation of secondary aerosols and daily variability of air pollutant concentration (Zhang Ziyin *et al* 2017). In the Beijing autumn season, the Pacific subtropical high and the intrusion of cold air at the surface will lead to a stable atmosphere over North China Plain and accompanying inversion conditions, which prevent the vertical dispersion of air pollutants. In layman terms, the different natural characteristics of airmasses results in the creation of a form of 'lid' over the town which does not allow ground air to rise up the atmosphere where it would otherwise dissipate better. The humid air from the Bohai Sea, only 110 km away, will exacerbate this condition and facilitate the formation of secondary aerosols (Zhang *et al* 2015; Shao *et al* 2017).

Furthermore, some abnormal meteorological conditions aggravate the haze and cause extreme haze weather. Research shows that the Beijing haze in the winter of 2015 was caused by large-scale atmospheric circulation and conditions that were particularly bad for air quality. The meteorological conditions at the time had four features: weakened winds, lower boundary layers, unusually strong temperature inversion [4]and high relative humidity, which were favourable for accumulation of pollutants (Zhang Ziyin *et al* 2017). Another example of unfavourable meteorological conditions is a weak East Asian winter monsoon (compared to climatological average) over eastern China, that in the 2013 winter led to stable meteorological condition conducive to haze formation in Beijing, and similar conditions has also been recorded previously (Zhang *et al* 2015).

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[4] Temperature inversion is meteorological phenomenon in which the temperature in the troposphere (the lowest atmosphere layer of the Earth's surface) increases with height, which is contrary to the normal phenomenon that the higher the altitude, the lower the temperature. The inversion acts as a cap to prevent convection produced by the heating of air from below and reduce the producing of rain. In this condition, dusts, smoke and pollutants are limited to release (Britannica Academic 2019).

3.2 Current anthropogenic emissions

Both topography and meteorological conditions are physical factors. However, human action is the chief culprit of haze problem. Much research has been carried out, and the debates are ongoing, but the primary causes of haze in Beijing is still a controversy. Generally, man-made reasons of haze in Beijing depend on many aspects. The anthropogenic emission come from 1) industrial emission; 2) the large domestic energy consumption based on fossil fuels, in particularly from heating in winter; 3) rapid increased motor vehicle possession and related emissions (Li and Zhang 2014; Li and Tang 2018).

The heavy industrial emissions are the result of an unbalanced industrial structure and unsustainable economic growth model in China. GDP growth is driven by high pollution and high energy consumption. Coal, the most abundant and a relatively cheap energy resource in China, is the dominant energy supply currently and in a foreseeable future. Chinese energy system is coal-based in terms of both energy production and consumption, which results in a typical coal-smoke pollution, low energy efficiency and a large degree of environmental damage (Zhang *et al* 2011; Li, X *et al* 2018). The 2016 BP statistical review of world energy shows that the proportion of coal in China's primary energy production and consumption has been at the level of 70% since the 1980s. By 2013, China's coal consumption accounted for 50.3% of the global coal consumption, which was 4.2 and 6.7 times higher than that of the United States and European Union (Li, X *et al* 2018).

The source of air pollutants does not only come from Beijing. Pollutions also come from emission from the Beijing-Tianjin-Hebei (BTH) region. This region located in northern China, includes two municipalities (Beijing, Tianjin) and one province (Hebei). Both Hebei province and Tianjin are heavily industrialized. Coal fire plants, steel plants, chemical plants and construction material factories are highly concentrated in this region. Hebei is the centre of steel and iron production with a very high annual production. In 2016, the annual production of Hebei was c. 23-26% of the total production in China (see Table 3; NBS 2017).

Table 3: Steel and Iron Production of Hebei and China 2016 (from NBS 2017)

	Hebei	China	Proportion (Hebei/China)
Crude Steel	19259.97	80760.94	23.84%
Pig Iron	18398.37	70227.33	26.19%
Rolled Steel	26150.42	113460.74	23.04%

Unit: 10000 tons

According to '*WORLD STEEL IN FIGUES 2017'* issued by Worldsteel Association (2017), the world crude steel production is 1630 million tons and China stands for 49.6% of this production. The large output results in a huge coal consumption and emissions of pollutants (Table 4 and 5). Satellite images released by National Aeronautics and Space Administration (NASA) in winter 2015 and 2016 have recorded the heavy haze all over the BTH region (Figure 2). The air pollutants spread and transport across this whole region. When southern or eastern winds are prevalent in the NCP, the air pollutants will be blocked in Beijing and research shows that part of $PM_{2.5}$ concentration in Beijing is contributed to by high trans-boundary emissions which comes mainly from the Hebei province (Lang *et al* 2013).

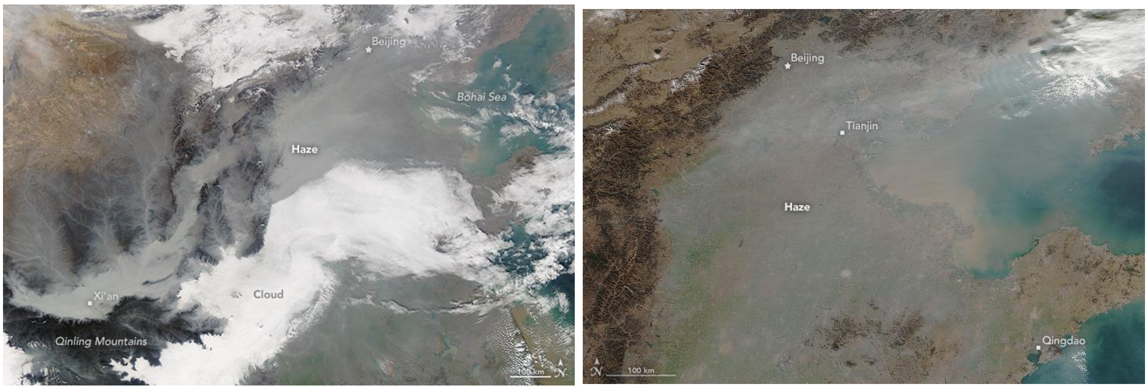
Table 4: Emissions of major pollutants in exhaust gas (2016)

Region	SO_2	NOx	Dust
China	1102.86	1394.31	1010.66
Beijing	3.32	9.61	3.45
Hebei Province	78.94	112.66	125.68

Unite: 10000 tons

Table 5. Primary energy consumption and its composition in 2016

Region	Total Energy Consumption (10000 tons of SCE)	As Percentage of Primary Energy Production (%)			
		Coal	Petroleum	Natural Gas	Primary Electricity
China	435819	62	18.5	6.2	13.3
Beijing	6961.7	9.81	32.93	31.68	0.66
Hebei	29794.4	85.01	8.63	3.14	3.22



Photographed date: December-7-2015 Photographed date: December-6-2016

Figure 2: Satellite images by NASA
(From NASA 2015, 2016. https://earthobservatory.nasa.gov/images/87129/haze-over-eastern-china; https://earthobservatory.nasa.gov/images/89228/smog-and-haze-in-northern-china)

The contributions of residential coal combustion (RCC) to air quality should also not be neglected. The RCC is mainly used for heating and cooking in winter (around four months), especially in rural area of northern China. The coverage of residential coal usage is over 80% in relation to other heat/cooking sources in rural Beijing. Researchers have found a significant contribution of RRC to air pollution and $PM_{2.5}$ concentration in BTH region (Li, X *et al* 2018; Liu *et al* 2017; Zhang Zhongzhi *et al* 2017). The $PM_{2.5}$ control measures, which have been widely used in industrial burners, are lacking in RCC. Therefore, even though the annual RCC accounts for a small part of total coal consumption in BTH region, the emission factors of primary pollutants including $PM_{2.5}$ from RCC are much higher than those from coal-fired power plants and industries (Liu *et al* 2017; Zhang Zhongzhi *et al* 2017). An analysis of the severe haze in Beijing Dec 2015 (Zhang Zhongzhi *et al* 2017) demonstrates that RCC in BTH region contributed 50% to the monthly averaged $PM_{2.5}$ concentration and 29% from them came from Beijing. The RCC has become the major coal consumption in Beijing since almost all the heavy industries and coal fire plants have now been moved out Beijing. Another survey carried out by Li *et al* (2018) shows that the mass $PM_{2.5}$ concentration can be decreased by 18% in Beijing on average when the RCC emissions in Beijing are excluded. If the RCC emissions from the whole of the BTH region are excluded the rate of decrease can reach 30% in. Additionally, the air quality in Beijing would be improved if residential coal could be replaced by clean energy. However, considering the impact of trans-boundary transport on Beijing and its heavily affected by surrounding pollutants emission (strongly affected by Hebei province), the residential coal replacement will not be enough for air quality improving if it is only implemented in Beijing. The whole BTH region should be involved in this transition, but the challenges in implementing this are huge.

The rapid growth of vehicles in China is considered as another major air pollutant source, especially in big cities such as Beijing. The vehicles emission can change the pollution pattern from coal-based air pollution to a mix of coal and vehicle-based pollution, which is the major contributor to ambient $PM_{2.5}$. (Shen *et al* 2014; Zhang *et al* 2014). The contribution of vehicles to $PM_{2.5}$ comes from two factors: one is the direct discharge of respirable particles. The other is that gaseous pollutant emitted by vehicle exhaust can lead to the secondary pollution through a complicated chemical reaction and the forming of new particles (Li, Y *et al* 2018). By 2017, Beijing's resident population was 21.7 million and the total vehicle population reached 5.9 million (BMBS 2017). In 2014, Beijing Municipal Environmental Protection Bureau (BMEP) announced a detailed analysis of sources of $PM_{2.5}$ emissions (BMEP 2018b). The result showed that the regional transportation contribution accounts for 28%-36% of $PM_{2.5}$, and the local pollution emissions accounts for 64%-72%. The local pollution emissions contribution was respectively from Vehicles (31.1%), coal (22.4%), industrial production (18.1%) and dust (14.3%). The BMEP updated their analyses in 2018. The indicator of vehicle is now replaced by 'mobile source', which includes road mobile sources (automobile, motorcycle, tricycle) and non-road mobile sources (non-road mobile machinery, vessel, aircraft, rail locomotive). The definition of $PM_{2.5}$ in this regard has changed, so that the proportion of mobile source in $PM_{2.5}$ increased and the proportion of industrial source declined (BMEP 2018b). I translate the data and make them into Figure 3.

The increasing population and urbanization results in serious expanding traffic and increased emissions. When the traffic is congested, the drivers will keep the engine idling to keep power for accessories, such as the air conditioner and lights. In this state, the engine can provide enough energy to use its subsidized functions, such as generators, but generally cannot perform useful work, such as moving the car. In the idling state, the engine cannot work at peak operating temperature and the combustion of fuel is incomplete, which results in leaving fuel residues and increasing emissions (CO_2, NO_X and particles) (Rahman *et al* 2013; Frey and Kuo 2009). The emission of vehicles increases in traffic jam conditions, can aggravate air pollution.

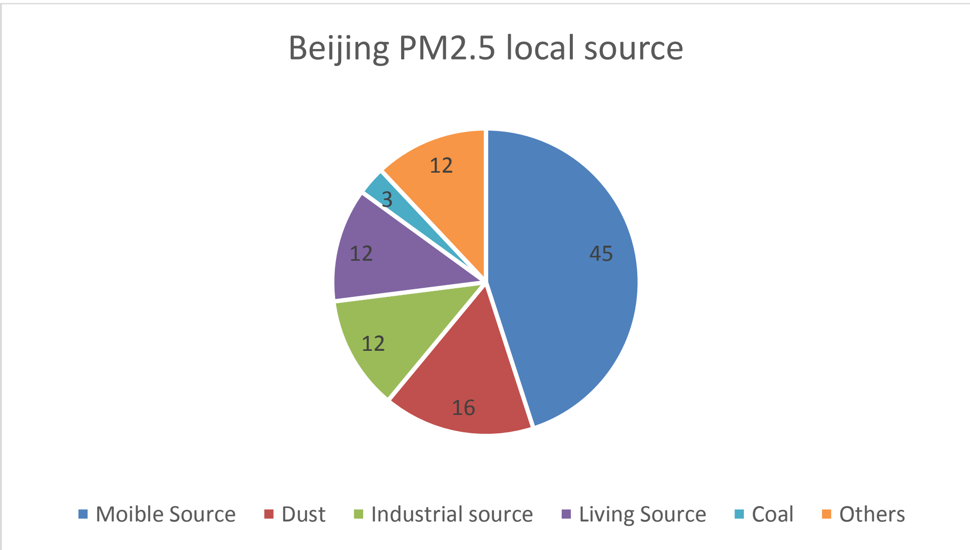


Figure 3: Beijing $PM_{2.5}$ local source construction in current stage.

4. The history of law of air pollution control in China

The implementation of air pollution control measures is the necessary result of health protection as well as economic development. In 2015, the outdoor air pollution caused 173,100 premature deaths in the BTH region. Based on this data, Zhang *et al* (2019) from Peking University calculated the economic losses of the disease and death caused by air pollution and found the health loss related to outdoor air pollution costing up to 199.6 billion RMB (Chinese currency). This amount accounts to 2.73% of the GDP of BTH region. Improving the air quality will definitely reduce the economic loss in this sector.

Consequently, the Chinese government have made the efforts to enhance the monitoring of $PM_{2.5}$ and started to release pollution data in a transparent way. A series of policies, laws and improvement on existing regulations have been implemented in following years. As a background to the coming discussion, I will therefore give a brief introduction to history of environmental law and air pollution control in China.

For a long time after the founding of the People's Republic of China, environmental issues were not a priority on the political agenda and the ambition to 'conquer nature' became a nation-wide movement in Great Leap Forward (1958-1960) (He *et al* 2012). To complete the industrialization quickly, the Chinese central government proposed the goal of refining 10.7 million tons of steel in 1958 (Liu 2016). This goal was far beyond the productivity of China at that time. The resulting large expansion of logging and coal mining for steelmaking to fulfil the already unrealistic target caused serious damage to China's ecological environment. The Chinese government did not realize the seriousness of the Chinese environment until after participating in the Stockholm Conference on Human Environment in 1972 (He *et al* 2012). In the aftermath of the Stockholm conference, China held the first national environmental protection conference in 1973. China also established the National Environmental Protection Agency the same year, which marked China had opened up the modern environmental management. In 1979, the first 'Environmental Protection Law of the People's Republic of China' (trial) was passed and again amended in 1989. In this period, the environmental management focused on controlling industrial pollution (air, water and solid waste) (He *et al* 2012).

When it comes to air pollution the first efforts in mitigation took place in 1982 when the Ambient Air Quality Standards (AAQS) in China were published, which was the first official document aiming to improve the air quality. The first Law of the People's Republic of China on the Prevention and Control of Atmospheric Pollution came into effect on June 1, 1988. The quality standard was further amended in 1996 and 2000. In February 2012, Ministry of Environmental Protection published the third amendment, which included the standards of $PM_{2.5}$ and tightened the values of NO_2 and PM_{10} (Zhang *et al* 2016). Gradual awareness of the air quality was increasing in urban areas. The number of cities that officially announced the real-time ambient $PM_{2.5}$ data had reached 367 by 2015, which demonstrated that more and more cities have begun to not only monitor the air quality but also to make these figures public. Before 2012 there were no cities that formally monitored air quality data or publicised it (Shi *et al* 2016). This to me show that China's air pollution has increasingly become a national concern.

As a response to critical air pollution and the demand from the public, the State Council of China issued the ‘Air Pollution Prevention and Control Action Plan’ in September 2013 (hereinafter called Control Action Plan). This plan set the target that by 2017, the $PM_{2.5}$ concentration should be reduced significantly: in the BTH region (25%), Yangtze River (20%) Delta and Pearl River Delta (15%), compared to 2012. Additionally, the Control Action Plan specified that the annual average $PM_{2.5}$ level in Beijing should be controlled within 60 $\mu g/m^{-3}$. The Control Action Plan proposed ten measures that will be summarised here[5].

With these measures, the Control Action Plan recognizes the importance of energy system transformation, which has overlapped with greenhouse gas emissions. China’s economic growth is based on huge fossil fuel emissions, especially from coal consumption as discussed in Chapter 1 and 2. In the world total CO_2 emission growth in past decades, China accounted for over two-thirds (Sheehan *et al* 2014). Therefore, another policy named the ‘energy-saving and emission reduction’ had been implemented in 2006. This policy is guided by the ‘sustainable development strategy’ in China, which is the combination of the general principle of ’sustainable development’ as specified in the United Nations Agenda 21 and the specific conditions of China’s. The policy specifies that human’s development should not undermine the integrity and stability of the natural system. The ‘Energy-saving and emission reduction’ policy aims to achieve the sustainability in both economic growth and energy development. Many measures such new energy promotion and desulphurization equipment’s installation on coal-fired power plants have correlation with air pollution mitigation.

There are different targets in the ‘energy-saving and emission reduction’ policy in each China Five-Year-Plan. In the 13th Five-Year-Plan (2016-2020), by 2020, the energy consumption per unit of GDP should be reduced by 15% compared to 2015 and the total energy consumption should be less than five-billion-ton SCE[6] (Standard Coal Equivalent). Meanwhile, the total emissions of chemical oxygen and NH-N, SO_2 and NO_X should be controlled and reduced to 10%, 10%, 15% and 15% respectively compared to 2015. The national total volatile organic compounds[7] emissions should reduce more than 10% (State Council 2016). According to the China official report, the target of the ‘energy-saving and emission reduction’ policy in the 12th Five-Year-Plan (2011-2015) had been achieved but the challenges for future were harsh. The official data shows that, in 2018, the power generation from non-fossil sources increased by 29%. Increases in wind power and solar power accounts for 20% and 50% respectively.

In fact, China’s carbon emission has surpassed those of the United Stated since 2005(Li 2016). The 12th Five-Year-Plan was deemed as an important turning point in China’s development model because China’s economic policy transferred from energy-intensive growth to a more balanced economy characterized by slower growth but a focus on low-carbon technologies (Hilton and Kerr 2017). In 2016, China signed the Paris Agreement and submitted Intended Nationally Determined Contribution (INDC): China intended to peak carbon emissions by 2030 and to reduce carbon intensity by 60-65% compared to 2005 levels (Li 2016). It is worth

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[5] In detail these measures were: optimizing industry structure and energy structure, increasing the clean energy supply; accelerating technological transformation and innovation of enterprise; improving the legal system and the environmental economic policies; establishing monitoring emergency system and mobilizing the public participating in environmental protection

[6] SCE: Standard Coal Equivalent, refers to coal with a calorific value of 7 Mcal/kg. It is a representation of standard energy. (Wikipedia 2018, https://zh.wikipedia.org/wiki/标准煤).

[7] Volatile organic compounds (VOCs): China defines it as "*originated from automobiles, industrial production and civilian use, burning of all types of fuels, storage and transportation of oils, fitment finish, coating for furniture and machines, cooking oil fume and fine particles ($PM_{2.5}$), and similar sources*” (Wikipedia 2019, https://en.wikipedia.org/wiki/Volatile_organic_compound)

noting that carbon intensity is not the volume of carbon emissions, which refers to 'carbon emissions per unit of GDP'. Therefore, the reduction in carbon intensity does not mean a reduction in total carbon emissions. China's interest in mitigating climate change also lies in addressing its domestic environmental problems brought by 30 years high growth of economic development (Li 2016), such as haze problem. However, it is very difficult to solve domestic pollution ensure economic development and reduce carbon emissions at the same time. In 2018, although the carbon intensity dropped by 4%, the total CO2 emissions in China still grew by 2.3%. It is higher than the 1.7% growth of CO2 emissions in 2017. It is the second year that Chinese emissions continue to grow after a pause in past three years (Korsbakken et al 2019). The International Energy Agency (IEA) pointed out that the growth rate of global carbon emissions in 2018 would be 1.6%, the same as for 2017. Meanwhile, the policies aiming to mitigate air pollution in cities implemented by China also contributed to growth of global oil demand and gas use (IEA, 2018). I will explore how does it happen in chapters below. The continuous growth in global carbon emissions will disappoint the hopes that fight against climate change (Nordhaus, 2018).

5. Control measures in Beijing and Clean Air Plan (2013-2017)

5.1 Control actions for 2008 Beijing Olympic Game

Benefited by the long-term and short-term control actions, the air quality in Beijing significantly improved during Olympic Games (8-24, August 2018). The concentration of SO_2, NO_2, $PM_{2.5}$ and Organic Carbon decreased 60%, 43%, 27% and 22% respectively from pre-Olympic to during-Olympic period (Rich *et al* 2012; Zhang *et al* 2016). The radical actions adapted at such large scale an in a short time on the one hand presented a good image of China to the world, but also demonstrated the effects of a strong central power under the authoritarian regime as will be discussed here. Over USD 10 billion was spent on air pollution control and 42.9 billion cost on city infrastructure and Olympic stadiums construction made Beijing Olympics the most expensive Games in Olympic history (Chen et al 2013).

Some measures contributed the long-term benefits for Beijing air quality. Measures included converting 1,500 coal furnaces into clean fuel furnaces, weeding out 23,000 old automobiles, reducing 30 thousand tons emissions of major industrial plants and increasing areas under green coverage by 100 km^2. The industrial high emitters such as the Beijing Dyeing Plant, the coal-fired generators in the Capital Steel Company and Beijing Coking Plant were closed in 2003 and 2004. By 2006, devises for desulfurization, dust removal and denitrification had been installed in remaining high polluting companies such as the YanShan Petrochemical Company, Beijing Thermal Power Plant and the Power Plant of the Capital Steel. (Zhang *et al* 2016)

Furthermore, winning the bid to host Olympic Games directly promoted a relocation project for the Capital Steel, one of the biggest steel companies in North China. The location of the plant had subject for political contention since 1997. The Capital Steel is one of the China's top ten steel plant and enormously important for revenues. Taking data in 2004 as an example, the Capital Steel realized sales revenue of 61.9 billion and paid taxed of 2.8 billion to Beijing, accounting for one-twentieth of Beijing's fiscal revenue (Li, 2007). The relocation of Capital Steel was politically contentious as with relocation, the local fiscal revenue might be transferred to new local government: Hebei province. Beijing also had to solve the fact that a large number of employees' resident in Beijing could not relocate or travel to Hebei. However, the strongest reason to relocate Capital Steel, in the final analysis, was due to the environmental issues as the environmental pressure of the industry was enormous. Data shows that by 1995, the steel output reached approximately 8 million tons, but resulting in 9 million tons of SCE consumption, 9.06 million tons of water consumption, 40 thousand tons of SO_2 emissions, and 21 million tons of CO_2 emissions (Zhao and Wei 2017). The relocation of the plant started in 2005 and was finally completed in 2010. During this period, the production of the Capital Steel plant decreased gradually, which absolutely reduced the air pollution in Beijing. The three indicator elements used as indicators for pollution from metal processing industry especially, namely Carbon Oxide (Co), Nickel (Ni) and Chromium (Cr) decreased. The concentrations of these element in Beijing reached the minimum after relocation (Chen *et al*, 2014). The new Capital Steel is now located in Hebei province. As a response to the public's worries about pollution transfer, authorities promised that the new technologies, energy-saving equipment and advanced pollution control actions would also be available in new construction of Capital Steel.

Apart from closing down, relocating or regulation pollution from high emitting industries, restrictions on vehicle emissions were another important control action in preparation for the Olympic Games, an intervention which has also continued until now. Beijing is the pioneer of China in terms of vehicle emission control. Beijing implemented the Euro emission standard on January 1, 1999 and required new gasoline cars be equipped with electronic fuel injection and three-way catalysts (an equipment can simultaneously purify the hydrocarbons, CO and NO_X from vehicle emissions), which was one year earlier than national emission standards requirement (Wu *et al* 2011). Other actions included improving fuel quality, providing economic subsidies for purchasing light-duty vehicles, banning old/ high-emitting vehicles, developing public transportation. Lastly Beijing has also been promoting new energy vehicles including hybrid electric vehicles, pure electric vehicles and fuel-cell vehicles (Wu *et al* 2011). This policy in combination with temporary traffic control has gone some way of regulating emissions. In the city public transportation system, compressed natural gas buses (CNG) and hybrid electric-diesel buses (HEV) were introduced in 1999 and 2009. CNG buses emit low particle and NO_X than traditional diesel buses. By 2008, the number CNG reached 4,200, making Beijing bus fleet become one of the biggest CNG bus fleets in the world (Wu *et al* 2011; Zhang *et al* 2014).

The labelling policy allows the specific management on different emission standards types of vehicles. For example, the pre-Euro I light-duty gasoline vehicles (LDGV) will be issued with a yellow label and Euro I ~ IV will be issued green label with stars indicating the standard (e.g. Euro IV shows as a four-star on green label). The label should be affixed to the vehicle's front window. In 1998-1999, more than 20,000 yellow labelled mini-van cabs were banned and approximately 300,000 yellow labelled vehicles were banned in period of July and September 2008. Meanwhile, the owners of yellow labelled vehicle could get up to 6000 RMB as financial compensation if his vehicle banned (Wu *et al* 2011).

During the Olympic Games, the restrictions on vehicle emissions became even more stringent. From July 1, 2008 to September 20, 2008, Beijing implemented mandatory restrictions for private vehicles, permitting them on roads depending on the odd-and-even of license plate number. This action cut off a half on-road private vehicles during the Games. Likewise, around 70% of government vehicles was kept off road. This policy brought immediately air quality improving by reducing 24.9% of air pollution indices compared to the same period in 2007 (Xie *et al* 2017).

After the Olympic Games, a weaker and moderate control called '1/5 restriction measure' replaced the stringent policy enforced during the Olympic Games. The 1/5 measure has become a long-term solution for reducing Beijing air pollution and alleviating traffic congestion. For example, cars with registration numbers finishing with 1 and 6 should be off road on Monday, 2 and 7 should be off road on Tuesday and so on. There is no restriction on weekend and legal holidays. The driving restriction policy has also been promoted and implemented in other China big cities such as Guangzhou and Chengdu (southwest economic centre), however, here the policy has failed to meet the expectation (*Xie et al* 2017). There are limitation and hidden risks of driving restriction policy. It only has an effect over the short period. The license plate restriction cannot prevent the increase in the number of vehicles. Based on Beijing Olympic example, it is found that the annual increase of the total numbers of vehicles will not be curbed by driving restriction (Xie *et al* 2017). Furthermore, although the improvements on air quality are obvious, such strong control cannot last over a long period. Once the restriction policies end, the number of on-road vehicles will rapidly increase again, which will make the vehicles number exceed the threshold level before the control implementation. Therefore, the positive effect on air pollution mitigation will be offset by such growth (see discussion in Xie *et al* 2017).

The vehicle restriction policy is the method to limit the private vehicle trip and mandatorily transfers private vehicle trip to other trip models, such us public transportation and walking (Xu and Ma 2012). Researchers analyse policy from aspects of what in academic language is called 'trip utility', which is constituted by marginal cost and marginal benefit. People will prefer to use the car if marginal benefits (e.g. traffic comfort and traffic safety) are larger than marginal cost (the amount of explicit monetary costs of parking, fuel, vehicle tax and hidden costs of traffic jam). Xu and Ma (2012) make the conclusion that the driving restriction policy can alleviate traffic congestion, and correspondingly reduce vehicle emissions over short term, but this function will become increasingly smaller over time.

In addition to the local actions for air pollution control in Beijing, the neighbouring municipality (Tianjin), and the provinces (Hebei, Shandong, Shanxi and Inner Mongolia) also took joint regional actions against emissions from traffic. They all adopted similar measures but weaker in magnitude. Tianjin and Hebei implemented odd-even driving restriction, but only during Olympic Games. Shandong closed 132 heavy polluting plants and installed desulfurization facilities for power plants (Chen *et al* 2014; Zhang *et al* 2016). Similar integrated cross-regional controls have been adopted during some important events also after the Olympic Games, such as APEC summit in 2014 (see Chapter 5.3). The return to 'normal' after the Olympics Games brought the air pollution and haze weather back and 60% of the effect of drastic measures faded away one year later (Chen *et al* 2014). From the case of haze control during the Olympic Games, it can be known that air quality can be significantly improved through strong measures but can only be effective in the short term. The actions for Olympic Games are valuable and worth to be appreciate, which make China aware that Beijing need more comprehensive long-term measures for air quality improving.

5.2 Beijing Clean Air Action Plan (2013-2017)

> "The integration development of an urban agglomeration or metropolitan area requires the local governments to coordinate and cooperate in all aspects of environmental management, regional planning, infrastructure construction, industrial development, and public services. However, in view of the present difficulties in regional harmonious development, the bottleneck of regional integration lies in the administrative management system. Local governments in their respective jurisdictions implement layered and divided responsibility systems." (Liu *et al* 2016)

This quote from Liu *et al* (2016) clearly and professionally indicates the necessity of local measures under the national Control Action Plan. In 2013, BMEP issued 'Beijing Clean Air Action Plan 2013-2017' (hereinafter called the Beijing Air Action Plan) to prevent and control air pollution, especially $PM_{2.5}$ matters. The Beijing Air Action Plan was a more stringent local policy compared to the national Control Action Plan, specifying a clear target and a corresponding long-term plan: by 2017, Beijing air quality should significantly improve. The annual concentration of $PM_{2.5}$ should be controlled below 60 μg/ m³, decreased by 25% compared to 2012. The total amount of volatile organic emissions should cumulative decrease by

50% compared to 2012. To ensure this target, the Beijing government promoted eight major projects of air pollution prevention and control. The two most important projects were control over number of vehicles owned and energy structure optimization. Beijing planned to restrict the number of vehicles ownership within 6 million by the end of 2017. In terms of energy structure optimization, Beijing planned to significantly reduce the coal consumption, promoting the coal-free programme in six districts in urban Beijing and by gradually replaced coal by clean energy in the rural and rural-urban intersection. By 2017, the total coal consumption should be 13 million tons less than 2012 and controlled within 10 million tons. Meanwhile, Beijing planned to adjust vehicle structure, promote new energy vehicle (NEV) and implement the "public transportation priority" strategy. The city rail transit would reach 660 km in 2015. The six level vehicle emission standards[8] should be in active in 2016; 1 million old vehicles should be eliminated in 2017. Other actions included emission project and structure adjustment in industry, pollution end management, construction dust harnessing, ecological mitigation projects construction, and the implementation of regional cooperation emergency emission reduction for heavy polluted day.

Additionally, Beijing Action included six 'guarantee measures' which contained legal support, scientific and technological upgrading, economic innovation, evaluation and accountability. It also called for public participation in three aspects: enterprise self-discipline, public supervision and public voluntary emission reduction. The most outstanding of Beijing Air Action Plan was that there were comprehensive, detailed rules and regulations. The action plan also specified responsible institutions and directors under each major task and over 30 relative administrations, committees and enterprises were involved (Cai 2013). Here, I will discuss the three of most important projects in the Beijing Air Action Plan: vehicle emission reduction, coal-free and bike-sharing promotion to argue their advantages and challenges.

5.2.1 Vehicle emission reduction and NEVs promotion

As mentioned above, vehicle emission is one of the major pollutions contributing to Beijing haze problem. Therefore, the new Beijing Action puts transport in a very primary position.

First, the vehicle ownerships in Beijing was 5.9 million by end of 2017 (BMBS 2018). The target was to maintain control the number of cars in Beijing to within 6 million, and so far, this has been achieved. To fulfil this target, Beijing combined the policies of driving restriction by license-plate and the 'license-plate lottery'. Beijing have started driving restriction since 2009. The 1/5 restriction measure is still kept, and the odd-and-even licence plate restriction is used in heavy polluted days and during special events. However, researches show that in fact the effect of driving restrictions is very limited (Yi *et al* 2011; Xu *et al* 2012). Driving restriction can cut off the number of on-road vehicles in a very short period, thus mitigate traffic congestion and air pollution. Nevertheless, the number of private vehicles may actually increase after a certain period because the risk is that this policy will promote people to buy a second car to avoid the inconvenience caused by the odd-and-even licence plate driving restriction. Therefore, the policy effect is likely to decline as vehicle ownership increases.

To mitigate an increase in the number of cars, and together with driving restrictions, Beijing has implemented license plate lottery since 2011. The annual vehicle number has a fixed quota. The quota was 240,000/year in 2011, 2012 and 2013 and decreased to 150,000/year from 2014 to 2017. This quota further shrank to 100,000/year in 2018 (BMCT 2018). The person who is eligible to buy the car need to register and wait for a positive draw in the lottery. The winning

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[8] Slightly stricter than Euro-V emission standards

rate decreases year by year with the increase of people registering. It is worth noting that, the lottery policy does not apply to new energy vehicles (NEVs). People can apply for NEVs directly and wait for distribution. With the lottery quota, the number of NEVs and its proportion has gone up over the years: 20,000/year in 2014, 30,000/year in 2015 and 60,000/year from 2016 to 2018. Thus, the lottery policy successfully transfers people from buying traditional cars to NEVs. The policy has also induced people to use public transportation to a greater extent. Because of the oversupply of NEVs quota, people so far have been able to obtain a new energy vehicle immediately, but this situation changed in 2018. Under the double effect of policy and the technological development in NEVs, such as the extending in battery life, more and more people apply to buy the NEVs. The waiting queue to buy a NEV has thus increased and is now until in 2025 (Xinhua net 2018a). At this point, a dilemma has arisen: this policy has prompted people to switch from traditional car purchases to NEVs purchases, but it still cannot effectively limit the growth of total vehicles ownerships. Moreover, is the NEVs totally clean? I will analyse this further below.

A second policy has been for Beijing to increase the oil price and adopt a regional differential parking fee system. This policy can increase the cost of vehicle use and reduce the use of vehicles in the downtown centre. However, the policy is quite controversial. On the one hand, the public complain about the high oil price. The rise in oil price resulted both from changes in the international oil price and the Beijing policy adjustment, ultimately aiming to increase travel cost and limit the on-road vehicles. Already before this policy oil prices in China were not cheap. Considering daily price changes and the slight differences in various oil suppliers and different regions, I will here take the average oil price on August 27, 2018 as an example. The oil price was 7.57 RMB per litre in China and 5.66 RMB per litre in the United State (Sohu 2018a). Furthermore, China's per capita GDP is much lower than the United States. Consequently, it is not easy to afford a car in China, let alone to buy fuel, thus in this situation many citizens will have no choice but to leave the car at home. However, Yi *et al* (2011) argues that the long-term effect of rise in oil price fails to reach the expectation. Drivers will gradually adapt to new oil prices. The second aspect is that although drivers will reduce their trip or change their trip mode by walking or using public transportation when oil price just rises, drivers who cannot adapt to this change will return to drive vehicles after a period.

The third and related policy is to build out and develop the public transport system on a large scale. The, exclusive bus lanes should be built, with the total mileage of 480KM in 2017. Shared bike system and relevant service construction are included as well.

The third and related policy is to build out and develop the public transport system on a large scale. The Beijing Air Action Plan specified that exclusive bus lanes should be built, with the total mileage of 480KM in 2017. Shared bike system and relevant service construction are included in the plan as well and will be discussed further below. Apart from promoting NEVs through the lottery and other policies the fourth measure is to improve the structure of bus, taxi, intercity bus and postal vehicle. Supporting measures include: 1) emission standard enhancement and high-quality fuel oil supply; 2) elimination of old and excessive emissions cars; 3) increasing the proportion of NEVs in buses and taxis. In the original plan it was prospected that in 2017, the total amount of NEVs would account for 65% of public transportation vehicles. The latest date from Beijing public transportation group shows that the NEVs now accounted for 68.3% of public transport vehicles by 2017 and will reach 80% in 2019 (Sohu 2017a).

Beijing's vigorous promotion of NEVs is inseparable from the NEVs incentive policies introduced by China government. For example, license plate restriction does not apply to pure electric vehicles. Two major factors stimulate China to promote NEVs: 1) the aggressive urban air pollution and 2) energy security. By 2016, 64.4% oil consumption depended on foreign countries, which is a potential risk. The rapidly growing automobiles industry accounted for major share of oil consumption. NEVs are regarded as an optimal strategy considering they emit less pollutants and relying less on oil (Du & Ouyang 2016; Zhao & Liu 2017 in Wang *et al* 2018). The State Council of China has assigned NEV development as national strategy and priority in long-term development plan (State Council 2006). In this sense, China has learnt the lessons from the United State experience about NEVs promotion, such as subsidies and tax exemption on NEV cars. Nowadays, China is the largest motor vehicles market in world, occupying around 30% of the world trading volume (Du and Ouyang 2016; Li *et al* 2018; Wang *et al* 2018). China has also become the country with the largest number of NEVs in the world (MOF 2016). The production and sales of NEVs have reached 1.27 million and 1.25 million in 2018, 61.7% increasing compared to 2017 (MIIT 2018). Despite the phenomenal growth rate, China's NEVs development still face challenges: overdependence on subsidy, poorly developed technologies for internal combustion engine (ICE) vehicles and insufficient NEV infrastructure, such as battery charging stations. (Du and Ouyang 2016). Additionally, under the current coal-based energy structure, most of the electricity for NEVs is still produced by coal. Thus, at the moment, the use of NEVs in favour of petrol or diesel cars, cannot fundamentally solve the problems of air pollution and carbon emission (Sohu 2017b).

The national policy is however contributing to change the car ownership also in Beijing. When China officially issued subsidy policy, called 'green -car subsidy program' in 2009, it successfully boosted the NEV industry and reduced the vehicle emissions (Li *et al* 2018). However, subsidy policy is not panacea. The green-car subsidy, as an imperfect policy, not only brought a heavy fiscal burden to government, but also led manufactures to focus on NEV quantity growth rather than quality and technology improvement, in some cases even cheating with subsidies to gain a profit. According to the policy, NEV automakers can receive subsidies in both development and sales. Some speculative companies use 'electric vehicle modification' to cheat with subsidies. They buy the bodywork from the car body manufacturer and install a purchased battery. A basic technical test will be carried out before sales. Cheating companies usually use inferior battery. The stability and safety of the vehicle cannot be guaranteed due to the lack of research and development. A successful sale can get a subsidy up to 120,000 RMB and the maximum subsidies for a new energy bus can cover the total cost of the production. Some speculative companies will set up vehicle leasing companies and sell these vehicles to their own leasing companies to cheat the subsidies. These vehicles will not run on the road. Companies will sell the batteries or reassemble the vehicles for new round of subsidies cheating (Liu, X and Liu, J 2016). Due to the high subsidies policy and poor supervision, it has been estimated that about 10 billion RMB was spent on cheating companies (MOF 2016; Li *et al* 2018).

After becoming aware of the above problems, a new measure named 'dual-credit' policy has been implemented since April 1st, 2018 and the green subsidy policy will be stopped by 2020 (Li 2017; Li *et al* 2018). The original subsidy policy that pay a fixed subsidy for NEVs will not stop immediately but will be faded out. According to the latest notification from government on March 26, 2019, the direct subsidy for pure electric vehicle has been reduced by 50% compared to 2018. Meanwhile, NEVs subsidy applying raises the technical threshold, including longer endurance mileage and lower energy consumption (Zhang 2019).

The dual-credit system refers to the parallel corporate average fuel consumption (CAFC) and the NEV credit schemes, which draws the experience on the Zero Emission Vehicle mandate in California (Wang *et al* 2018). In brief, a car producer will obtain a negative credit by producing (or importing) conventional gasoline/diesel vehicles (CGV) and a positive credit by producing (or importing) a NEV. The dual-credit policy (MIIT 2017) sets a standard value for car producers. Standard Value=CGV * NEVs proportion. This proportion is regulated in policy that 8%, 10%, 12% in 2018, 2019 and 2020 respectively. For example, if an automaker can produce 1,000 CGVs in 2019, its standard value should be 1,000*10%=100.

Automakers should keep the credits positive, otherwise, they will be fined. The government can even stop the production of some high fuel consuming vehicles. The part of NEV credits exceeding the standard value can be used to offset the negative credits caused by CGV producers. Furthermore, the balance of NEV credits is tradable. Automakers with negative credits can purchase NEV credits from automakers who has extra credits. The aims of dual-credits policy are obvious: forcing automakers to produce more NEVs to collect credits and develop energy technologies. Dual-credits policy transfers the fiscal burden from government to the enterprises through the changing of incentive for NEV production from subsidy-driven to market-driven, which demonstrates the China's management model on NEVs has shifted from encouragement to enforcement (Li *et al* 2018).

However, this policy is not friendly for traditional automakers, who mainly produce CGVs. Less than three years passed from the policy first being debated through public opinions to its official implementation (Li 2017). The time is insufficient for the transformation of structure and required upgrading of technologies for car producing companies. As a result, traditional automakers must enhance cooperation with NEV automakers for survival, both domestic and foreign companies (Sohu 2017c).

Dual-credit policy brings challenges not only for automakers, but also environment. According to the credit calculation formula[9], NEVs with longer endurance mileage can earn more credits, which encourages automakers to produce long-endurance NEVs. But this kind of NEV demand more batteries and higher power consumption. At present, the power generation in China mainly rely on coal. Higher demand power consumption will result in more carbon emission and air pollution. Based on this reason, the dual-credit policy might counter the goals of low-carbon development (Sohu 2017b, see more discussion on this below).

Based on the argument of this chapter, the combination methods of vehicle driving restriction and vehicle lottery purchase policy have successfully controlled the number of vehicle ownerships within six million in 2017. The promotion of NEVs can also reduce the concentration of $PM_{2.5}$. However, the current energy structure in China is still based on coal-fired power generation, which means that the NEVs are not driven by clean energy. Moreover, only reducing the vehicle emissions is not enough to achieve the target of $PM_{2.5}$ concentration in Beijing Air Action Plan. Hence, Beijing has taken another strong measure: coal-free policy

5.2.2 Coal-free policy

Statistics on China emissions from Deutsche Bank and Greenpeace East Asia have shown that in all kind of industries, the coal burning is the main emission source of $PM_{2.5}$, contributing to 45%, and the coal-fired power is the largest independent industrial emission source of $PM_{2.5}$ in BTH region (Liu *et al* 2016). Control measures solely adopted in industrial field (e.g. improving emission standard, using clean energy for centralized heating system in urban area) fail to achieve significant improvement on winter air quality. In addition to industry emissions, the residential coal consumption also significantly contributes to form of $PM_{2.5}$ as have been discussed in Chapter 2.3. In rural areas, where there is usually a lack the environmental concern from the side of policy makers, most residents still use unprocessed bulk coal and low-

[9] NEV credits=0.8+0.012* 'pure electric endurance mileage' (MIIT, 2017)

efficiency stoves to carry out cooking and for winter heating without any pollutant control measures. Residential coal use not only produce heavy pollution, but also seriously threatens the health of residents. Research shows that if the $PM_{2.5}$ concentration in the BTH region can decrease to the national standard (35 μg/m^3), around 76, 000 premature death and 34,000 hospitalizations can be avoided (Liu *et al* 2017; Zhang Zhongzhi *et al* 2017; Zhang *et al* 2019).

For this reason, the coal-free programme, which has the ambition to replace coal in both industries and residential households, became an important part of energy structure optimization in the Beijing Air Action Plan. In brief, the coal-free programme mainly included 1) reducing coal consumption; 2) strengthening clean energy supply; 3) promoting clean energy using in producing enterprises; 4) wiping out coal consumption in urban six districts and reducing coal consumption in suburb of Beijing; 5) improving energy efficiency.

A target was specified that by 2017 the total coal consumption in Beijing should be reduced by 13 million compared with 2012. In the coal-free programme, Beijing planned to accelerate the construction of external dispatch based and diversified power support system. The proportion of external dispatch power[10] should reach 70% by 2017. Beijing would facilitate the construction of natural gas-fired power plant and close four major coal-fired plants (Guo Hua, Gao Jing, Jing Neng and Hua Neng) before the end of 2016. Meanwhile, natural gas supply strives to reach 24 billion cubic meters.

The coal-free programme covered a wide range of companies and residential, urban and rural areas. Coal-fired facilities in large-scale enterprises, factories and service industry in six urban districts, as well as suburb new cities, should be replaced by clean energy facilities. Clean energy should replace coal gradually in the centralized heating system. Beijing would establish LNC (liquefied natural gas) delivery service system and promoted clean energy heating methods, such as electric heat pumps and solar energy to reduce coal fired heating.

Furthermore, Beijing issued a 'Three-year plan on defending the blue sky in Beijing' in September 2018 as the continuation of Beijing Air Action Plan, which emphasized the coal-free should be achieved in the plain area of Beijing before end of 2018. The coal-free programme, officially called 'coal-to-clean energy', is formulated with the ambition of replacing coal with any clean energy. China National Development and Reform Commission (NDRC) defines 'clean energy' in the coal-free programme to include natural gas, electricity, geothermal, biomass, solar, industrial waste heat, and coal-based clean energy (e.g. SNG: synthetic natural gas) and also nuclear energy (NDRC 2017). However, due to the condition of clean energy supply nationally, the status of infrastructure and income level of rural residents, the implementation process of coal-free was mainly divided into *coal-to-gas* and *coal-to-electricity*. In terms of results, the coal-free programme has been successful. The annual average $PM_{2.5}$ concentration value of Beijing was 58 μg/m^3 in 2017, which means that Beijing has achieved the target that annual average $PM_{2.5}$ concentration should below 60 μg/m^3, setting in the Beijing Clean Air Plan (BMEP 2018c).

In aspect of energy supply, the last coal-fired power plant in Beijing, Hua Neng Beijing Plant, was shut down on March 18, 2017. In the same year, four major gas-fired power stations were put into operation. It was the first time that Beijing realized a coal-free heating supply, which could reduce 9.2 million tons of coal consumption per year. Beijing has become the first city where all the power is generated by clean energy. 70% of the electricity will be dispatched

[10] External dispatch power: power is not generated in Beijing, but dispatched from other provinces such as Hebei, Inner Mongolia.

from provinces surrounding Beijing, such as Hebei and Tianjin. The rests of electricity will be mostly generated by natural gas. (Ifeng 2013; Guanchazhe 2017; Xinhua net 2017a)

When it comes to residential areas the coal-free programme has decreased use of coal on a large scale. Electricity is the most widely used alternative energy source, which not only can improve outdoor and indoor air quality, but also bring huge health benefits to rural households (Zhang *et al* 2019). The programme *coal-to-electricity* in Beijing can be traced back to 2003, which started in core of the city and gradually expanded. When the Olympics approached, combined with air pollution mitigation for target of the Green Olympics, *coal-to-electricity* then became an important part of the improvement of the urban environmental system. Several coal-free projects have been officially launched since the release of Beijing Clean Air Plan (Liu 2018). As of November 2016, 227,000 households in 663 villages in Beijing have completed the coal-free transformation, of which 29,000 households shifted from *coal-to-gas* and 198, 000 households from *coal-to-electricit*y (Sohu 2017d). By the end of October 2018, 1.1 million households in 2963 villages in Beijing had completed the coal-free transformation, and Beijing had taken the lead in achieving the coal-free programme in China (He 2018).

As an important part of China's energy saving, emission reduction and energy structure transformation, *coal-to-clean* energy has received high attention since its very beginning. In the implementation process, it has encountered many problems and faced a lot of challenges and public debate. In particular, there are two issues which has raised continuous public debates.

Severe shortage of natural gas supply

Although Beijing finally reached the target of annual average $PM_{2.5}$ concentration value specified in the Beijing Clean Air Plan from 2013 (see Chapter 5.2), the annual average $PM_{2.5}$ concentration value was still 73 μg/m^3 in 2016, only one year away from the target. Decreasing air quality from 73 μg/m^3 to 60 μg/m^3, 18% was not an easy target to achieve within one year. Pushed by the critical time limit and the set target for 2017, multiple sectors in central and local government in the BTH region jointly issued the 'Air Pollution Prevention and Control Action Plan in BTH and surrounding areas 2017' (hereinafter called Plan-2017). Plan-2017 had the ambition to intensify the air pollution management (MEE 2017). This policy involved two municipalities (Beijing and Tianjin), and 26 cities in Hebei, Shanxi, Shandong and Henan provinces (the so called 2+26 cities). Plan-2017 emphasized the management of unprocessed bulk coal and designated Beijing, Tianjing, Langfang and Baoding as four coal forbidden zones. Plan-2017 also required to completely remove all the small coal-fired furnaces in the coal forbidden zone before the end of October 2017. Meanwhile, all the 2+26 cities should complete the *coal-to-electricity* and *coal-to-gas* programme over 3 million households. From 2017, a very large-scale energy transformations in residential households began.

However, the scale of *coal-to-gas* and *coal-to-electricity* was even larger than expected. Around 4 million residential households energy transformation had been completed by 2017, which exceeded the target number of 3 million in Plan-2017. In the Hebei Province, the final total number of *coal-to-gas* and *coal-to-electricity* was 2.53 million households, 30% exceeding the original target of 1.8 million. Among them, there were 2.31 million *coal-to-gas* and 0.21 million *coal-to-electricity* households. Although Hebei provinces prepared for providing 6.5 billion cubic meters of gas, taking into account the prospected increase, the actual gas demand for the winter heating 2017 reached up to 8.2 billion cubic meters. The scale of increase between calculated and actual demand related to year-to-year growth of use of gas for household consumption of 234% (Caixin 2017). By 2017, Shanxi province had completed 1 million residential households energy transformations, which also exceeded the target number of 0.39 million. (Sina 2017). The surge in *coal-to-gas* transformation led to a severe shortage of gas supply. Beijing even restarted the Hua Neng coal-fired plant to guarantee the winter heating supply as a result.

The very rapid increase in *coal-to-gas* household consumption and resulting shortage of gas supply was caused by two major factors: First, the environmental management model was based on ‘task completion’. China's environmental management approach is top-down and government-oriented and the government announces a set target the provincial government should achieve. The provincial government in turn specifies targets for municipalities, which then specifies further targets for areas in the municipalities. The achievement of the target is strongly related to the assessment of what can be called a political will, thus achievements are rewarded politically. Therefore, every level of government strives to overfulfill the tasks. For example, the China central government assigns the task of 100 households’ *coal-to-gas* construction to the provincial government. The provincial government will increase the task volume (e.g. 120 households) and allocate the task to subordinate cities and counties. The task will be gradually intensified because each level tries to overfulfill in terms of the set goals and for a good performance. If a city government fails to achieve target, or achieves much less than other cities, local officials will be blamed

Second, the financial subsidy policy acts as an encouragement and stimulate increases further for *coal-to-gas* and *coal-to-electricity*. In general, subsidies can accelerate the rapid development of specific goals in a certain period. For example, subsidies have directly promoted the development of NEVs. Since subsidies will bring financial burdens to the government, they will not always be maintained, or they will be gradually faded out. The maximum completion of *coal-to-gas* construction within the time limit of subsidies policy can save costs for enterprises and local governments. Therefore, provincial government boosted relevant constructions in anticipation of a possible reduction of subsidies in the future (Sina 2017).

As a result of new policies to mitigate emissions and improve air quality, China's natural gas consumption increased sharply in 2017. Data from National Development and Reform Commission shows that natural gas consumption in 2017 was 237.3 billion cubic meters, increasing by 15.3% compared to 2016, which broke the record of natural gas consumption (NDRC 2018). Among this increasing, *coal-to-gas* consumption accounts for nearly 20 billion of the gas increases (Sohu 2018b). The gas shortage caused by a wide range of coal-free programmes led to the soaring increase of gas price. Some residents and institutions were affected by gas supply limitation.

High cost and inadequate infrastructures

The large-scale *coal-to-new energy* programme has brought huge financial burdens to government. First, the financial subsidy is a booster for *coal-to-new energy*. For example, Beijing government provides 50% of the funds for the investment in thermal storage facilities through centralized heating projects for civil use, such as geothermal and solar power. These subsidies provide 30% of the funds for gas-based and electricity-based centralized heating projects (BMEP 2017). Second, the *coal-to-gas* programme require infrastructural investments in terms of pipelines and systems to provide gas. Similarly, the *coal-to-electricity* programme needs construction of substation and transmission equipment. Other green energy programmes such as coal-to-solar and wind power needs equipment such as solar panel and wind turbine and systems to transport and store energy. The investment amount is very huge for rural areas with poor infrastructure.

As a result of the transition the heating costs for residents has sharply risen. A villager in Xingtai city, Hebei Province told a journalist that the average cost for gas heating was 40 RMB per day. He spent nearly 5,000 RMB for the whole heating period (4 months), which was 2,500 RMB higher than what he had previously paid for coal-fired heating (Sohu 2017d). Additionally, some interviewed villagers stressed that improving the heating of the house would be more economical and effective than solely switching from coal to gas. In addition to the increase in heating costs, households in rural area, especially very remoted places, doubted the safety and stability of natural gas. Their long-term habits of using coal for heating made them reluctant to change the way of heating. The rising cost of heating, the shortage of natural gas supply, and the unwillingness to change heating habits have caused people to complain more about the *coal-to-gas* programme.

Whether large-scale use of natural gas can improve air quality?

With the rapid spreading of *coal-to-gas* project in North China and the growing shortage of natural gas, public attention has begun to focus on natural gas itself: the questions whether natural gas can really improve air quality has become a controversial point in public debate. First, natural gas is believed to be cleaner than coal because its greenhouse gas emission (GHG) from direct combustion is much lower than coal. However, the natural gas will also cause significant GHG emissions if we calculate the GHG of the life-cycle air emission of gas. The life-cycle air emission of natural gas should include the gas leakage at mining and the consumption in compressor stations of the pipeline. In this case, during the conversion to electricity production, the carbon dioxide emission in a gas-fired power unit is comparable to coal-fired unit (Stanek and Białecki 2014). Considering the cross-regional transmission of natural gas, the GHG of gas should be calculated as the cumulative emission in the whole process instead of solely local emission. Looking at the cumulative emissions of natural gas this energy source is high in GHG emissions.

During the entire *coal-to-gas* programme process a coal-based synthetic natural gas (SNG) has been launched heavily as a 'clean' energy source of great potential. As a substitute for direct coal consumption, SNG is marketed as low in dust emissions. A developed industry and mature technology make it possible for SNG to become an alternative way for China to mitigate air pollution and to optimize energy structure and get the favour of policymakers and investors (Li *et a*l 2016; Liu *et al* 2016). Hence, in 'Implementation Guidelines for Regional Presentation and Control of Air pollution' (State Council 2010), SNG was listed as one of the important development targets. However, SNG does not really reduce energy consumption based on coal because it is the product of gasification from coal. The inclusion of SNG in the *coal-to-gas* programme just changes the position and role of coal in the energy supply chain: from primary energy consumption (coal to electricity) to secondary energy consumption (coal-gas-electricity) (Liu *et al* 2016). Moreover, the lifecycle GHG emissions of SNG are even higher than for pulverized coal fired power, and much higher than conventional natural gas (Yang & Jackson 2013). It is worth noting that the resulting carbon emissions from natural gas will impact on global climate change (Jaramillo *et al* 2007). Additionally, the production of SNG demand huge amount of water. Considering that most of the SNG plants are placed in Xinjiang and Inner Mongolia province, where is already very short of water, the large-scale development of SNG plants will worsen the water stress and aggravate environment (Yang & Jackson 2013). As mentioned above, 70% of power in Beijing is produced in provinces surrounding Beijing. It is a change that coal-fired in local moves to gas-fired in other places, which means that *coal-to-gas* can improve air quality in Beijing but cannot promote the overall reduction of GHG emissions in North China.

Although the process is full of challenges and controversy, the Chinese government has no plans to give up the coal-free programme. In the latest document 'Winter cleaning and heating plan for the northern region (2017-2021)' issued by NDRC, it is specified that by 2019, the clean heating rate in the northern region will reach 50% and this proportion should increase to 70% in 2021. On the positive side, the implementation of the new policy has enabled a few important lessons. The number of *coal-to-gas* projects implemented should be based on gas source and planning for provisioning of gas. LNG, SNG and Compressed Natural Gas (CNG) should be comprehensively utilized (NDRC 2017).

Where is wind power and solar power?

Here comes a question: where is wind and solar power generation in coal-free programme? Although China's installed capacity of new energy generation (mainly in wind power and solar power) has increased rapidly in the past decade, new energy generation resulting from these types of energy sources only accounts for 6.5% of total power generation as of 2017 (CEC 2018). Renewable energy types still cannot be used as the main source for generation and heating in current stage of China. China has large spatial disparities between resources and between regions (Kahrl *et al* 2011). For example, coal resources are concentrated in north and hydropower in the central and south. Wind power plants is mainly located in north and north-west, such as Xinjiang province and Inner Mongolia because of the good wind resource in these places. In the case of *coal-free* programme in Beijing and surrounding area, wind power could potentially have been heavily utilized, however, China is facing serious curtailment problems with wind energy.

Wind curtailment here refers to the abandonment of wind generation and the shutdown of wind turbines due to the problems of safety, technology and grid access management Luo *et al* 2016). One of the major reasons is that China's electricity consumption structure is dominated by thermal power generation. Although the proportion of thermal power generation is declining year by year, the latest data indicated that the thermal power generation still accounts for 62.2%, of all kind of power generation in 2017 and coal-based power dominated. This situation is closely related to China's electricity consumption structure as a whole. China's industrial electricity consumption is extremely high and as I mentioned in Chapter 2 the Hebei province and Tianjin, where the *coal free* programme is mainly carried out, are heavily industrialized. In 2017, the industrial electricity consumption accounted for 69.4% of China's electricity consumption (CEC 2018). As the result of high share of industrial load, China's electricity system requires stable, high load power generation rather than peaking generation. Compared with wind power, the turn on and turn off boiler in thermal power are controllable, which leads to the heavy reliance on coal-fired generation. In most countries, coal-fired generation is used as the baseload resource, which means that coal-fired generation plays a role to stabilized grid system (Kahrl *et al* 2011). In this circumstance, wind power cannot provide stable power output due to its technology and reliance on nature condition. For example, in the 193 wind farms disconnection accidents were reported from January to August 2011 (Wang 2014 in Luo *et al* 2016). Additionally, the uncertainty of wind resources leads to fluctuations in wind power output and poor predictability of power generation. This characteristic of wind power requires grid reserve capacity to meet wind power grid connection. This is also referred to as 'peaking adjustment service'. In the case of fixed grid capacity, the peaking adjustment service is mainly achieved by reducing the output of other power supplies. However, in the northern China winter, most of the heating supply is guaranteed by thermal power generation as discussed above. The grid can therefore provide very few capacities for peaking adjustment services. In this condition, wind power output is usually restricted to guarantee grid system safety.

Another reason for the limitation of wind energy is the inconsistency between wind power development and the grid construction. As the wind power capacity grows so fast, it creates a mismatch with grid transmission capacity. The construction period of a wind farm is usually short while the grid access system is complicated in project approval and project construction. Briefly, the grid access construction and wind power construction cannot keep synchronous, which leads the insufficient grid access for wind power (Kahrl *et al* 2011; Luo *et al* 2016).

In addition to the above-mentioned reasons, other factors include power consumption of long-distance transmission and high electricity retail price of wind power also restrict the role of wind in generation ((Luo *et al* 2016). It is worth noting that solar power also has faced similar limiting problems. Despite the constant optimization of the grid structure, a considerable portion of the power generated by wind and solar is abandoned due to the inability to access the grid. The ratio of abandoned wind/solar power to total wind/solar power output is called 'abandonment rate of wind/solar power'. The abandonment rate of wind power and solar power was 12% and 6% respectively in 2017 (CEC 2018). In summary, wind power and solar power cannot play a meaningful role in the *coal free* project under the current conditions of China's power grid structure.

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5.2.3 Bike-sharing promotion

One of the biggest changes around the Chinese in recent years when it comes to transport are the rapid development of the bike-sharing system. The bike-sharing system have had profound effects on increasing transit use, improving public health, decreasing air and noise pollution (Demaio 2009; Fishman 2015). Here, I will mainly focus on the impact of bike-sharing system on air quality improving, emissions reduction and sustainable development in Beijing.

In the Beijing Air Plan, the development of the bike-sharing service is encouraged by government. Most of the shared bikes are based on manpower driving. They are welcomed around the world because of the sustainable features, such as zero emissions, health lifestyle and energy saving. The bike-sharing system is a service that makes bikes available for shared use, with a purpose to provide clean and sustainable option for people's daily transportation. The first bike-sharing service emerged in Amsterdam 1965 but ended up with bikes bring stolen and damaged (Demaio 2009; Marshall 2018). The first bike-sharing service in Beijing began in 2005 and was run by private rent companies. The bike-sharing service resulted in the first boom of usage during the Beijing Olympics (Liu *et al* 2012; Tang *et al* 2011 in Campbell *et al* 2016). At that time, the bike-sharing system not only met the theme of Green Olympics but also provided people an alternative way for daily trips when the odd-and-even driving restriction policy was implemented. More than four million people switched from private vehicles to public transportation during the two-month odd-and-even driving restriction, and the bike-sharing system also placed an effective role in facilitating transport (Liu *et al* 2012)). However, there was little cooperation between different bike rent companies at that time. Users who rented a bike from one company had to return it to the specific station owned by the same company. The actual average spacing distance between bike stations owned by the same company were more than 800 meters, were the recommended distance is 300 to 400 meters. This situation of sparsely placed stations increased time consumption and users' costs of rental fee (Liu *et al* 2012)). Similar with the case in Amsterdam, bike-sharing service in Beijing therefore quickly faded away after Olympics due to poor user experience, the unreasonable distribution of bike stations and poor bike maintenance (Liu *et al* 2012)).

The real prosperity of bike-sharing system in Beijing began only in 2015 and was boosted in the next two years. In the beginning, various bike-sharing companies also provided discount to attract customers, which made the riding cost very low. Named as IT-based shared bike, the rapid development of the new generation of shared bikes benefits from GPS technology and mobile payments. The application of electronic lock and the fact that the bike does not require the docking station (e.g. in China it is referred to as 'dockless') has been influential in its success. Bikes can be picked and parked in any defined district, such as a small area in front of shopping mall or along the sidewalk. For example, user can use GPS in mobile APP to track an available bike nearby. The user will receive a dynamic password to release the bike if his account has enough balance. The fee will be charged by riding duration or distance. The IT-based bike-sharing service provides users with maximum convenience and eliminates the users' worries about bike maintenance and bike theft.

However, the development of bike-sharing service in China does not proceed in a sustainable way and its effect on air quality improving is overstated. The effect of shared bike on air quality improvement is mainly achieved by reducing private vehicle using and easing traffic congestion. In terms of reducing private vehicle using, bike-sharing service performs well, and the proportion of bike trips has increased. In the Beijing urban area, the proportion of bike trip accounted 10.3% in all traffic trip in 2016 and this number went up to 11.9% in 2017 Beijing Transport Institute 2018). However, the increase was still lower than the expectation. Beijing Traffic Committee set a goal in 2015 that the proportion of bike trip reach 18% in 2020 (Xinhua net 2015). This target might be difficult to achieve in the current situation. Research shows that the bike-sharing system has had little impact on current motorization rates in Beijing because the using of shared bike is heavily limited by distance, weather, air quality and individual travel habits (Campbell *et al* 2016). The private vehicle user who need long distance drive will not switch to shared bike and an individual will prefer to take bus or metro rather than bike in haze and rainy weather.

In terms of easing traffic congestion, bike-sharing even plays a counter-productive role. Due to the dockless features, the parking of shared bike is difficult to regulate. Although there are many defined parking spots in the urban area, with the rapid increase in the number of shared bikes parking spaces are far from enough. As a result, the parking of many shared bikes squeezes the sidewalks and even the motorway, which causes traffic problems. In addition to the disadvantages in functions, the operation process of bike-sharing system has been criticized as a 'fake environmental protection'. Bike-sharing service in China is different from the typical sharing economy model such as Airbnb and Uber, which use an existing house and car and share them to achieve resource conservation. Shared bike companies purchase a large number of new bikes and deliver them into market. The development of shared bike from 2016 to 2017 somewhat resembles what I would call a 'barbaric growth'. Many companies rushed into the bike-sharing market and immoderately put new bikes into road to gain the market share. The number of shared bikes in Beijing increased from 0.7 million in April 2017 to 2.35 million in September 2017. This number largely exceeded the maximum capacity of bikes imposed by Beijing Transportation Commission, set at 1.9 million (Xinhua net 2017b).

The barbaric growth of shared bikes makes bike-sharing system lose its sustainability. In the process of shared bike production, it is often overlooked that the carbon emissions generated by the life cycle of shared bike are 6.8 times higher than common bikes due to extra equipment installation, including electronic lock, aluminium alloys body and GPS devices (Ding *et al* 2018). Mass production even can increase the GHG emissions. Furthermore, individuals tend to be less protective of shared bikes than then as personally owned bikes, resulting in the life of shared bikes being shorter than that of common bikes. Due to the short life cycle of shared bikes, bicycle companies need to deliver new bicycles to the market more frequently, but they ignore the recycling of discarded bicycles, resulting in more waste. The Guardian (2018) reported the enormous scale of bike waste and called it as bicycle graveyards.

Facing the fast-growing shared bikes, Beijing Commission of Transport issued The *Guidance on shared bike development in Beijing* to regulate the bike-sharing market. Although this policy stops putting new shared bikes into market and reduces the number of shared bikes to below 1.9 million, it still demonstrates the government's supports for bike-sharing. This policy will not only guide the development of shared bike system, but also provide practical supports, including the construction of bike lanes and parking spaces (BMCT 2017). Many shared bike companies went bankrupt after the chaotic expansion in the market. The attitude of investors and public to the shared bike is also now more moderate calm (Pham 2018). In the current situation in Beijing, the contribution of bike-sharing to haze mitigation and air quality improving is much less effective than policies of vehicle restriction and coal-to-clean energy. But bike-sharing is sustainable over the long-term perspective. More importantly, the concept of low carbon lifestyle conveyed by the shared bike is significant. The concept of 'share' is also expanding from shared bike to other areas. For example, the shared car service named Car2go has entered in Chongqing, a southwest city in China (Tan 2016). It is also possible to see more features of sharing and sustainable common use emerging in the daily life.

5.3 'APEC blue' and deep thinking

The air quality has not significantly improved since Beijing Air Action Plan implemented. However, a new word called *APEC blue* a word that spread with a viral success in 2014. The 21st Asia-Pacific Economic Cooperation Summit (APEC) was held on November the 10th and 11th in Beijing. Relevant control actions were undertaken one week before the summit on the morning on the 8th of November. As a result, the $PM_{2.5}$ average concentration in Beijing downtown decreased by 37 µg/ m³ and kept on 43 µg/ m³ during the whole summit. BMEP made a comparison that if no control action was undertaken, the $PM_{2.5}$ concentrate would increase by 61.6%, reaching 69.5 µg/ m³. Among them, Beijing local actions contributed 19.8 µg/ m³ in $PM_{2.5}$ concentration reduction and regional actions (cities and provinces surrounding Beijing) contributed 6.8 µg/ m³ in reduction (BMEP 2014). As a result, of these efforts the sky in Beijing presented as clear and amazingly blue. People called this long-lost weather condition as the *APEC blue*. This word rapidly spread through social media and first appeared in the People's Daily on November the 7th (an official media outlet). The good air quality during the summit and actions adopted by government are called as *APEC blue phenomenon* (Zhang, 2016). However, like the policy actions before the Olympic Games, the strong control actions implemented for APEC achieved visible results in a very short time. The air pollution quickly rebounded after the APEC summit.

5.3.1 Specific actions for APEC summit

Before discussing the social problems reflected behind the *APEC blue*, it is necessary to understand the specific actions. The key measures included: 1) odd-and-even driving restriction for vehicles; 2) control actions for 141 high emissions industries and factories; 3) stopping all construction work relating to dust producing.

The odd-and-even Odd-even driving restriction policy for Beijing private cars implemented on Nov.3rd. 70% government cars stopped to use and vehicles (including truck and intercity bus) from outside Beijing are limited to enter. The contribution rate for $PM_{2.5}$ reduction of this policy was 39.5%. Among 141 controlled high emissions industries and factories, 9 were temporarily closed and 72 were limited in production. The emissions reduction in SO_2, NO_X, PM_{10}, $PM_{2.5}$ were significant. Meanwhile, Beijing public institutions (security, central state organs and city operation maintenance department exclusive), schools and universities left in lieu 6 days from Nov.7th to 12th, which reduced 10% permanent resident population of Beijing and cut 20% city traffic flow, called as ‘APEC holiday’. (BMEP 2014)

In addition to Beijing local actions, cities and provinces surrounding Beijing also undertook various measures to support air quality improving in Beijing. 24 enterprises in Shanxi province, including coking, power and cement plants closed. 881 construction sites in Hebei province stopped on Oct. 31st. Another 1564 construction sites should be closed if heavy polluted weather happened. Hebei province started the highest emission reducing measures to guarantee Beijing air quality. Residents within a five km radius of Yanxi Lake, one of the APEC conference places, were forced to use natural gas instead of coal for cooking and heating in order to prevent smoke from kitchen chimneys. Ten cities, such as Tianjin, Shijiazhuang and Tangshan in Hebei province also implemented odd-even driving restriction on Nov 4th. (Zhang 2016) Meanwhile, during the APEC, buses were free in Shijiazhuang and Tangshan cities

5.3.2 Reflection behind *APEC blue*

Although China’s official media highly appreciated the air quality during the APEC summit (see Li 2014), the actions for *APEC blue* have damaged the interests of individuals and factories. Not everyone was happy with *APEC blue phenomenon*. People enjoyed fresh air but doubted the rationality of government’s approach. The impact of control action on individual’s daily life was much larger than what was shown on official media. The traffic restriction on trucks also blocked the food deliveries, including of milk supplies to home. The APEC holiday were not free. Officials and students/teachers had to compensate for the holiday in the consecutive weekends after APEC (Tatlow 2014).

APEC blue also brought negative effects on enterprises and factories in the surrounding region. Considering the mandatory shutting down during APEC, factories had to reschedule the production plan. Factories increased their workload before the APEC summit to ensure that their production plans were not affected. Therefore, a surge in production rates happened before APEC, which worsened the air quality in October, prior to the APEC (Tatlow 2014). There was also no compensation for factory owners, and employees, who had to stop work during the restriction period. There was also no compensation to the taxi and bus drivers who were not allowed on road (Zhang 2016). The short staying of *APEC Blue* has made people consider about whether it was necessary to carry out such strong control measures. In fact, some issues behind the *APEC blue phenomenon* should not be ignored. Below I will discuss these concerns in detail.

***APEC blue* reflected the characteristics in China governance system**.

China's environmental management approach has strong characteristics of top-down and centralized. Judith Shapiro argues these characteristics in her book *China's Environmental Challenge* as below:

> “China remains a top-down, centralized, authoritarian state…. Civil initiatives remain sharply curtailed… the administrative and legal systems that might help China to enforce its many excellent environmental laws remain weak. Well-intentioned environmental initiatives are often implemented in heavy-handed fashion, with negative implications for social justice.” (Shapiro 2016: 57).

The top-down system brings many benefits to China in its rapid development. It guarantees the quick and effective implementation of policies. However, the disadvantages of this system are of concern. Zhang (2016) criticizes the strong control actions adopted in APEC from a legal perspective. Zhang reviews policy actions taken before the Olympics and APEC, and also the so called ‘Military Parade Blue’[11] in August 2015. In Zhang’s argument the nature behind ‘blue’ and good air quality is that government use coercive measures to present a good national image to world. However, such coercive measures have prejudiced individual rights.

The restrictive measures were essentially a state action that used state administrative power to take unconventional measures to achieve a certain target in a certain period. In APEC case, target refers to good air quality and certain period refers to during to meeting. It would limit the legal rights and freedom of citizens, legal persons, social organizations, institutions and other social subjects to a certain extent. Combined with the centralized governance system of China, this action could effectively accomplish a particular goal (Zhang 2016). The odd-and-even policy, school closures and factories shutting down undermined the right of using property, the right of education and the right of enterprises' autonomy. The lack of legitimacy in the use of power during the APEC was also contrary to the principle of ‘governing the country according to law’. Some measures can be seen as exceptional measures that would normally be used in state emergency conditions. New York Times in fact titled the *APCE blue* campaign as the ‘APEC war’ when reporting Beijing’s special actions for air quality improving (Tatlow 2014).

The Communist Party of China (CPC) have emphasised that the ‘Rule of Law’ should be insisted upon as a fundamental principle in running the country since 18th National Congress of CPC in 2012. The principle of ‘Rule of Law’ should be put into practice of governance and social management. CPC was required to promote law-based governance. This means that Chinese leading officials should be guided by law in both thinking and action. The first time that the concept of ‘state governance’ appeared in the CPC documents was in 2012. Compared with state management, state governance emphasised the management mode of interaction between top and down instead of top to down. This was an indication that governance from CPC’s perspective should shift from management to service, from power to non-power (China Daily 2012; Zhang 2016).

However, as argued by Zhang (2016) the ‘rule of law’ got lost in *APEC blue* campaign. In fact, *APEC blue* reflected two extreme action models of Chinese officials: 1) they were dereliction of duty in normal; 2) they were very efficient and effective in special events due to pressure of the superior or centre government. In normal times, the handling of a pollution incident may be slow. The shift between two extreme models of governance made the effect of environmental management difficult to maintain (Zhang 2016).

Aside from the problems of central governance and lack of adherence to rule of law the air quality quickly deteriorated after APEC. The $PM_{2.5}$ concentration became higher than before after the ending of traffic restriction, the re-start of factories production and the coming of the heating season. In my understanding, the most significant behind *APEC blue* was to make both leading officials and common people consider how to transfer emergency measures to sustainable governance.

[11] PM2.5 concentration falls to lowest levels (19.5 μg/ m³) in at least three years before China's mega-military parade commemorating the 70th anniversary of victory in World War II

The *APEC blue* campaign reflected the disadvantages in the relationship between government mobilization and the public participation in environmental protection.

In *APEC blue* campaign, the public actively or passively respond to environmental measures taken by the government, which is called 'government-mobilized public participation'. 'Government － mobilized public participation' refers to the model that the public respond to the government's call and participates in environmental protection activities (Mei 2015), which has become an important model for the public to participate in environment management and social construction.

This model has the characteristics as following: 1) It is directly organized by government with high efficiency and quick effect. 2) The mobilizer is government (both centre and local government) and the numerous participants includes individuals, government stakeholders, public institutions, enterprises, social communities and other organizations. 3) the mobilizer holds the dominant position, which occupies huge administrative, judicial, economic and social resources. Participants in a specific area (e.g. BTH region in APEC summit) response to the government call to participate in related activities. 4) The purpose is clear that is to achieve an environmental public interest of a certain area in a certain period. 5) Mobilizer has comprehensive work division and deliberate plan. They focus on efficiency once administrative actions decided. On the contrary, participants lack the opportunities and individual rights to express opinions and defences. (Mei 2015)

This mode has great advantage in execution and effect. It not only embodies the institutional advantages of a socialist system that enables the mobilisation of necessary resources for big undertakings, but also is embedded in a form of patriotism and in traditional virtues that collective interests take precedence over personal interests. People, especially enterprises in the BTH region made great contributions and sacrifices for *APEC blue*. The public contribution has also been officially recognized. In the '*APEC air quality and control actions effect assessment report* issued by Beijing Municipal Environmental Protection Bureau, public participation and the adoption of green lifestyle are listed as one of the important contributions to improve Beijing air quality (BMEP 2014).

However, as mentioned above, the measures taken in APEC summit fundamentally lack legitimacy in many ways. In the Chinese system, the relationship between the official and the civil has never been a consultative relationship of equal dialogue (Mei 2015). The public have few opportunities to question and reject administrative actions. Although this situation is changing due to the legalization process, it is still very slow.

From the public's point of view, first, measures taken for APEC lacked information disclosure. Few public opinions were collected before implementation of various restriction actions. There was also a lack of public assessment and discussion afterwards. Second, because of the leading position of government, the public will be pressed by the government authority to ignore, even give up their legitimate rights, which provide opportunities for officials to abuse their power. Third, administrative law enforcement should follow the principle of proportionality, also called 'principle of minimum damage'. It means that, when achieving an administrative goal that may have adverse effect on rights and interests of relative person, administrative subject should limit this adverse effect to the smallest range, keep the goal and adverse effect in a moderate proportion, in order to achieve the requirements of fairness and justice (Zhao 2018). In brief, the administrative goals should not be achieved at a very high cost. However, measures in APEC violated this principle. Various mandatory control actions brought huge loss to enterprises. During the APEC summit, the total output value of enterprises decreased by 12.42 billion yuan in only Shijiazhuang city due to the restriction policy

(Mei 2015). The *APEC blue* campaign therefore reflected the missing or insufficient of procedure principle when China government implements some unconventional measures.

6. Living in haze

6.1 Interview

The purposes of the policies examine in the previous chapters are to promote the sustainable development and response people's demand for good environment and health. The mitigation of haze is a constant battle. Various researches have demonstrated that the impact of haze on people is multifaceted, long-term, and imperceptible. The concerning on health risk brought by haze will lower people's happiness and disrupt the trip plan (Zhu 2018; Zheng *et al* 2019). On one hand, in haze weather, people prefer to stay indoors to avoid long-term exposure to haze. On the other hand, heavy haze can cause highway closure and flight cancellation, resulting in travelling disruption.

For this thesis I wanted to include a section on how people in Beijing think about haze and how haze affects their lives. To contemplate these questions, I visited Beijing in the last week of December 2018, a normally smoggy season and carried out interviews of a few residents in semi-structured format. Compared with structured interview which fix the questions, semi-structured allows for new ideas to be brought up beyond the question scope. It is a better use of the knowledge-producing potentials of dialogues because interviewees can express what they deem important (Brinkmann 2014: 286). Following questions will be included but not limited in interview: 1) When did you start to realize the haze? 2) How do you cope with haze? 3) What changes have occurred in recent years related to smog? 4) What do you think of Beijing's measures to control haze? 5) Will you take the initiative to change your lifestyle to mitigate haze, such as riding shared bike?

During my visit and before and after, I collected some personal feedback on haze. Most of the interviews were conducted face-to-face and the rests were done through internet. A study that would actually attempt to represent more general sentiments across age, social status, gender roles and personalities would require a very large-scale survey that has not been possible here. Instead I will quote the individual experiences of haze from the perspectives of the selected interviewees. Some of the interviewees are locals in Beijing, but also migrant workers from other provinces and tourists. Additionally, I add an interview from the documentary film named Le Masque Et La Brume, to show a totally different attitude towards haze than what has come up in my interviews. Obviously, the responses of the interviewees are reflecting their personal feelings and sentiments about the haze, but their narratives also reflect the impacts of haze on personal life from different angles and the changes people make in response to haze. To fully present people's cognitive process of haze, I will present the interviews in the form of storytelling instead of mechanical question and answer.

The first interviewee was Mr. Zhao, a native who grew up in Beijing, who has now retired. I met him at the electronics store while he was buying an air purifier[12]. Because the birth of his grandson, he needed to buy another air purifier to place in the grandson's room. I first asked him how long he has been aware of the smog:

[12] Mr. Zhao is a random interviewee. When he was asked if he agreed to the interview, he accepted.

> Mr. Zhao: I cannot remember when the smog started, probably after the Olympics? I had the habit of running in the morning, but my son prevented me one day and prepared many masks in home. He told me not to go out in the hazy weather. The haze was very harmful to the lungs. News on TV also frequently reported haze. It was as if suddenly, everyone around me began to talk about haze. Of course, I followed these suggestions. Health is the most important, especially at my age.

We also talked about haze control measures in Beijing. Zhao said the air quality was acceptable this year, much better than that of last year. He hoped that Beijing could continue the control measures and made the air quality as good as it was 20 years ago. In the interview, I found that Mr. Zhao was very aware of the health hazards of $PM_{2.5}$ and he also referred to this when I also asked him why he was now buying an air purifier.

> Mr. Zhao: The purifier is really very useful. I didn't believe it before. My son bought me the first one three years ago. At that time, the haze in Beijing was serious. When the purifier was just turned on at home, the detected value was extremely high. You know, the higher the value, the more $PM_{2.5}$ in the house. After running for a while, I really felt the air in the house was getting better. The new air purifier can purify the formaldehyde, I hope so.

The surge in sales of air purifiers has indicated that many people have more understanding of indoor air pollution than before. From 2013 to 2018, the number of air purifiers in China has increased from 3.1 million to an estimated 7.5 million according to Euromonitor (Stokel-Walker 2018). Obviously, media will influence the public's perception of pollution. Frequent reports from the media have promoted people's understanding of haze. The more the media reports air pollution, the more information about its effects the public receives. In media reports or publicities, the hazards of haze will be amplified usually, which makes people pay more attention to air pollution (Hong and Wang 2018). However, this goes both ways, for example, air purifier manufacturers might exaggerate the dangers of haze in order to sell more products.

Connecting to Zhao's story about how talk about the dangers of haze flared during the Olympics, in fact and as has been discussed in previous chapters, the haze of Beijing and related problems has been present earlier than most people in Beijing now recognised. According to the BMEP data, the average annual $PM_{2.5}$ of Beijing was 100-110 $\mu g/m^3$ in 2000 (People 2012), which was higher than the 90 $\mu g/m^3$ in 2013. But, in the perception of the people I have interviewed the problem of pollution started to become noticed from 2013. This might be connected to the fact that in 2013, the MEE introduced $PM_{2.5}$ into air quality testing indicators that was also publicised as discussed in Chapter 4. More and more cities began to announce $PM_{2.5}$ data and AQI to the public, making people feel more urgency perhaps in the problems of pollution. Another interviewee who also became aware of haze from the media is Ms. Pan.

Ms. Pan is a 30 years old project manager in a big foreign company. She graduated from the same university with me. I contacted her in advance through alumni network and visited her in Beijing. She is the interviewee who gave me the most comprehensive feedback among the people I interviewed. Living in Beijing's Fourth Circle district, she has been in Beijing six years since she actively applied to transfer from Chengdu Branch to the Beijing headquarter in 2013. Like many young people who are eager for opportunities, her main purpose in coming to Beijing is to achieve a better self-development. Compared with the branch office in

Chengdu, Beijing, as the capital, undoubtedly has better resources and greater space for development. When discussing the effects of mitigation with Ms. Pan is clear that results of haze mitigation has come very slow, as also people's perception of changes of environment (both negative and positive):

> Ms. Pan: A lot of knowledge about haze was only known after I arrived in Beijing. It is totally different to directly feel the haze and watching it on news report. I used to think that the weather with low visibility was fog, but now I can clearly identify what is fog and what is haze.

It wasn't until the winter of 2018 that Ms. Pan was surprised that the number of haze days became less. When talking about the problem of haze, Ms. Pan told me that this year's air quality was much better than before:

> Ms. Pan: In fact, the air in Beijing has improved a lot. The whole week is good, blue sky and white clouds, and there is no important meeting or event during this period. If you were in Beijing a few years ago, this feeling would be more obvious. When I arrived in Beijing, it was the most serious period of haze. From 2013 to 2016, especially in winter, it was difficult to see the blue sky. If the air was particularly good for a certain period, the big probability was that there were important meetings or international events.

Ms. Pan clearly associates the blue sky with the APEC meeting and the temporary mitigation in relation to this. But as she points out the air has now improved. Although the air quality in Beijing is improving, I could still feel Ms. Pan's anxiety about the haze and health effects during our conversation. She admitted that she was diagnosed with thyroid nodules recently. "I have good working schedule, living and diet habits. I guess it (thyroid nodules) has a lot do with air pollution" she explained. Additionally, she talked about her colleagues with weak respiratory systems or poor immune systems that were particularly susceptible to coughing, and even pneumonia in winter.

> Ms. Pan: I try to adapt to living in haze and become more careful about haze after diagnosis. To get up in the morning and see the AQI on mobile phone APP have almost become habit. If the pollution is very serious, unless it is a mandatory working day, I will go out as little as possible, or wear a mask. However, I heard that the general mask was not protective from $PM_{2.5}$. Anyway, psychological comfort is still needed and now, many masks are made fashionable and cute, which can help me to keep in a good mood.

Ms. Pan thus showed me her anxiety about haze, especially related to her health concerns. Although there is an obvious improvement in the air quality in Beijing, she still fears that the potential risks of haze impact on health could be higher than she expected. Such worries became stronger and stronger after her disease was detected:

> Ms. Pan: Haze is a risk. I mean that many people's health is fine at present, but someone might be diagnosed with a disease, which is caused by haze. As you know, China has very high

incidence of lung cancer.[13] I am worried that when my generation enters 40 or 50 years old, the lung cancer might breakout.

In the end of our conversation, Ms. Pan told me she had the plan to leave Beijing in the future but that this was rather due to the desperate house prices than the haze problem. She pointed out that many other cities in China had a worse air quality than Beijing, but those cities were of less concern from the side of media. Indeed, on the day I interviewed Ms. Pan, on December 26, Beijing's AQI was 33, which qualified as a 'good level' in air quality standard. At the same time, Chengdu, Ms. Pan's hometown, had an AQI of 80. The quality was significantly worse than that of Beijing. Meanwhile, the air quality of Shijiazhuang and Tianjin cities surrounding Beijing were also below satisfaction[14].

The third interviewee also looked forward to the future improvement of air quality of Beijing. Mr. Zhang, 27 years old, is Beijing native and an amateur marathon runner. I met him in an online forum about haze and interviewed him in Beijing. He told me more about how haze had affected his daily life and activities.

> Mr. Zhang: I think the impact of haze is subtle over long-term. For example, I have been used to paying attention to whether haze will affect flight and highways before I travel. My wife and I are passionate about the marathon. We will cancel the marathon exercise in haze weather. But I remember that, several years ago, the marathon was held in a very serious haze day. Maybe the haze was not fully understood at that time.

The marathon event mentioned by Zhang was 34th Beijing International Marathon in 2014. Runners wore masks to cope with haze and many of them had to quit from the marathon that day. Many voices later criticized the organizer for insisting on keeping the marathon open and thereby exposing runners to hazardous weather (BBC 2014). "In that case, I would not participate marathon." Zhang told me even though he would be unhappy and frustrated if his plan was cancelled due to the haze, he still put health first. He was adapting to these situations and such frustration was no longer as strong as before. He even felt happier now than before if good weather came. Zhang praised Beijing's current information campaigns about haze, which could remind public to do something for haze mitigation.

> Mr. Zhang: The information on haze becomes more and more transparent. It is very easy to access AQI data and $PM_{2.5}$ concentration. Beijing government call on us to participate in the activity of 'I voluntarily drive one day less per week'. I like this and basically agree, even though it is sometimes inconvenient. My home is very close to my company and I can walk if I go out early. I prefer to use a shared bike. But many shared bike companies have closed due to too fast expansion. I really like the promotion of that. It is environmental-friendly, very cheap, and I can exercise on the way to work. This idea is good, but it may require some regulation constraints. But, in the haze weather, I will not use bike.

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[13] Lung cancer ranks first in the incidence of malignant tumours (Xinhua net 2018b).
[14] History data of AQI can be referred in China air quality online monitoring and analysis platform: https://www.aqistudy.cn/historydata/weather.php

The 'I voluntarily drive one day less per week' is a public campaign initiated by Beijing government starting on June 11th, 2017. As of August 28th, 2018, it has been estimated that this campaign has resulted in reducing 23-thousand-ton carbon emissions (BMPG 2018).

Like many young people, Zhang has shared his feeling about haze on Weibo[15]. The development of social media and its widespread availability have promoted the Chinese to speak out about their dissatisfaction on air quality and other issues relating to health (Wang *et al* 2015). However, Zhang was also critical in his opinions on how people area sharing those feelings in media:

> Mr. Zhang: When haze comes, people upload pictures and share their feeling on Weibo and other social medias, just simple complaints or an entertained attitude to ease the worry about haze. It is a little bit scary. I mean the adaption to haze. As the haze gradually becomes a part of life, people will complain less and less. We should do something significant rather than only complain on internet.

In the end, Zhang boldly expressed his optimism about Beijing's future. In Zhang's opinion, Beijing represents the national image of China. China must prove its ability to improve the environment of whole country by successfully improving Beijing's air quality. Therefore, Zhang believes that government will continue to enforce various measures to tackle haze. In addition, as the capital, there are often important conferences and events held in Beijing.

As has been discussed in previous chapter, in order to guarantee the air quality during the conferences and events, Beijing often adopts unconventional measures. These unconventional measures will cause problems for some people. Ms. Wang is the management of a small logistics company. She used to provide logistics proposals for my former company. I visited her when I went to Beijing and heard her thoughts:

> Ms. Wang: I can understand the unconventional measures. At least, the sky should be very blue in that period. I don't have any opinion on whether these measures lack legality. What if it is lacking? As a common person, you can only choose to comply. These are experts' matters. What if it is lacking? As a common person, you can only choose to comply. In general, the more important the activity, the stricter the control actions and traffic restrictions are very common. I work in an inter-provincial logistics company. During the event, the trucks entering Beijing are often restricted, which may cause us some troubles. We must adjust the truck route and delivery time. In fact, we usually prepare several alternative plans and we can get notification of driving restriction in advance. We have been used to it. However, some unconventional measures will still cause an increase in costs.

From the dialogue we can see that Ms. Wang and her company have become accustomed to the unconventional measures taken by Beijing during important events. Although there are alternative plans for special time, these measures will still cause inconvenience to the operation of the company, resulting in increased costs.

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[15] Microblogging platform in China, similar to Twitter

In addition to the people living in Beijing, I got some information from a foreign tourist. Mr. Ando, a Japanese. The first time I met Mr. Ando was in a course on sustainability at Uppsala University. He was a student of that course. We keep in touch after he graduates. I know that he has been to Beijing and has experienced haze. After learning about my research, he accepted my online interview and expressed me something different about Beijing's haze problem in perspective of a foreign tourist. Mr.Ando visited Beijing in early August 2017 as a tourist. During that period, the air quality in Beijing was very poor. The average AQI was over 100, equivalent to lightly polluted level.

> Mr. Ando: I cannot say my impression of Beijing is good or bad, because I stayed there very short time. But the fog, it should be haze, was serious at that time. I could only see the plane until it was very close at airport. In the beginning, because it was in morning, I did not realize that was haze. It was not until I read news about flight cancellation due to haze that I knew the truth. Anyway, the reports on haze problems in Beijing have become relatively rare in Japan. There were a lot of reports about haze before the Beijing Olympics.

Ando regards air pollution as an inevitable process of a country's development. China, India, Bangladesh and other developing countries are confronting the same problem (WHO 2014). Tokyo also suffered the air pollution in the period of rapid economic booming after World War II. It is the implementation of various strong policies (e.g. Air Pollution Prevention Law in 1968) that mitigate the air pollution (Wang and Huang 2018).

> Mr. Ando: In fact, I do not know why haze in Beijing is so serious. Same as Beijing, Tokyo has a large population density and crowded traffic. Probably because of climate and geographic factors? I am not very sure. Japan is maritime climate with winds all year around and I think it is not easy for haze to form. I know Beijing is probably managing to tackle the haze, but the specific measures are not clear for me. I believe Beijing's air quality is improving. The less the international medias report on haze problem, the better it should be.

In the end, Ando told me he won't take haze places as first choice for tourism. Ando visited Beijing in summer 2017, this was not during the haze season. According to the 'Beijing Environmental Statement 2017' (BMEP 2018c), Beijing's air quality has significantly improved. The annual average $PM_{2.5}$ concentration is 58 μg/ m^3, 20.5% decreasing compared to 2016 (still higher than WHO guild value) as has been discussed. However, the haze has indeed affected the tourism development of Beijing. As one of the most popular tourist destinations, Beijing's haze condition is widely publicized. Considering the adverse effects of haze on health, tourists may cancel the trip to Beijing because they perceive the high risks (Li *et al* 2016).

In my interviews, no matter what kind of attitude held by interviewees toward current living environment, optimistic or pessimistic, none of them like living in haze. However, the documentary film by the name 'Le Masque Et La Brume' (mask and haze) shows me another way of seeing life in haze. It is produced by a French journalist named Pierre-Philippe Berson, who has worked in Beijing for four years. Berson's documentary (2018) is divided into seven parts with seven minutes for each part. Seven ordinary people in Beijing tell seven stories about their own experience on how haze changed their lives. The movie a young musician features who is allergic to haze. He must live with a heavy professional mask every day. A female artist makes a wedding dress with discarded masks to express people's living conditions in haze. There is also a British bicycle enthusiast who is equipped with an air purifier on his bicycle.

Among seven interviewees, a young man named Joseph holds a different attitude towards haze. He likes ‘roof topping’, another name for the activity of shoot scenery from the roof of skyscrapers. Joseph loves Beijing in haze. To Joseph when the haze comes, the whole city looks like covered by a veil. The buildings in the distance seem fading away because they cannot be seen clearly. The image of city under the haze presents a misty beauty that spark Joseph’s inspiration for photography. In Berson’s opinion, Joseph’s enthusiasm for shooting Beijing in haze reflects that haze has entered people’s model of thinking. People in Beijing will adapt to haze in various ways. During this process, persons with higher perceptivity on art and beauty may be strongly attracted by the sight of haze and such attraction will go beyond the aversion to haze (Berson 2018).

6.2 Outcome

Based on interviews, I have drawn some conclusions, which can provide further insights to understanding the impact of haze on people in Beijing. One based on these few interviews it is obvious that personal experience of suffering the effects of haze has strong influence on individuals’ daily habits and changes to their habits. Someone with a higher concern and greater knowledge on risks of haze will prefer to change her/his behaviours to protect health (Ban *et al* 2017). As shown in the interviews, with the increasing knowledge of haze, Ms. Pan tries to avoid exposure to haze, especially after the diagnosis of Thyroid nodules. There is also a worry about the cumulative effects of health risks that work as a continuous worry, that is not only present with Ms. Pan, but I think also present with many other people.

Another outcome is that social medias and social platform play important role in haze campaign. The information campaign and easy-access information on multiple social medias have strengthened the individual awareness of how to adopt right behaviours to reduce the health risks of haze. More individuals living in haze know more about haze and air pollution today than before. Research shows that people in both the cleanest and dirtiest cities are more sensitive to air pollution and individuals in dirty cities are more concerned about the relationship between health and long-term pollution exposure (Ban *et al* 2017; Zheng *et al* 2019). It does not mean that everyone is an expert in haze. $PM_{2.5}$ is part of the haze, but not the haze itself. However, most people regard $PM_{2.5}$ as a symptom of haze. Not everyone can tell how haze form, but most people know that how to protect themselves in haze. In the haze campaign, people actively or passively receive the knowledge of haze. Some knowledge come from the science popularization on TV and some come from the exaggerated propaganda of the business, such as air purifier companies and mask producers. However, from the results, the social medias have helped the public to raise awareness of haze and pushed public to know what is happening surrounding, what are they breathing and how to cope with.

The last outcome is also significant. Behaviour changes forced by polluted environments are positive and advanced, despite the fact that not all of them are voluntary. In the interview, I found many people who prefer to reduce emissions actively by using public transportation or shared bike. Not only Mr. Zhang reduces vehicle driving to make effort for haze mitigation, official data shows that 118 thousand people have joined in event of “I voluntarily drive one day less per week”. Furthermore, policy encouragement plays an important role. Various preferential policies for purchase of NEV have guided people to use environmental-friendly transport.

There is still some extra information besides major conclusions above. The control measures, especially some strong restrictions during important events, bring inconvenience to people's daily lives. Basically, among the people I interviewed, most of them said they could understand and also supported these measures. This seems to be mainly for health reasons, because measures can actually improve the health as well as the environment. At the same time, some people said that it was difficult for citizens to participate in decision-making (see my argument in Chapter 5.3.2 and Chapter 7).

In the end, I often heard sentences in the interviews such as “our lifestyle is changing.” or “We are progressing towards more energy efficient and sustainable way.”, or “energy-saving life? It is very good, I like it”. The haze is evidently making people's living habits change to a more environmentally friendly direction. One day in the future, Beijing would have successfully overcome the haze problem. The environmentally friendly lifestyles that people form in haze would be preserved and long-term benefit the environment.

7. Discussion and Summary

There are some the overlaps between haze mitigation and responding to global climate change, such as reducing vehicle emissions, saving energy and optimizing industrial structures. In this chapter, I will discuss what we can learn from the Beijing example both positive and negative experiences of the mitigation that has been implemented so far. I will also discuss whether the method of Beijing's haze mitigation can help to cope with climate change, whether it meets the requirements of sustainable development and how it can be better promoted.

7.1 Learnt experiences: the Beijing example

From the results, Beijing's haze mitigation is successful. Beijing has announced the new clean air plan from 2018 to 2020 to keep improving air quality. According to the data of 2017, Beijing's annual average $PM_{2.5}$ concentration was 58 μg/m^3, a decreasing of 20.5% compared to 2016, which was mainly due to the large-scale coal-free policy. Other indicators (SO_2, NO_2, CO, PM_{10} and O_3) also declined but not as much as $PM_{2.5}$. The number of heavy polluted days was 23 days, 35 days decreasing compared to 2013(BMEP 2018). Although the result failed to meet the standard of 10 μg/m^3 of WHO, the targets of Beijing Air Plan have been achieved.

In terms of reducing the vehicle emissions, the combination methods of vehicle driving restriction, vehicle lottery purchase policy, incentive policies for NEVs and the promotion of shared bikes has been introduced to many cities in China, such as Chengdu, Shanghai. It has indeed alleviated road traffic congestion and reduced exhaust emissions. However, in terms of energy structure optimizing, I think it is not easy to fully copy or extend Beijing's experience to other provinces in the current stage.

China's energy structure is still coal-based, especially in North China, where the coal resource is concentrated (Zhang 2011). As the capital of China, Beijing has many advantages in terms of political and economic status. In Chapter 5, I have discussed that Beijing relocated the Capital Steel Company and closed most of local power plant. Currently, most of the electricity was dispatched from provinces surrounding Beijing. These facts demonstrate that Beijing can reduce local pollution emissions while schedule the energy resource from other provinces. However, this model is difficult to adopt cities where are heavy industrialized, such as Tianjin city and Hebei province. Taking Hebei as an example, the steel industry has the features of high energy consumption and high pollution. It is also a pillar industry in Hebei. Therefore, Hebei cannot reduce emissions by shutting down or moving out of the steel plants like Beijing. Additionally, in the process of haze mitigation, some measures are contrary to sustainable development. as have been discussed here. Below I will discuss these problems in more detail

7.2 The problem of command-and-control policy and its environmental effects

Diamond (2005: 375) argues China's environmental management lacks evaluation of long-term consequences. China's environmental policy heavily relies on direct state actions (such as subsidies) and command-and-control (such as forced shutting down the coal-fired plant during coal-free programme.), but less on market-based mechanisms, which means that administrative interference is the main tool to implement environmental policies (Zhang 2015). Direct economic subsidies not only bring a huge economic burden to the government, but also risk pacifying companies making enterprises loose the spirit of innovation, even lead to the behaviour of cheating subsidies.

The command-and-control system is born in China's top-down ruling system. China's environmental management is still top-down and formulated in government-oriented mode. China utilizes this system to quickly implement some measures and achieve certain targets. However, the command-and-control policy is a high cost measure because it applies the same standard on all provinces and companies regardless of their capability (Zhang 2015). As I argued in Chapter 5, the implementation of dual-credit policy will bring much burden to automakers who mainly produce CGVs. Additionally, China has adopted a special control method to guarantee target achievement: Cadre Performance Evaluation system, which makes leading cadres of local government and enterprises personally responsible for meeting the targets. The enterprises that fail to meet the target would lose their licenses; government officials would bear the joint responsibility (Zhang 2015). For this reason, governments and enterprises focus on completing tasks, not innovation. This is a typical Chinese way often used by the government where concentrated efforts and large resources are dedicated to a specific target in a certain period (He *et al* 2012). However, a reactive environmental deterioration may occur after the implementation of such a policy is weakened or disappeared, thus it is not effective over long term. For example, although unprecedented stringent actions were undertaken during Beijing Olympics and APEC summit, the air pollution quickly rebounded after these actions become weak.

Furthermore, these fierce actions not only lack legal rationality, but also undermine sustainable development. In the coal-free programme, a large amount of natural gas replaced coal, making $PM_{2.5}$ concentration of Beijing successfully reached the target value. However, as I analysed in Chapter 5, the GHG emissions of life cycle of natural gas is no less than that of coal. Therefore, *Coal-to-gas* is not a good option to mitigate climate change. More seriously, the production of SNG has worsened the quality of water resources in Xinjiang province and Inner Mongolia, violating the principles of sustainable and low-carbon development.

In addition, the ozone concentration has not significantly decreased during the period of Beijing Air Plan implementation. The ground-level ozone pollution has even risen in megacities of BTH region. The aggravated ozone pollution comes from two aspects. 1) The particle matters can absorb hydroperoxyl radicals, a kind of chemical that can promote ozone production. The significantly reduced PM concentration also reduces absorption capacity for hydroperoxyl radicals. 2) The NO_2 pollution, which is the main premise of ozone formation, has not improved much in the BTH region (Wang and Huang 2018; Dockrill 2019). In the process of haze control, China at the moment ignores the ozone pollution caused by rapid reduction of $PM_{2.5.}$ However, China should consider solving the new problem of ozone pollution in the future strategy

In fact, because environmental improvement requires long-term and continuous progress, and despite the efforts of governments and enterprises to complete environmental tasks, there is no guarantee that every task can be completed within the specified time. In this case, environmental reporting fraud and corruption have occurred. The gap between the expectation and reality of transparency in environmental reporting is very large (He *et al* 2012). An example is the emissions fraud scandal in Linfen, Shanxi province. From April 2017 to March 2018, the local officials in local environmental protection administration tampered with state air monitoring stations on nearly 100 occasions. This behaviour resulted in 53 severe distortions in the monitoring data. Located in Shanxi province, the centre of coal resources, Linfen has a high emission of coal-fired pollution. In 2016, Linfen government committed to the Ministry of Environmental Protection to take measures to improve air pollution. However, the air quality was still bad in 2017. This led Linfen officials to interfere with the monitoring data to honour the promise only on paper. 16 suspects have been disposed in accordance with law (Kou 2018; Xu and Stanway 2018).

7.3 Civil society engagement

In addition to the above reasons, Beijing's haze control and even China's environmental management, lack the participation of people and non-governmental organizations (NGOs). This makes China's environmental protection always a top-down command-and-control but lacks bottom-up supervision. In fact, China’s air pollution control measures, including dual-credit policy and regional cooperation management have been based on experiences from countries which have tackled similar problems, such as Japan, the United States and European countries. BTH region and Tokyo metropolitan area have many similarities in the air pollution sources (coal-based smoke and vehicle emissions) and major pollutants (SO_2, NO_2, $PM_{2.5}$ and PM_{10}). After analysing the air pollution control in Tokyo, it is found that Tokyo residents' litigations[16] on improving air quality have promoted the formation of Tokyo's air pollution control policies (Wang and Huang, 2018). However, China lacks a bottom-up complaint system from civil society. In recent years, this situation has improved with the development of social media. It is easier for the public to express their own demands or supervise environmental issues through the media and the Internet. Taking *APEC blue* as an example, the overnight hit of *APEC blue* and its rapid spreading amongst citizens depended on internet and social media. People used the *APEC blue* event to express the desire for good air quality and hoped it could last long. Some voices also questioned and criticized the rationality and legality of mandatory restriction measures. The government positively responded to the controversies and promised to take further actions to improve environment. The attitude of government indicated that public opinions was becoming more and more important in policy making.

It is worth noting, however, in the context of China, the government still has the dominant voice of social media, and it has unmatched power to guide the direction of public opinion. In the contest of guidance of public opinion in the APEC complain, Beijing official used various channel to propagandize the positive sides of the *APEC blue*. They stressed the correctness of the measures taken during APEC but did not mention the negative impact of these measures on the public and factories. The network block in China stopped major negative criticisms from worldwide. These measures resulted in the prevalence of positive comment on control measures adopting in APEC summit. Meanwhile, people's urgent need for environmental improvement increased the acceptability and tolerance for such unconventional measures.

Environmental management needs civil society because it can provide the countervailing forces to strengthen the implementation of environmental policies, such as the environmental litigation and the disclosure of fraud local environmental reports. The participation of the public and NGOs in environmental issues can make environmental management more sustainable in continuous improvement. However, as I analysed in Chapter 4.3.2, civil cannot make an

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[16] From May 1996 to February 2006, a total of 522 residents who lived or worked in Tokyo metropolitan had filed six lawsuits to the Tokyo District Court on the grounds that their bronchial asthma was caused by exhaust emissions from vehicles. They asked the relevant automakers to stop air pollution emitting and pay compensation. These lawsuits promoted the development of air pollution prevention in the Tokyo metropolitan.

equal dialogue with officials in China (Mei 2015). In the condition of the poorly functioning system of the rule of law, environmental NGOs and the public are very limited in their decision-making and their protests or participation in environment issues are often overruled by government (He et al 2012). Throughout the environmental management process, we can see the growth of the civil power, but it is still very slow.

Additionally, Zhang (2015) argues that China's environmental policies emphasis on reducing emissions but ignores low carbon development. Emissions reduction is about improving existing systems, while low-carbon development is about system innovation and changes in industrial structure (Zhang 2015). This makes China's green technologies very backward despite the rapid growth in wind power and solar power. China was ranked the18th in the 2017 Global Cleantech Innovation Index and China's ranking in this index was 19th in 2014, thus there is a very slow progress in green energy (WWF and Cleantech Group 2017: 13). and the grid systems are also not conducive to green energy at the moment as discussed in Chapter 5.2.2.

7.4 Final summary

Based on the argument above, Beijing's haze control and China air pollution control measures are remarkable in terms of PM reduction but still lack sustainability, which are powerless in reducing carbon emissions. China's development is accompanied by a large amount of coal consumption and carbon emissions. China's 2017 carbon emissions were 9232.6 million tons, accounting for 27.6% of global carbon emissions, topping the list (BP 2018). the problem of haze has spread to many cities in China. In cities far from economic centres and media attentions, such as Linfen, the imperfections of environmental protection mechanisms and the lack of civil supervision have made them unable to improve air quality as quickly and effectively as Beijing. Not only air pollution control but the whole environmental protection is the protracted war. China's long-term environmental improvement requires the optimizing of energy structure, the innovation of green technologies, the improvement of the governance system and the participation of civil and NGOs, which are big challenges and require strenuous efforts.

References

AQI monitoring platform. 2019. https://www.aqistudy.cn. Accessed on 2019.01.12.

Asian Development Bank, 2013. Toward an Environmentally Sustainable Future: Country Environmental Analysis of the People's Republic of China. https://www.adb.org/publications/toward-environmentally-sustainable-future-country-environmental-analysis-prc. Accessed on 2019.04.12.

Baker, S. 2015. Sustainable Development. London and New York: Routledge Taylor & Francis Group.

Ban, J., Zhou, L., Zhang, Y., Anderson, G., Li, T. 2017. The health policy implications of individual adaptive behavior responses to smog pollution in urban China. *Environment International* 106: 144-152

BBC, 2014. Beijing marathon runners don masks to cope with smog https://www.bbc.com/news/29679782. Accessed on 2019.01.01.

Beijing Municipal Bureau of Statistics (BMBS). 2018. Beijing Statistical Yearbook 2018. http://tjj.beijing.gov.cn/nj/main/2018-tjnj/zk/indexch.htm. Accessed on 2019.03.01.

Beijing Municipal Commission of Transport (BMCT), 2017. 北京市鼓励规范发展共享自行车的指导意见[Beijing encourage developing shared bikes in specification]. http://jtw.beijing.gov.cn/xxgk/flfg/fgbz/201709/t20170915_187384.html. Accessed on 2019.04.11.

Beijing Municipal Commission of Transport (BMCT). 2018. 2018 年小客车购车指标 10 万个[The quota of passenger car in 2018 is 100,000] https://www.bjhjyd.gov.cn/xwzz/201867/1528347145110_1.html. Accessed on 2019.04.22.

Beijing Municipal Environmental Protection Bureau (BMEP), 2014. APEC air quality and control actions effect assessment report. http://www.bjepb.gov.cn/bjhrb/xxgk/jgzn/jgsz/jjgjgszjzz/xcjyc/xwfb/607506/index.html. Accessed on 2019.05.01.

Beijing Municipal Environmental Protection Bureau (BMEP). 2017. 关于《北京市城镇居民"煤改电"、"煤改气"相关政策的意见》相关事项补充规定的函. [The supplementary explanation for policy of *coal-to-electricity* and *coal-to-gas*] http://www.bjepb.gov.cn/bjhrb/xxgk/fgwj/qtwj/hbjfw/815239/index.html. Accessed on 2019.04.22.

Beijing Municipal Environmental Protection Bureau (BMEP). 2018a. Beijing Air Pollution Emergency Plan. http://www.bjepb.gov.cn/bjhrb/xxgk/jgzn/jgsz/jjgjgszjzz/xcjyc/xwfb/840689/index.html. Accessed on 2019.03.01.

Beijing Municipal Environmental Protection Bureau (BMEP). 2018b. 最新科研成果新一轮北京市 PM2.5 来源解析正式发布 [A new round of Beijing $PM_{2.5}$ source analysis officially released]. http://www.bjepb.gov.cn/bjhrb/xxgk/jgzn/jgsz/jjgjgszjzz/xcjyc/xwfb/832588/index.html. Accessed on 2019.03.01.

Beijing Municipal Environmental Protection Bureau (BMEP). 2018c. Beijing Environmental Statement 2017. http://sthjj.beijing.gov.cn/bjhrb/xxgk/ywdt/hjzlzk/hjzkgb65/index.html. Accessed on 2019.03.01.

Beijing Transport Institute, 2018. Annual Report of Beijing transportation development. http://www.bjtrc.org.cn/JGJS.aspx?id=5.2&Menu=GZCG. Accessed on 2019.04.11.

Berson, P. 2018. Le Masque Et La Brume. https://www.france.tv/slash/le-masque-et-la-brume/. Accessed on 2019.05.01.

BP. 2018. BP Statistical Review of World Energy.

Brinkmann, S. 2014. Unstructured and Semi-Structured Interviewing. In: Leavy, J. (ed.) The Oxford Handbook of Qualitative Research, 277-299. Oxford, Oxford University Press

Cai, H. 2013. 重点任务，重点分解: 北京市 2013-2017 年清洁空气行动计划 [Key task analysis: Beijing Clean Air Action Plan 2013-2017]. Transpoworld 18.

Caixin. 2017. 河北承认煤改气搞得"太多了" 今冬天然气需求为去年同期 234% [Hebei recognizes too many *coal-to-gas*. The demand for natural gas this winter is 234% in the same period last year]. http://china.caixin.com/2017-12-12/101183936.html.Accessed on 2019.04.05.

Cao, C., Jiang, W., Wang, B., Fang, J., Lang, J., Tian, G., Jiang, J., Zhu, T. 2014. Inhalable Microorganisms in Beijing's $PM_{2.5}$ and PM_{10} Pollutants during a Severe Smog Event. *Environmental Science & Technology* 48: 1499-1507.

Campbell, A., Cherry, C., Ryerson, M. and Yang, X. 2016. Factors influencing the choice of shared bicycles and shared electric bikes in Beijing. *Transportation Research* Part C 67: 399-414.

China Daily. 2012. Full text of Hu's report at 18th Party Congress. http://language.chinadaily.com.cn/news/2012-11/19/content_15941774_6.htm. Accessed on 2019.05.04.

China Electricity Council (CEC). 2018. China Electricity Annual Development Report 2018. Beijing, China Market Press.

Chen, Y., Jin, G., Kumar, N., Shi G. (2013). The promise of Beijing: Evaluating the impact of the 2008 Olympic Games on air quality. J*ournal of Environmental Economics and Management* 66(3): 424-443.

Chen, Y., Schleicher, N., Chen, Y., Chai, F., Norra, S. 2014. The influence of governmental mitigation measures on contamination characteristics of $PM_{2.5}$ in Beijing. *Science of the Total Environment* 490: 647–658.

DeMaio, P. 2009. Bike-sharing: history, impacts, models of provision, and future. *Journal of Public Transportation*.12 (4): 41-56.

Diamond, J. 2005. *Collapse: How Societies Choose to Fail or Succeed*. London: The Penguin Group.

Ding, N., Yang, J., Lu, X., Liu, J. 2018. Life cycle assessment of bike sharing and the its effects on greenhouse gas emissions of urban transport-A case study of Beijing. *Acta Scientiae Circumstantiae*: 1-14.

Dockrill, P. 2019. China's War on Air Pollution Has Had a Sinister Side Effect No One Saw Coming. https://www.sciencealert.com/china-s-war-on-air-pollution-has-had-a-sinister-side-effect-we-never-expected. Accessed on 2019.05.01.

Du, J. and Ouyang, D. 2017. Progress of Chinese electric vehicles industrialization in 2015: A review. *Applied Energy* 188: 529-546.

Fishman, E. 2015. Bikeshare: a review of recent literature. *Transport Reviews* 36 (1): 92-113.

Frey HC., Kuo P-Y. 2009. Real-world energy use and emission rates for idling long-haul trucks and selected idle reduction technologies. *Air Waste Manage* 59:857–864.

Guanchazhe, 2017. 北京最后一座燃煤电厂停机备用 [The last coal-fired power plant in Beijing was shut down]. https://www.guancha.cn/economy/2017_03_20_399537.shtml. Accessed on 2019.03.11.
He, G., Lu, Y., Mol, A., Becers, T. 2012. Changes and challenges: China's environmental management in transition. *Environmental Development* 3: 25–38.
He, Y. 2018. 北京实现基本无煤化目标 [Beijing achieves the goal of coal-free]. http://www.xinhuanet.com/power/2018-12/21/c_1210021219.htm. Accessed on 2019.02.22.
Hilton, I., Kerr, O. 2017. The Paris Agreement: China's 'New Normal' role in international climate negotiations. *Climate Policy* 17(1): 48-58.
Hong, W., Wang, S. 2018. Purity and Danger: Public Perceptions of Air Pollution from A Perspective of Cultural Anthropology. Harvard-Yenching Institute Working Paper Series, Tsinghua University.
Huang, A. 2015a. China Blocks Web Access to 'Under the Dome' Documentary on Pollution. https://cn.nytimes.com/china/20150308/c08dome/dual/. Accessed on 2019.03.01.
Huang, A. 2015b. Beijing Issues Red Alert Over Air Pollution for the First Time https://cn.nytimes.com/china/20151208/c08china/dual/. Accessed on 2019.03.01.
Ifeng. 2013. 北京 2017 年前关停所有燃煤电厂 用电主要依靠外调 [Beijing shuts down all coal-fired power plants by 2017. Electricity mainly relies on external dispatchment]. http://news.ifeng.com/shendu/21sjjjbd/detail_2013_11/26/31553276_0.shtml. Accessed on 2019. 02.01.
IEA, 2018. Carbon emissions from advanced economies set to rise in 2018 for first time in five years, reversing a declining trend. https://www.iea.org/newsroom/news/2018/december/carbon-emissions-from-advanced-economies-set-to-rise-in-2018-for-first-time-in-fi.html. Accessed on 2019.05.05.
Jaramillo, P., Griffin, W., Matthew, H. 2007. Comparative Life-Cycle Air Emissions of Coal, Domestic Natural Gas, LNG, and SNG for Electricity Generation. *ENVIRONMENTAL SCIENCE & TECHNOLOGY* 41(17):6290-6296.
Kahrl, F., Williams, J., Ding, J., Hu, J. 2011. Challenges to China's transition to a low carbon electricity system. *Energy Policy* 39: 4032-4041.
Korsbakken J., Andrew, R., Peters, G. 2019. China's CO2 emissions grew slower than expected in 2018. Carbon Brief. https://www.carbonbrief.org/guest-post-chinas-co2-emissions-grew-slower-than-expected-in-2018. Accessed on 2019.04.05.
Kou, J. 2018. 临汾环保数据造假涉案官员竟不知是犯罪. People's Daily. http://app.peopleapp.com/Api/600/DetailApi/shareArticle?type=0&article_id=2146204 Accessed on 2019.04.01
Lang, J., Cheng, S., Li, J., Chen, D., Zhou, Y., Wei, X., Han, L., Wang, H. 2013. A Monitoring and Modeling Study to Investigate Regional Transport and Characteristics of $PM_{2.5}$ Pollution. *Aerosol and Air Quality Research* 3: 943–956.
Li, A. 2016. Hopes of Limiting Global Warming? China and the Paris Agreement on Climate Change. *China Perspectives* 1: 49-54.
Li, J., Pearce, P., Morrison, A., Wu, B. 2016. Up in Smoke? The Impact of Smog on Risk Perception and Satisfaction of International Tourists in Beijing. *International Journal of Tourism Research*. 18: 373–386.
Li, F. 2017. BBC: Credit policy aims to push production of new energy cars http://www.chinadaily.com.cn/business/motoring/2017-07/31/content_30300408.htm. Accessed on 2019.02.01.
Li, H., Yang, S., Zhang, J., Qian, Y. 2016. Coal-based synthetic natural gas (SNG) for municipal heating in China: analysis of haze pollutants and greenhouse gases (GHGs) emissions. *Journal of Cleaner Production* 112: 1350-1359.

Li, S. 2007. 首钢谢幕北京 [The Capital Steel Closed in Beijing]. Beijing Document 8.
Li, M., Zhang, L. 2014. Haze in China: current and future challenges. *Environmental Pollution* 189 (12): 85- 86.
Li, X., Wu, J., Elser, M., Feng, T., Cao, J., El-Haddad, I., Huang, R., Tie, X., Prévôt, A., Li, G. 2018. Contributions of residential coal combustion to the air quality in Beijing–Tianjin–Hebei (BTH), China: a case study. *Atmospheric, Chemistry and Physics*. 18: 10675–10691.
Li, Y., Zhang, Q., Liu, B., McLellan, B., Gao, Y. and Tang, Y. 2018. Substitution effect of New-Energy Vehicle Credit Program and Corporate Average Fuel Consumption Regulation for Green-car Subsidy. *Energy* 152: 223-236.
Li, Z. 2014. 让"APEC 蓝"永驻天空(人民时评) [Let *APEC Blue* stay in the sky forever]. http://opinion.people.com.cn/n/2014/1107/c1003-25990070.html. Accessed on 2019.04.22.
Li, Z., Tang, D. 2018. Comparative Analysis of Haze Control Measures in Beijing: Simulation and Prediction Based on System Dynamics. *Science and Technology Management Research* 20.
Liu, G., Yang, Z., Chen, B., Zhang, Y., Su, M., Ulgiati, S. 2016. Prevention and control policy analysis for energy -related regional pollution management in China. *Applied Energy* 166: 292-300.
Liu, S. 2016. 档案中的全民大炼钢运动 [Steelmaking movement in archives]. *Hundred Year Tide* 4. 62-67.
Liu, P., Zhang, C., Xue, C., Mu, Y., Liu, J., Zhang, Y., Tian, D., Ye, C., Zhang, H., Guan, J. 2017. The contribution of residential coal combustion to atmospheric PM2:5 in northern China during winter. *Atmospheric, Chemistry and Physics*. 17: 11503–11520.
Liu, W. 2018. 北京 "煤改电" 样本背后：从"煤改电"到"煤改清洁能源"[Behind the sample of *coal-to-electricity* in Beijing: from *coal-to-electricity* to *coal-to-new energy*]. *Energy Review* 2018(12). http://www.indaa.com.cn/zz/nypl/nypl201813qi/. Accessed on 2019.01.05.
Liu, X., Liu, J. 2016. 新能源车骗补内幕:空壳公司套取亿元补贴 [The inside story of NEVs cheating for subsidies: shell companies take 100 million yuan subsidies] http://auto.sina.com.cn/news/hy/2016-01-18/detail-ifxnqrkc6614301.shtml. Accessed on 2019.05.21.
Liu, Z., Jia, X., Cheng, W., 2012. Solving the last mile problem: ensure the success of public bicycle system in Beijing. *Procedia – Social and Behavioral Sciences* 43: 73-78.
Luo, G., Li, Y., Tang, W., Wei, X. 2016. Wind curtailment of China's wind power operation: Evolution, causes and solutions. *Renewable and Sustainable Energy Reviews* 53: 1190-1201.
Marshall, A. 2018. Americans are falling in love with bike share. Transportation. WIRED. https://www.wired.com/story/americans-falling-in-love-bike-share/. Accessed on 2019.03.11.
Mei, X. 2015. On the Government 一 mobilized Public Participation in Environmental Protection---A Case Study of APEC Blue. *Journal of Hainan Normal University* 28(10): 115-120.
Ministry of Ecology and Environment of the People's Republic of China (MEE). 2012. Technical Regulation on Ambient Air Quality Index. http://kjs.mee.gov.cn/hjbhbz/bzwb/jcffbz/201203/t20120302_224166.shtml. Accessed on 2019.04.12.

Ministry of Ecology and Environment (MEE). 2017. 关于印发《京津冀及周边地区 2017 年大气污染防治工作方案》的通知 [Notice of Air Pollution Prevention and Control Action Plan in BTH and surrounding areas 2017]. http://dqhj.mee.gov.cn/zcfg/201709/t20170915_421697.shtml. Accessed on 2019.04.01.
Ministry of Finance of the People's Republic of China (MOF). 2016. 关于地方预决算公开和新能源汽车推广应用补助资金专项检查的通报 [Report on the special inspection of subsidies for public and new energy vehicles.] http://www.mof.gov.cn/zhengwuxinxi/bulinggonggao/tongzhitonggao/201609/t20160908_2413434.htm. Accessed on 2019.04.2.
Ministry of Industry and Information Technology (MIIT). 2017. 乘用车企业平均燃料消耗量与新能源汽车积分并行管理办法[The Management Guideline of NEVs Dual-credit] http://www.gov.cn/xinwen/2017-09/28/content_5228217.htm. Accessed on 2019.03.01.
Ministry of Industry and Information Technology (MIIT). 2018. Economic operation of China's auto industry in 2018 http://www.miit.gov.cn/n1146312/n1146904/n1648362/n1648363/c6600517/content.html. Accessed on 2019.05.11
National Bureau of Statistics (NBS). 2017. China Statistics Yearbook 2017: http://www.stats.gov.cn/tjsj/ndsj/. Accessed on 2019.04.12.
NASA. 2015. Haze over Eastern China. https://earthobservatory.nasa.gov/images/87129/haze-over-eastern-china. Accessed on 2019.04.01
NASA. 2016. Smog and Haze in Northern China. https://earthobservatory.nasa.gov/images/89228/smog-and-haze-in-northern-china. Accessed on 2019.04.12.
National Development and Reform Commission (NDRC). 2017. 关于印发北方地区冬季清洁取暖规划（2017-2021 年）的通知 [Winter cleaning and heating plan for the northern region (2017-2021)]. http://www.gov.cn/xinwen/2017-12/20/content_5248855.htm. Accessed on 2019.05.01.
National Development and Reform Commission (NDRC). 2018. 2017 Natural Gas Operation Profile. http://yxj.ndrc.gov.cn/mtzhgl/201801/t20180131_876378.html. Accessed on 2019.01.22.
Nordhaus, T. 2018. The Two-Degree Delusion. https://www.foreignaffairs.com/articles/world/2018-02-08/two-degree-delusion. Accessed on 2019.04.11.
Park, C., Allaby, M. 2017. "haze". In A Dictionary of Environment and Conservation (3 ed.): Oxford University Press. https://www-oxfordreference-com.ezproxy.its.uu.se/view/10.1093/acref/9780191826320.001.0001/acref-9780191826320-e-3636. Accessed on 2019.05.24.
People, 2012. 北京首公布 $PM_{2.5}$ 历史数据 近十年 $PM_{2.5}$ 年均浓度下降 [Beijing first announced $PM_{2.5}$ historical data, the average annual concentration of PM2.5 decreased in the past decade]. http://politics.people.com.cn/GB/14562/16817235.html. Accessed on 2019.02.01.
Pham, S. 2018. CNN: Chinese bike-sharing startup Ofo went global. Now it may go bust https://edition.cnn.com/2018/12/21/tech/ofo-china-bike-sharing-crisis/index.html. Accessed on 2019.05.22.
Pope, C.A., Dockery, D.W. 2006. Health Effects of Fine Particulate Air Pollution: Lines that Connect. *Journal of the Air & Waste Management Association* 56: 709-742.
Rahman, S.M., Masjuki, H.H., Abedin, M.J., Sanjid, A., Sajjad, H. 2013. Impact of idling on fuel consumption and exhaust emissions and available idle-reduction technologies for diesel vehicles – A review. *Energy Conversion and Management* 74: 171–182.
Rich,D., Kipen, H., Huang,W., Wang, G., Wang, Y., Zhu,P., Ohman-Strickland, P., Hu, M., Philipp, C., Diehl, S., Lu, S., Tong, J., Gong, J., Thomas, D., Zhu, T., Zhang, J. 2012. As-

sociation Between Changes in Air Pollution Levels During the Beijing Olympics and Biomarkers of Inflammation and Thrombosis in Healthy Young Adults. *JAMA* 307(19): 2068-2078.
Shao, Y., Ulbrich, S. and Chen, D. 2017. Air pumping for alleviation of heavy smog in Beijing. *Science China Earth Sciences* 61: 973–979.
Shapiro, J. 2016. *China's Environmental Challenges.* Polity Press. second edition.
Sheehan, P., Cheng, E., English, A., Sun, F. 2014. China’s response to the air pollution shock. *Nature Climate Change* 4: 306-309.
Shen, X., Yao, Z., Huo, H., He, K., Zhang, Y., Liu, H., Ye, Y. 2014. PM2.5 emissions from light-duty gasoline vehicles in Beijing, China. *Science of the Total Environment* 487: 521–527.
Shi, H., Wang, Y., Chen, J., Huisingh, D. 2016. Preventing smog crises in China and globally. *Journal of Cleaner Production* 112: 1261-1271.
Sina, 2017. “煤改气”之后的反思，我们是不是太着急了？ [*Coal-to-gas* reflection: are we too hurry?] http://news.sina.com.cn/o/2017-12-12/doc-ifypnyqi4239575.shtml. Accessed on 2019.05.01.
Sohu, 2017a. 2017 年底北京新能源公交车占比将达七成 [Before the end of 2017, the proportion of Beijing new energy buses will reach 70%] http://www.sohu.com/a/167807444_383324. Accessed on. 2019.04.05.
Sohu. 2017b. 专家质疑新能源双积分政策导向 认为鼓励长纯电续驶里程有弊端 [The drawback of dual-credit policy.] http://www.sohu.com/a/211856465_100084983. Accessed on 2019.04.08.
Sohu, 2017c. 双积分政策对车企的影响 [The impact of dual-credit policy on automakers]. https://www.sohu.com/a/201015027_813374. Accessed on. 2019.04.05.
Sohu, 2017d. “煤改气”为什么没有干过“煤改电”？大规模“煤改气”弊端已现[Why is the size of *coal-to-gas* not as good as *coal to electricity*? The drawbacks of large-scale *coal-togas* have emerged]. https://www.sohu.com/a/192261983_465907. Accessed on 2019.03.01.
Sohu, 2018a. 国内油价暴涨破 8，美国才 5.6！看看中美油价到底有多少差距？ [Domestic oil prices have skyrocketed by 8, and the United States has only 5.6! How much difference does China-US oil price have?] http://www.sohu.com/a/271760699_194632. Accessed on 2019.03.27.
Sohu, 2018b. 2018 年以后的 “煤改气” 仍将砥砺前行 [*Coal-to-gas* after 2018 will continue to move forward] https://www.sohu.com/a/236477326_174505. Accessed on 2019.05.11.
Smog 2019. *Britannica Academic*. https://academic-eb-com.ezproxy.its.uu.se/levels/collegiate/article/smog/68319. Accessed on 2019.04.05.
Stanek, W., Białecki, R. 2014. Can natural gas warm the climate more than coal? *Fuel* 136: 341–348.
Stone, R. 2008. Beijing's Marathon Run to Clean Foul Air Nears Finish Line. *Science* 321: 636-637.
State Council of the People's Republic of China, 2006. 国家中长期科学和技术发展规划纲要（2006━2020 年）[The National Outlines for Medium and Long-term Planning for Scientific and Technological Development (2006-2020)] http://www.gov.cn/jrzg/2006-02/09/content_183787.htm. Accessed on 2019.02.01.
State Council of the People's Republic of China, 2010. Implementation Guidelines for Regional Presentation and Control of Air pollution. http://www.gov.cn/xxgk/pub/govpublic/mrlm/201005/t20100513_56516.html. Accessed on 2019.04.11.

State Council of the People's Republic of China. 2016. 国务院关于印发 “十三五”节能减排综合工作方案的通知 [Notice of the State Council on Printing and Distributing the Comprehensive Work Plan for Energy Saving and Emission Reduction during the 13th Five-Year Plan]. http://www.gov.cn/zhengce/content/2017-01/05/content_5156789.htm. Accessed on 2019.04.01.
Stokel-Walker,C. 2018. BBC: The hidden air pollution inside your workplace. http://www.bbc.com/capital/story/20181016-the-hidden-air-pollution-inside-your-workplace. Accessed on 2019.05.11.
Streets, D., Fu, J., Jang, C., Hao, J., He, K., Tang, X., Zhang, Y., Wang, Z., Li, Z., Zhang, Q., Wang, L., Wang, B., Yu, C. 2007. Air quality during the 2008 Beijing Olympic Games. *Atomospheric Environment* 41: 480-492.
Tan, Y. 2016. Car2go's strong first month in Chongqing. http://www.chinadaily.com.cn/business/motoring/2016-05/20/content_25380986.htm. Accessed on 2019.05.26.
Tatlow, D. 2014. Preparing for ‘APEC War’ in China. The New York Times. https://sinosphere.blogs.nytimes.com/2014/11/03/preparing-for-apec-war-in-china/. Accessed on 2019.04.05.
Temperature inversion 2019. *Britannica Academic*. https://academic-eb-com.ezproxy.its.uu.se/levels/collegiate/article/temperature-inversion/71634. Accessed on 2019.04.05.
Tiezzi, S. 2015. Can a Documentary Change the Course of China's 'War on Pollution'? https://thediplomat.com/2015/03/can-a-documentary-change-the-course-of-chinas-war-on-pollution/. Accessed on 2019.03.12.
The Guardian. 2018. The unexpected beauty of China's bicycle graveyards – in pictures. https://www.theguardian.com/cities/gallery/2018/may/01/unexpected-beauty-china-bicycle-graveyards-share-bikes-in-pictures. Accessed on 2019.05.26.
The People’s Government of Beijing Municipality (BMPG) 2018. I voluntarily drive one day less per week. http://www.beijing.gov.cn/ywdt/zwzt/skytc/. Accessed on 2019.05.24
United Nations. 1992. AGENDA 21. https://sustainabledevelopment.un.org/content/documents/Agenda21.pdf. Accessed on 2019.05.12.
United Nations. 2015. Sustainable development goals. https://sustainabledevelopment.un.org/. Accessed on 2019.05.12.
United States Environmental Protection Agency (EPA). 2018. Particulate Matter (PM) Pollution. https://www.epa.gov/pm-pollution. Accessed on 2019.04.01.
VOA. 2015. Beijing Issues Another Red Alert for Smog. https://www.voanews.com/a/beijing-issues-another-red-alert-for-smog/3108448.html. Accessed on 2019.03.01.
Wang, Q., Huang, J. 2018. Atmospheric pollution control policies of the Tokyo metropolitan area as a reference for the Beijing-Tianjin-Hebei urban agglomeration. *Progress in Geography* 37(6): 790-800.
Wang, S., Paul, M. J., Dredze, M. 2015. Social media as a sensor of air quality and public response in China. *Journal of Medical Internet Research* 17
Wang, Y., Zhao, F., Yuan, Y., Hao, H., Liu, Z. 2018. Analysis of Typical Automakers’ Strategies for Meeting the Dual-Credit Regulations Regarding CAFC and NEVs. *Automotive Innovation* 1:15–23.
Wikipedia, 2018. Standard Coal Equivalent (SCE). https://zh.wikipedia.org/wiki/标准煤 Accessed on 2019.05.11.
Wikipedia, 2019. Volatile organic compounds (VOCs). https://en.wikipedia.org/wiki/Volatile_organic_compound. Accessed on 2019.05.11.

World Health Organization (WHO). 2005. WHO Air quality guidelines for particulate matter, ozone, nitrogen dioxide and sulfur dioxide. https://apps.who.int/iris/handle/10665/69477. Accessed on 2019.05.12
World Health Organization (WHO). 2014. Air quality deteriorating in many of the world's cities. https://www.who.int/mediacentre/news/releases/2014/air-quality/en/.Accessed on 2019.04.05
World Health Organization (WHO). 2018. 9 out of 10 people worldwide breathe polluted air, but more countries are taking action. https://www.who.int/news-room/detail/02-05-2018-9-out-of-10-people-worldwide-breathe-polluted-air-but-more-countries-are-taking-action. Accessed on 2019.05.14.
Worldsteel Association. 2017. World Steel in Figures 2017. https://www.worldsteel.org/media-centre/press-releases/2017/world-steel-in-figures-2017.html. Accessed on 2019.03.01.
Wu, Y., Wang, R., Zhou, Y., Lin, B., Fu, L., He, K., Hao, J. 2011. On-Road Vehicle Emission Control in Beijing; Past, Present, and Future. *ENVIRONMENTAL SCIENCE & TECHNOLOGY* 45: 147–153.
WWF and Cleantech Group. 2017. The Global Cleantech Innovation Index 2017. https://wwf.fi/mediabank/9906.pdf. Accessed on 2019.04.23.
Xie, X., Tou, X., Zhang, L. 2017. Effect analysis of air pollution control in Beijing based on an odd-and-even license plate model. *Journal of Cleaner Production* 142: 936-945.
Xinhua net, 2015. 北京交通部门：2020 年骑车出行比例计划恢复到 18% [Beijing Transportation Institute: 2020 bicycle travel ratio plan restored to 18%]. http://www.xinhuanet.com/travel/2015-09/23/c_128258321.htm. Accessed on 2019.04.12
Xinhua net, 2017a. 北京最后燃煤电厂停机 成全国首个清洁能源发电城市. [Shutting down the last coal-fired Plant, Beijing has become the first clean energy power generation city in China]. http://www.xinhuanet.com//local/2017-03/20/c_1120655036.htm. Accessed on 2019.04.12.
Xinhua net. 2017b. 北京市叫停共享单车新增投放[Beijing stops new shared bike putting into market]. http://www.xinhuanet.com/tech/2017-09/08/c_1121626586.htm. Accessed on 2019.05.01.
Xinhua net, 2018a. 北京：新能源车指标新申请者需等到 2025 年 [Beijing: waiting queue for NEVs has been until in 2025]. http://www.xinhuanet.com/politics/2018-08/27/c_1123331989.htm?baike. Accessed on 2019.05.14.
Xinhua net, 2018b. 国家癌症中心：肺癌居恶性肿瘤发病第一位[National Cancer Center: lung cancer ranks first in the incidence of malignant tumors]. http://www.xinhuanet.com/politics/2018-04/06/c_1122643981.htm Accessed on 2019.04.01.
Xu, J., Ma, J. 2012. Economic analysis of driving restriction by car tail number. World Automation Congress 06/2012.
Xu, M., Stanway, D. 2018. China arrests three for fake reports about smog crackdown. Reuters. https://www.reuters.com/article/us-china-pollution/china-arrests-three-for-fake-reports-about-smog-crackdown-idUSKCN1L80CP. Accessed on 2019.05.04.
Yang, C., Jackson, R. 2013. China's synthetic natural gas revolution. *NATURE CLIMATE CHANGE* 3: 852-854.
Yi, R., Zhang, S., Xie, X, Wu, D., Zhang, X., Wang, J. 2011. Comparison Analysis on Policy Effects for Driving Restriction and Gasoline Pricing in Beijing. *China Population, Resources and Environment* 21(12): 108-112.
Zhao, X. 2018. 行政比例原则在社会主义建设中的应用[The Application of Administrative principle of proportionality in Socialist Construction]. *Economic Research Guide* 04:183-184.

Zhang, H., Wang, S., Hao, J., Wang, X., Wang, S., Chai, F., Li, M. 2016. Air pollution and control action in Beijing. *Journal of Cleaner Production* 112: 1519-1527.

Zhang, J., Shen, B. 2018. 改革开放 40 年中国经济发展成就及其对世界的影响[The achievements of China's economic development in the 40 years of reform and opening up and its impact on the world]. http://theory.people.com.cn/n1/2018/0515/c40531-29991327.html. Accessed on 2019.05.12.

Zhang, L. 2015. Rethinking China's Low-Carbon Strategy. Paulson Policy Memorandum. http://www.paulsoninstitute.org/think-tank/2015/01/22/rethinking-chinas-low-carbon-strategy/.accessed on 2019.04.01.

Zhang, L., Wang, T., Lv, M., Zhang, Q. 2015. On the severe haze in Beijing during January 2013: Unraveling the effects of meteorological anomalies with WRF-Chem. *Atmospheric Environment* 104:11-21.

Zhang, M. 2016. On the relationship between the power use and the law China-from the analysis of the phenomena of APEC blue. *Journal of Jiangsu Normal University. (Philosophy and Social Sciences Edition)* 42(2): 115-126.

Zhang, N., Lior, N., Jin, H. 2011. The energy situation and its sustainable development strategy in China. *Energy* 36: 3639-3649.

Zhang, S., Wu, Y., Wu, X., Li, M., Ge, Y., Liang, B., Xu, Y., Zhou, Y., Liu, H., Fu, L., Hao, J. 2014. Historic and future trends of vehicle emissions in Beijing, 1998-2020: A policy assessment for the most stringent vehicle emission control program in China. *Atmospheric Environment* 89: 216-229.

Zhang, X., Dai, H., Jin, Y., Zhang, S. 2019. Evaluation of Health and Economic Benefits from "Coal to Electricity" Policy in the Residential Sector in the Jing-Jin-Ji Region. *Acta Scientiarum Naturalium Universitatis Pekinensis* 55(2) :367-376.

Zhang, Z., Gong, D., Mao, R., Kim, S., Xu, J., Zhao, X., Ma, Z. 2017. Cause and predictability for the severe haze pollution in downtown Beijing in November–December 2015. *Science of the Total Environment* 592: 627–638.

Zhang, Z., Wang, W., Cheng, M., Liu, S., Xu, J., He, Y., Meng, F. 2017. The contribution of residential coal combustion to $PM_{2.5}$ pollution over China's Beijing-Tianjin-Hebei region in winter. *Atmospheric Environment* 159: 147-161.

Zhang, Z. 2019. "断奶"后的新能源汽车何去何从 [The future of NEVs without subsidies]. China Youth Daily April-4.

Zheng, S., Wang, J., Sun, C., Zhang, X., Kahn, M. 2018. Air pollution lowers Chinese urbanites' expressed happiness on social media. *Nature Human Behaviour* 3: 237–243.

Zhu, R. 2018. Analysis on the Impact of haze on Beijing Residents' Traveling Intention and Decision-Making. *Materials Science and Engineering* 394