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Evolution of the Air Pollution Mitigation Policies in 11th, 12th, and 13th Five-Year Plans for National Development of China

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Author’s declaration

No portion of the work referred to in this thesis has been submitted in support of an application for another degree or qualification of this or any other university or other institutes of learning.

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ABSTRACT OF THESIS submitted by:

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Air pollution is one of the major environmental risk factors that contribute to over 7 million annual premature deaths in the world. China is one of the biggest air polluters in the world and most of the country's metro cities have air qualities above the WHO air quality standards. As a measure of mitigation, China has declared war on air pollution and has taken several actions including strict policy regulations on all concerned sectors. China's national five-year plan (FYP) for socio-economic development is one of the major policy documents, and although air pollution was an issue of concern for a long time, it made its way into the five-year plans only after 2005. Therefore, this study discusses the evolution of the air pollution-related policies in the 11^{th}, 12^{th}, and 13^{th} five-year plans. Three policy documents were thoroughly read-through to identify the policies with a direct or indirect impact on air pollution, and the policies were categorized into 4 themes and 12 sub-themes. A logic model with attention to outcomes, aims, activities, and externalities was used to analyze the policies to understand how the policies improved from the previous FYP to the next one. It was concluded that there is a positive evolution in many sectors, in the air pollution mitigation policies in the national five-year plans from 11^{th} to 13^{th} FYPs. However, there is much room for improvement in each policy target to achieve the ambitious goals set by the Chinese government for the future.

Keywords: Air pollution, Five-year plans, China, Air pollution policies

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List of Abbreviations

AQG: WHO Air Quality Guidelines

AQI: Air Quality Index

BTH: Beijing-Tianjin-Hebei

BUSPH: Boston University School of Public Health

CCAC: Climate and Clean Air Coalition

CDC: Center for Disease Control and Prevention

COD: Chemical Oxygen Demand

COPD: Chronic Obstructive Pulmonary Disease

COVID-19: Coronavirus Disease

DALY: Disability-Adjusted Life Years

EPA: Environmental Protection Agency

EU: European Union

FYP: Five-year plans

GDP: Gross Domestic Product

GHG: Greenhouse gases

IEA: International Energy Agency

LAPPC: Law on Air Pollution Prevention and Control of the People's Republic of China

NAAQS: National Ambient Air Quality Standards

NCD: Non-communicable diseases

SARS: Severe acute respiratory syndrome

SILC: Sustainable Industry Low Carbon Initiative

UNEP: United Nations Environment Program

WHO: World Health Organization

Chemical Compounds

CO: Carbon monoxide

CO_2: Carbon dioxide

NO: Nitric Oxide

NO_2: Nitrogen dioxide

NO_x: Nitrogen oxides

PAH: Polycyclic Aromatic Hydrocarbons

PM: Particulate Matter

SO_2: Sulfur dioxide

VOC: Volatile Organic Compounds

Units

μgm^{-3}: Micrograms per cubic meters

ppb: Parts per billion

ppm: Parts per million

1.0. Introduction

1.1. Background

Although 'Air' is a necessity for the health and wellbeing of all living organisms, the majority of the world's population does not breathe clean and safe air. Densely packed cities such as Katmandu, Delhi, Dhaka, Santiago, Beijing, Wuhan, and Mumbai are above the orange light in US Air Quality Index (IQ Air 2021) with an air quality that's dangerously beyond the recommended air quality guidelines by the World Health Organization (WHO) (WHO 2021). The WHO recommended level of mean fine particulate matter (PM2.5) for a year suitable for living is 10 μgm^{-3}, which is the equivalent of 0-50 in the Air Quality Index (AQI) (WHO 2005; IQ AIR 2021). However, major cities such as Delhi, Dhaka, Kuwait, Shanghai, and Dubai have AQI values over 135 (IQ Air 2021), which is categorized as 'unhealthy' for humans (AQICN 2021). The air pollution levels vary from one place to another and near the vicinity of the point sources such as traffic-congested roads, highways, power plants, industrial areas, and large stationary sources, the accumulation of polluted air is even higher (WHO 2006).

The People's Republic of China (hereinafter referred to as "China") is one of the countries with the highest air pollution in the world. China currently has the largest population (World Bank 2019a) and the second-largest GDP (World Bank 2019b) in the world. With a high economic and population growth rate, China now has to deal with continuously increasing carbon emissions as well. Over 27% of the world's total carbon emissions came from China (Hu 2016; Friedlingstein 2020), making the country the top carbon emitter in the world. As a result of high greenhouse gas (GHG) emissions from sources such as industries and vehicles, several urban regions in China are hubs for air pollution. For example, Beijing had a peak average daily AQI of 262 in January 2020, which falls under the 'hazardous' category of AQI. While the air quality levels significantly got improved due to the lockdown during the COVID-

19 pandemic, the majority of the days from March to December in 2020 still had air qualities that were labeled as 'unhealthy' (AQICN 2021).

According to World Bank (2021a), in 2017, over 99.99% of the Chinese population was exposed to air quality levels exceeding WHO guidelines. Moreover, the number of deaths attributable to outdoor air pollution has increased from 300,000 in 2009 (WHO 2009) to 1.2 million by 2017 (Yin *et al.* 2020). In total, air pollution relates to an average of over 1.62 million deaths in China each year (Rohde and Muller 2015; Chan and Liao 2018).

1.2. China's War on Air Pollution: Policies at a glance

China has recognized air pollution as one of its worst enemies and a politically prioritized concern and has implemented different policy frameworks and other plans to fight back. The policies have gone through many changes within the past few decades, transitioning their implementation from weak to strong. Since the passing of the Law on Air Pollution Prevention and Control of the People's Republic of China (LAPPC) on September 15, 1987 (He *et al.* 2002), China has worked hard to improve the air quality of the urban regions to make it safe and healthy for all citizens. The Chinese government has undertaken several actions such as promotion of laws, regulations, and standards, the establishment of a national air pollution monitoring system, implementation of research and development programs for urban air pollution control, and investment in environmental infrastructures such as pollution control devices and natural gas pipelines, to "protect public health and environmental quality" in the country (He *et al.* 2002). On top of the existing conventional top-down approaches in air pollution control policies, in recent years, China also has adopted more stringent and innovative measures to reduce air pollution as well.

Implemented first in 1953, five-year plans (FYPs) can be considered one of the most significant national policy tools in China, which provides "a clear national strategy and intention" (Hu 2016). Before 2005, air pollution was not considered a major social issue or a political priority; hence first time any kind of air pollution prevention targets are seen in China's five-year plans are in the 11th FYP and early 12th FYP, that is from 2006 to 2012 (Jin *et al.* 2016). Responding to the 2013 PM2.5 crisis, China initiated the 'Action Plan', and starting from the 13th FYP, specific PM2.5 combating targets were inserted into the five-year plans (Jin *et al.* 2016). The air pollution control targets have been strengthened and carried onto the currently in-place five-year plan, 14th FYP (Yifan 2021).

1.3. Gap in Research

As 'air pollution' is a major environmental risk factor that has adverse health and socio-economic effects on all people in China, it has been widely discussed in the literature. Given that China has some of the most polluted cities in the world, it is not a novel area of study. While all three policy documents (11th, 12th, and 13th FYP) that are analyzed in this study have been widely studied in the context of air pollution targets, there were no cross analyses or comparative analyses done on all three documents so far. The air pollution targets in the 11th FYP, 12th FYP, and 13th FYP has been discussed independently in previous studies, but there is a gap in research when it comes to comparing the air pollution targets in them from a policy perspective. This paper intends to compare and analyze the three policy documents together, so that it will help understand the evolution of air pollution targets from the 11th five-year plan to the 13th five-year plan, from 2005 to 2020.

Jin *et al.* (2016) also agree that although there are several lines of broad literature discussing air pollution itself and policies from a national perspective in China, independent discussions on air pollution control policies are limited. Moreover, literature from fields of study like environmental law discusses the Chinese environmental regulations as a whole, while environmental economics focuses on individual policies (Jin *et al.* 2016). Though there are some reports on the latest developments of air pollution control policies in China, there is a gap for "more detailed, systematic follow-ups" in this context (Jin *et al.* 2016). I believe, this piece of literature will shed some light on the matter and fill the gap in research to a certain extent by providing a broader analysis on the evolution (or devolution) of air pollution targets in the national five-year plans in China, from 2005 to 2020.

1.4. Research Question

The main research question for this study comprises 3 sub-questions. The research question targets to achieve the aims and objectives mentioned in the below section using the policy analysis done in the coming sections. This question can be categorized under 2 of the 6 types of research questions of Denscombe (2010); 1). explaining type and 2). criticizing/evaluating type. This study aims to answer the following research question.

How have the policies targeting air pollution prevention and control in the five-year plans of China changed between 2005 and 2020?

1. Is the change evolution or devolution?
2. What sector of heavy air pollution (out of energy sector, industrial sector, transportation sector, and urban development sector) went through the biggest policy improvements, and what sector went through the least improvements?
3. Why did air pollution-related policies improve significantly in the 13th five-year plan compared to the 11th five-year plan?

These questions are answered in the discussion section and wrapped up the answer in the conclusion section.

1.5. Aims and Objectives

This study aims to understand the evolution of the air pollution targets in China's most significant national policy tool, five-year plans from 2005 to 2020, and this is achieved by attempting to answer the research question above. This thesis specifically intends to compare and analyze the 11th, 12th, and 13th five-year plans in the context of air pollution prevention targets. This aim can further be subdivided into the following objectives.

1. To provide a broader review into the changes the air pollution prevention targets went through in policy documents in China, from 2005 to 2020, and to understand the evolution (or devolution if any) of the targets over time

2. To identify the major improvements of each policy document compared to the previous one

3. To understand the alignment of the impacts with the aims of the policy

4. To identify what policies or strategies were carried out to the next document from the previous one

The objectives are achieved as follows. Chapters relevant to the air pollution control in the three policy documents, 11th, 12th, and 13th FYP are intensely analyzed in order to understand the depth of the targets. Air pollution prevention targets in each document are evaluated compared to the other 2 policy documents. The policies are divided into 4 themes where each theme has 3 sub-themes. Then, the policies under each theme are analyzed based on a logic model where the 1). Inputs 2). Outcomes, 3). Activities, 4). Impacts, 5). Aims, and 6). Externalities are discussed.

This paper majorly uses formal policy documents and other qualitative literature. While there are some empirical data used to provide evidence for certain arguments, they are not the major focal point of this piece of literature, and any kind of statistical analysis of those empirical data is not carried out during this study. While there are several studies where researchers extensively analyzed empirical datasets to identify the adverse effects of air pollution and similar topics; for example, Yin *et al.*'s 2020 study, 'The effect of air pollution on deaths, disease burden, and life expectancy across China and its provinces, 1990–2017: An analysis for the global burden of disease study 2017', there is a void in policy analyses in the context of five-year plans. Also, the available policy analyses relevant to this context are mostly on the air pollution-focused policy frameworks than the five-year plans. Therefore, as the author of this study, I find it relevant to focus on a policy analysis rather than a statistical analysis, for this specific context.

Additionally, it should also be emphasized that this study does not focus on the effectiveness of the air pollution policies, the extent of implementation of the policies, or the actual state of the air pollution after the implementation of these policies in China. While several sections briefly touch upon the status of the air pollution, and death and disease burden in China due to air pollution, it is to be noted that, those sections are to provide context and background, and not to provide extensive analysis on the matter. The aims and objectives listed above are achieved through policy analysis and literature review in line with some data from credible, open-source databases.

1.6. Structure of the Thesis

This thesis is structured as follows. Chapter 1, the introduction discusses briefly the background of air pollution in China, policies involved in the air pollution battle, the gap in research and novelty of the study, aims and objectives, and the structure. These topics are briefly touched upon in the introduction and are discussed broadly throughout the thesis. The introduction is followed by the methodology section which focuses on the site selection, parameters, policy selection, logic model, and also the methodology of the literature review. Chapter 3 is the literature review where major air pollutants, current status and evolution of air quality and pollution in China, sources of air pollution in China, disease, and death burden due to air pollution, and the history and evolution of air pollution prevention policies in China are broadly discussed. This chapter brings together a significant amount of literature from scholars who have previously studied the topics such as air pollution, death and disease burden of air pollution, and air pollution targets in policy documents, mainly in the context of China and also global. Following the literature review, the discussion section mainly focuses on the comparison and analysis of the 11th FYP, 12th FYP, and 13th FYP. They are analyzed according to a logic model that is mentioned and discussed in the methodology section of this study. The Discussion is followed by chapter 5; recommendations, where recommendations and proposals on how the existing policies should be changed based on the policy analysis done in this paper are discussed. Finally, the last chapter, the conclusion summarizes the thesis, wraps up the answers to the research question, and provides concluding remarks on the evolution of the air pollution control policies in the five-year plans of China from 2005 to 2020.

2.0. Methodology

2.1. Theory of the Policy Analysis

Policy analyses are an important addition to the literature of any sector due to many reasons. They are a critical step in advancing the understanding of the "impact of various federal, state, local, and organizational policies" (Sheldon 2016), and in identifying the potential performance goals for the society (Skees 2014). Skees (2014) further explains that contrary to the popular myth that good research leads to good policy, the policy process is an imperfect science where factors such as misunderstandings, institutional failures, and conflicts of interests can convert a "seemingly desirable and feasible" policy into an "unacceptable and ineffective" one. Therefore, timely and credible policy analyses must be conducted on all kinds of policy documents to avoid any implementation failures and also to provide a stronger foundation for future policy-making processes.

One of the key elements of a credible and effective policy analysis regardless of the sector is an analytical framework grounded in theories and models of policy-making (Sheldon 2016). Such a framework can help identify and interpret the interconnections between the variables of the issue in discussion, and provide a common structure for summarizing the advantages, limitations, synergies, trade-offs, externalities, etc. of the policies. This not only helps improve the policy-making in the future but also could smooth the implementation process of the policy.

Air pollution mitigation policies are an important sub-sector of policies that in most cases, falls under the umbrella of environmental protection. In contexts like the five-year plans for national social and economic development in China, where air pollution mitigation is not the main intention of the policy document, applying a credible analytical framework and analyze the relevant policies could provide crucial insights about those less focused sub-sectors.

Policy analysis is a multi-faceted field where some use qualitative or quantitative analysis while others "reconstruct and analyze political discourse or set up citizen fora" (Mayer et al. 2004). In the policy analysis field, analysts can belong to a plethora of groups such as independent researchers, process-facilitators, political advisors, change agents, policy advocates, and partners of stakeholders (Mayer et al. 2004; Sheldon 2016). This variety and multi-faceted nature of policy analysis makes it difficult, or even impossible to single out 'one best' way of conducting policy analyses (Mayer et al. 2004).

While there are several analytical frameworks to conduct effective policy analysis, the Center for Disease Control and Prevention (CDC) provides an integrated and holistic policy analytical framework that was made to provide a guide to identify, analyze, and prioritize the policies that can improve health. Though the context of the CDC policy analysis, and the issue discussed in this paper are different, the policy framework provided can be used to understand how the policy analysis happens in an ideal situation.

CDC's policy framework generally consists of 5 domains; 1). problem identification, 2). policy analysis, 3). strategy and policy development, 4). policy enactment, and 5). policy implementation, followed by evaluation and stakeholder engagement as the final steps (CDC 2013). However, the policy analysis process at an initial stage of the implementation majorly focuses only on the first three domains of the above-mentioned framework, as the main intention at that stage is to improve the analytic basis for identifying and prioritizing policies that can improve the status of the problem and improve the "strategic approach to identify and further the adoption of policy solutions" (CDC 2013).

According to the CDC guidelines for policy analysis, the key steps and sub-steps include the following (CDC 2013).

1. Problem identification
2. Policy analysis
    a. Identify and describe policy options

   b. Assess policy options
   c. Prioritize policy options
3. Develop a strategy for furthering the adoption of a policy solution

Problem identification is a crucial step in any policy analysis framework. This step doesn't simply mean identifying the issue and moving on to the next step. During this step, the problem should be well-defined and specified with context- and/or location-specific data. Synthesizing data that identifies and provides a clear view into the aspects of the problem like the burden, size, causes, severity, frequency, and scope (CDC 2013; Besharov *et al.* 2017) is important to clearly understand the problem to realize the extent of the policies needed to solve it. CDC (2013) suggests that in order to understand how best to address the problem, the data and literature gathered on the issue should define the problem as specific as possible, instead of identifying it in general terms.

The next key step in the framework at discussion, 'policy analysis', includes 3 sub-steps as mentioned above. Policy options specific and relevant to the problem can be identified by strategies such as reviewing available literature, surveying the best practices, and conducting an environmental scan (CDC 2013). The literature review and survey can include case studies from other close aspects of the problem, and even from different locations than the problem's context. Such a broad review of data could help identify the problem more holistically and in different contexts. For example, in the case of air pollution mitigation policies, other aspects of air quality such as climate change could be reviewed to understand the problem in a well-defined context. Moreover, it is important to collect evidence, literature, and data that are of alternative and contradictory points of view on the problem at the discussion in order to provide better policy options after the analyses. After identifying the policy options, describing them can be done mainly by answering the overarching questions such as follows (CDC 2013).

- What is the policy lever (legislative, administrative, regulatory, other)?
- What level of government or institution will implement?
- How does the policy operate? – Is it mandatory? Will enforcement be necessary? How is it funded? Who is responsible for administering the policy?
- What are the objectives of the policy?
- What is the legal landscape surrounding the policy?
- What is the historical context or has the policy been debated previously?
- What is the value-added of the policy?
- What are the expected short, intermediate, and long-term outcomes?
- What might be the unintended positive and negative consequences of the policy?

While these questions can be used as a guide to describing the policy options, the overarching questions that can be asked can vary depending on the problem identified, contexts, and even the location of the issue. These questions are not hard and fast rules to describe the policy options, but rather an outline to ask more questions that would better define the policy options. The answers that are obtained from these questions are used to assess, rate, and prioritize the policy options. For example, each policy can be rated as low, medium, or high in a spectrum under pre-determined criteria.

The final step in this framework is 'developing a strategy for furthering the adoption of a policy solution', which can be done using several steps like clarifying the method of operation or implementation and planning out the information dissemination for the key stakeholders. In a case where a specific policy is not prioritized during the previous steps, due to various reasons like insufficient data on the impact, lack of stakeholder support, and low feasibility, there is other background work that could be done to prepare the lacking policy to implement in future. Examples of such steps could include the development of a policy research agenda, identifying the key questions that need to be addressed (CDC 2013), and improving stakeholder engagement and participation.

The framework for policy analysis described above is a general framework that can be used in an ideal situation. The policy documents discussed in this study are not ideal, and the air pollution-related policies in those documents need much work to be considered ideal. While there are many policy frameworks in different sectors of studies to explain the theoretical framework for policy analysis, the above-detailed framework of CDC provides a closer resemblance to the one used in this study, compared to other frameworks available. The logic model I have used in this study corresponds to the main domains of the CDC's framework to some extent. The problem specification and analysis of the program design focusing on inputs, activities, outputs, outcomes, and impacts are done in this policy analysis. While the analysis may not directly overlap with the framework discussed here, the process compliments each step and mainly focus on the outcome of the step, formulating a more integrated and well-defined analysis. The logic model used in the study is explained in the coming sections of this chapter.

2.2. Site selection

This study fully focuses on the People's Republic of China. There are several reasons to select China as the site for this study. China has the largest population on earth and the second largest GDP with a growing economy focused mainly on industrial manufacturing. With the growth of the economy, environmental degradation is inevitable for any country, unless strict measures were taken to mitigate it. Due to many reasons such as urbanization, high population density in urban regions, heavy industrialization, and high economic growth, air pollution in China has been increasing drastically over the past decades. Therefore, it is necessary to recognize air pollution as a social and health concern in the country and incorporate it into the policy frameworks. It is also important to discuss and study the improvements of the air pollution-related policies in all the policy frameworks to ensure that they are being implemented successfully. Moreover, as a country with heavy air pollution and also a large impact on the world's power dynamics, understanding China's mitigation policies and their improvement over the years is important to understand the impact of those actions on the rest of the world.

Apart from these reasons, while air pollution in China has been widely discussed in the past decade, the COVID-19 pandemic sheds new light on the issue, bringing the attention back to the surface. Although the available literature and data about China's air pollution only run back for 10 years, as it has been discussed often within that time, there is much literature and data to discuss. For all these reasons, China is a great site to study the policies regarding air pollution mitigation.

2.3. Parameters: Pollutants and Time period

While there are many air pollutants, climate pollutants, and greenhouse gases to be discussed, due to lack of time and resources, this study specifically focuses on;

- Particulate matter – PM2.5,
- Sulfur dioxide,
- Ground-level ozone,
- Carbon dioxide, and
- Nitrogen oxides.

These pollutants are mainly generated by coal-based power generation, heavy-emitting industries, and the transportation sector. Among many other pollutants such as methane and black carbon, these pollutants affect the air quality of Chinese cities more. These air pollutants have a bigger and a direct impact on public health and are monitored closely; hence, there are data available in open source for the air quality for these specific pollutants.

The period chosen for this study is from 2005 to 2020. The main reason for this selection entirely depends on the selected policy frameworks, which expand over these 15 years. Moreover, China's industrial sector, technology, and many other aspects went through heavy advancements during the past 15 years, and it is important to study and understand how the policies for air pollution mitigation in national plans in a heavy emitting country like China changed within this time.

2.4. Policy selection

Three policy documents were chosen for this study. They are the 11th five-year plan, 12th five-year plan, and 13th five-year plan for the social and economic development of China. All three policy documents are available online for access to the public and the full official documents were downloaded from the 'Asia-Pacific Energy Portal', which can be accessed using the following URLs.

- 11th FYP: https://policy.asiapacificenergy.org/node/115
- 12th FYP: https://policy.asiapacificenergy.org/node/37
- 13th FYP: https://policy.asiapacificenergy.org/node/2509

Five-year plans are essentially the plans that were established for the entire country, traditionally detailing the economic development strategies for the five years the plan was initiated. In China, these five-year plans rank among the most important strategic policy documents for the country's development. While these plans predominantly focused on the economic development of the country for the better part of the years since the initiative was implemented, the environmental issues have made their way to these national five-year plans gradually.

There are several reasons for choosing these 3 specific five-year plans. Up until the 11th five-year plan, air pollution was not considered a social concern of the country. The 11th FYP which was launched for the period from 2006 to 2010, contained some policies that directly and indirectly addressed the air pollution issue. The 2 FYPs after that, the 12th and 13th FYPs contained more policies for air pollution mitigation, and it is very important to study the evolution of these policies from 11th to 12th and then to 13th five-year plans, in order to understand the way forward after the pandemic in 2020.

2.5. Logic model

The 3 policy documents were carefully read and first collected all the policies that could have any kind of direct or indirect impact on air pollution. Then, the policies were categorized under 4 themes and then further categorized into sub-themes under each sector.

- Energy sector
    - Energy consumption
    - Renewable energy and clean power
    - Coal in energy
- Industrial sector
    - Emissions, green-house gases, and pollutant discharge
    - Low-carbon technology in industries
    - Standards and schemes
- Transportation sector
    - Traffic and road network
    - Public transport
    - Vehicular emissions
- Urban development
    - Employment
    - Population
    - City development

After categorizing the policies under these themes and sub-themes, they were analyzed according to a preliminary logic model. The components of the used logic model are as follows

- Problem specification
- Policy design (as in the following diagram)

The problem of air pollution in the context of China is specified with numerical data and qualitative literature in the literature review, and also in the discussion section of this study. Problem specification mainly focuses on specifying what problem should be addressed by the policy or policies. In this study, air pollution by particulate matter, SO_2, NO_x, ground-level ozone, and CO_2 in China are studied and analyzed. Many aspects of the problem such as its characteristics, size, severity, causes, and main stakeholders are discussed during the problem specification.

In the discussion section, all the policies were analyzed with the policy design mentioned above. 12 tables were made for 12 sub-themes, where the inputs, outcomes, activities, aims, impacts, and externalities were discussed. The respective tables show the policies from all 3 policy documents under the relative sub-theme, side by side for easy reference and analysis. After the formation of tables, they are extensively discussed in the discussion section.

2.6. Literature Review Section: Methodology

The literature review was conducted with both qualitative literature and numerical data. The empirical data was gathered from open sources such as World Bank Database, AQICN Database, Our World in Data, and Statista, and also from recent research studies on the topic. Used data are high quality, credible, and up-to-date as well. All the origins and URLs for numerical data in the study are given in the following table.

Table 1: Sources for the empirical data in the literature review

SOURCE	URL
Boston University School of Public Health (BUSPH)	https://www.bu.edu/sph/
Environmental Protection Agency (EPA)	https://www.epa.gov/
International Energy Agency (IEA)	https://www.iea.org/
IQ Air	https://www.iqair.com/
Our World in Data	https://ourworldindata.org/
Statista	https://www.statista.com/
World Air Quality Index Project	https://waqi.info/
World Bank	https://www.worldbank.org/en/home
World Health Organization (WHO)	https://www.who.int/

The literature review was conducted mainly using literature available in online peer-reviewed journals such as Science Direct, Springer, and others. Apart from these sources, several China-specific data sources such as China Dialogue were also used to gather site-specific data. The complete list of online journals used in mainly the literature review section, and also in other sections of this study are given in table 2.

The credible articles and books for the literature review section were found mainly by conducting Google searches using several keywords and keyword combinations. The most-used keyword combinations are given below.

- Air pollution + DALY + China
- Air pollution + Five-year plans + China
- Air pollution in China
- Air pollution in megacities in China
- Air pollution policies in China
- Air quality China historical data
- Air quality in COVID in China
- Air quality index
- AQI data China
- AQICN data China
- Beijing air quality
- Beijing bad air quality
- Beijing topography and air pollution
- BTH region + China + air pollution
- China air pollution scholarly articles
- China five-year plans
- The concentration of fine PM 2.5
- Disease burden of air pollution in China
- Effects of population growth on air pollution in China
- GDP growth and vehicle ownership in China
- GDP growth in China

- Health and urbanization
- Mortality by air pollution + China
- Open database air quality world bank
- Ozone related deaths + China
- Ozone related diseases
- Particulate matter pollution in different countries
- PM concentration in air world Statista
- Sources of air pollution in China
- Urbanization and air pollution
- Vehicular emissions in China
- WHO air quality guidelines
- Why Beijing air quality is bad
- Worst air quality within cities world

Table 2: Complete list of journals used in the study

JOURNAL	URL
Advances in Climate Change Research	https://www.sciencedirect.com/journal/advances-in-climate-change-research
Advances in Experimental Medicine and Biology	https://www.springer.com/series/5584
American Geophysical Union Publications (AGU Pub)	https://www.agu.org/
American Lung Association	https://www.lung.org/
Annual Review of Energy and the Environment	https://www.annualreviews.org/journal/energy
Atmospheric Chemistry and Physics	https://www.atmospheric-chemistry-and-physics.net/
Atmospheric Environment	https://www.journals.elsevier.com/atmospheric-environment
Berkley Earth	http://berkeleyearth.org/
Carbon Balance and Management Journal	https://cbmjournal.biomedcentral.com/
Chemosphere	https://www.journals.elsevier.com/chemosphere
China Dialogue	https://chinadialogue.net/en/
China Research Center	https://www.chinacenter.net/
Current Opinion in Environmental Science & Health	https://www.journals.elsevier.com/current-opinion-in-environmental-science-and-health
Elsevier	https://www.elsevier.com/
Energy Policy	https://www.journals.elsevier.com/energy-policy
Environment International	https://www.journals.elsevier.com/environment-international
Environmental Health Perspectives	https://ehp.niehs.nih.gov/
Environmental Pollution	https://www.journals.elsevier.com/environmental-pollution
European Respiratory Journal	https://erj.ersjournals.com/
European Respiratory Review	https://err.ersjournals.com/
Every CRS Report (By Congressional Research Service)	https://www.everycrsreport.com/
Frontiers in Public Health	https://www.frontiersin.org/journals/public-health
Institute for Global Environmental Strategies (IGES)	https://www.iges.or.jp/en
Intech-Open Publishers	https://www.intechopen.com/
International Journal of Technology Policy and Management	https://www.inderscience.com/
International Journal of Scientific Research in Knowledge	http://www.ijsrpub.com/ijsrk
Iranian Journal of Public Health	https://ijph.tums.ac.ir/index.php/ijph
Journal of Agricultural & Applied Economics	https://www.cambridge.org/core/journals/journal-of-agricultural-and-applied-economics
Journal of Clinical Epidemiology	https://www.jclinepi.com/
Journal of the Air & Waste Management Association	https://www.awma.org/journal

Multidisciplinary Digital Publishing Institute (MDPI)	https://www.mdpi.com/
Multidisciplinary Respiratory Medicine	https://mrmjournal.biomedcentral.com/
Mutation Research - Reviews in Mutation Research	https://www.journals.elsevier.com/mutation-research-reviews-in-mutation-research
National Center for Biotechnology Information (NCBI)	https://www.ncbi.nlm.nih.gov/
National Institute of Environmental Health and Safety	https://www.niehs.nih.gov/
Nature	https://www.nature.com/
Ochsner Journal	http://www.ochsnerjournal.org/
OECD Journal	https://www.oecd.org/
Open-Edition Journals	https://journals.openedition.org/
Physical Therapy Journal	https://academic.oup.com/ptj
Procedia Engineering	https://www.sciencedirect.com/journal/procedia-engineering
Procedia Environmental Sciences	https://www.sciencedirect.com/journal/procedia-environmental-sciences
Public Library of Science (PLOS)	https://plos.org/
PubMed	https://pubmed.ncbi.nlm.nih.gov/
Research Gate	https://www.researchgate.net/
Science Direct	https://www.sciencedirect.com/
Science Magazine (By American Association for Advancement of Science)	https://www.sciencemag.org/
Science of the Total Environment	https://www.journals.elsevier.com/science-of-the-total-environment
Scientific Data	https://www.nature.com/sdata/
Springer	https://www.springer.com/in
Surveys and Perspectives Integrating Environment and Society	https://journals.openedition.org/sapiens/
Sustainability	https://www.mdpi.com/journal/sustainability
Taylor and Francis Online	https://www.tandfonline.com/
The Lancet Planetary Health	https://www.thelancet.com/

2.7. Limitations

This study is fully based on secondary data, official five-year plans of China, and some numerical data obtained from several open-source databases such as the World Bank and World Health Organization. It was done within a limited time where international travel restrictions were imposed due to the COVID-19 pandemic; hence traveling to the location to conduct more hands-on research was not possible. In this study, the main focus was to analyze the evolution of the air pollution mitigation policies in the five-year plans in China, from 2005 to 2020. The effectiveness of the policies was not the intention of this study due to limitations including lack of more recent data and lack of time and resources to formulate a research framework to collect data about the effectiveness of the policies. Since these 3 documents were not the only frameworks with policies to mitigate air pollution in China, it is practically not possible for this level of study to exactly pinpoint the results of the policies discussed in this paper. Such a research hypothesis would have been also affected by other external factors such as climatic conditions and major events like the Beijing Olympic festival in 2008 and COVID-19 lockdown in 2020 as well. Considering all these conditions and limitations, it was decided to base this study on the evolution of air pollution mitigation policies, rather than on their effectiveness or efficiency. However, as the author of this paper, I anticipate that this study would pave the path to conduct further researches on the effectiveness of these policies in the future.

3.0. Literature Review

It is now well-established that air pollution is a major environmental risk factor responsible for the death and health deterioration of millions of lives in the world. Manisalidis *et al*. (2020) name air pollution as "one of our era's greatest scourges", as it not only impacts climate change but also public health by increasing morbidity and mortality. Air pollution has 2 parts to it; outdoor (ambient) air pollution and indoor (household) air pollution. There are many international organizations such as World Health Organization, Climate, and Clean Air Coalition, and United Nations Environment Programme, that works relentlessly towards improving both the ambient and household air conditions to improve public health as well as climate impacts.

Among many countries that top the list of 'worst air qualities in the world', China takes a prime position due to their heavily polluted cities. This is fueled mainly by China being the world's leading annual emitter of greenhouse gases and mercury (U.S. Embassy in Georgia 2020).

3.1. Major Air Pollutants in China

In this section, data and information about the major air pollutants in the world, specifically in China, from interdisciplinary literature as well as several credible databases have been put together in an attempt to paint a picture of the severity of the issue of air pollution, and also to establish a base on what pollutants are majorly discussed in the five-year plans later on. Among the major air pollutants that contaminate the urban air in China, the following pollutants are prominent.

3.1.1. Particulate Matter (PM)

Particulate matter, also known as PM2.5 and PM10 refers to the minute-sized particles with an aerodynamic diameter of 2.5 microns and 10 microns respectively (EPA 2020). Due to the smaller size, PM2.5 particles can penetrate deeper into the respiratory and circulatory organs; hence they are considered more dangerous compared to the PM10 (EPA 2020). Although the WHO air quality guideline (WHO-AQG) for PM2.5 is 10 μgm^{-3} (WHO 2018), studies have shown that the population-weighted mean of PM2.5 in Chinese cities is as high as 61 μgm^{-3}, which is 3 times higher than the global population-weighted mean (Zhang and Cao 2015). Zhang and Cao (2015) further emphasize the remarkable seasonal variability of PM2.5, where the concentrations are observed to be highest during winter and lowest during summer. While the majority of the Chinese population breathes PM2.5 concentrations well above WHO guidelines (World Bank 2017), over 850,000 deaths were caused by ambient PM2.5 pollutions in 2017 alone (Yin *et al.* 2020). Long-term exposure to particulate matter can lead to many illnesses such as reduced lung function, asthma, heart problems, and irritations in the respiratory tract (EPA 2021).

Apart from the health effects of particulate matter, they also have adverse impacts on the environment as well. Due to the lightweight and small size of the particles, they are carried over long distances by the wind and depending on their chemical composition, they can cause different environmental impacts after settling on ground or water bodies (EPA 2021). Environmental impacts of PM pollution include acidification of freshwater bodies, depletion of soil nutrients, change of nutrient balance in the river basins and coastal waters, contribution to acid rain, and damage to the sensitive forests and farm crops (EPA 2021).

3.1.2. Sulfur Dioxide (SO_2)

Sulfur dioxide (SO_2) is a colorless gas with a strong, pungent odor. It is generated mainly during coal and fossil fuel combustion due to the burning of Sulfur, which is an impurity in them. While electricity generation remains the largest source of anthropogenic SO_2 emissions, other sources like industrial boilers, industrial processes like petroleum refining and metal processing, and diesel engines in old buses, trucks, ships, locomotives, and off-road diesel equipment contribute greatly to the increased SO_2 levels in the atmosphere (American

Lung Association 2021). Sulfur dioxide acts as a major component in acid rain by creating sulfuric acid upon reacting with water vapor in the atmosphere (Casiday and Frey 1998), and Mohanjan (2014) estimates that about 40% of China's land area is affected by acid rain. Although WHO-AQG for SO_2 is 20 μgm^{-3} in the 24-hour mean and 500 μgm^{-3} in the 10-minute mean (WHO 2018), many of China's major cities have SO_2 levels above the recommended levels, posing a serious threat to human health.

China is considered one of the world's largest SO_2 generating countries with more than 9 million tons of annual emissions from sources such as coal-burning power plants (Yang and Schreifels 2003). Yang and Schreifels (2003) further mention that China is responsible for one-fourth of the global anthropogenic SO_2 emissions since 1990, while Mohanjan (2014) agrees by mentioning that the proportion of SO_2 emissions from the industrial sector alone increased from 76% to 85% between 1998 and 2006.

Short-term exposure to sulfur dioxide can cause irritations in the skin and mucous membranes of the eyes, nose, respiratory tract, and lungs, while chronic exposure can result in reduced lung function and worsened asthma attacks.

3.1.3. Ground-Level Ozone

'Ground-Level Ozone, also known as smog, is synthesized in the air due to chemical reactions between nitrogen oxides (NO_x) and volatile organic compounds (VOC) in the presence of sunlight. Sources such as power plants, automobiles, industrial boilers, and consumer products like paint and solvents release the precursors for the smog to the air, increasing the level of ground-level ozone in urban areas.

The WHO air quality guideline for ground-level ozone is 100 μgm^{-3} (WHO 2018) and China's national standard is 160 μgm^{-3} (Zhao 2015). It is stated that the average ozone exposure increased by 17%, which increased the annual death toll by 12,000 deaths between 2014 and 2017 (Reuters 2017). Yin et al. (2020) reckon that, in 2017, over 175,000 deaths occurred due to ambient ozone pollution in China. It is estimated that, the increase in emissions, the exponential growth of population, and climate change to quadruple the ozone-related deaths in China by 2050 (Samuels 2018).

Short-term exposure to ground-level ozone can cause irritations in the eyes, nose, and throat, nausea, and coughing, while chronic exposure may result in permanent damage to the lungs and heart. Exposure to high levels of ground-level ozone can even lead to death by stroke or heart disease.

3.1.4. Carbon dioxide (CO_2)

Carbon dioxide (CO_2) is the largest contributor to the greenhouse effect that causes major climate crises such as global warming. Coal-fired power plants and fossil fuel-powered automobiles release CO_2 upon incomplete combustion together with several other major air pollutants such as carbon monoxide (CO), particulate matter, and black carbon (soot). However, CO_2 is majorly a climate pollutant than an air pollutant. When the planet's temperature has risen by 1.8^0C, the world's annual death rate is estimated to rise to 21,600, and it is a direct impact of CO_2 increase in the atmosphere (Zabarenko 2008). Although CO_2 as an air pollutant affects human health due to exposure, Jacobson (2008) states that the impact of carbon dioxide on human respiration directly is low or negligible due to its low ambient mixing ratios. Because of this reason, when it comes to carbon- or fossil fuel-based air pollution, CO_2 has not considered a classic air pollutant (Jacobson 2008). While particulate matter trumps as an air pollutant with a large number of directly caused premature deaths worldwide, carbon dioxide impacts human mortality through its climate impacts like global warming and sea-level rise. Air pollution and climate change caused by CO_2 emissions can have a number of health issues among the public. Aggravating pre-existing respiratory diseases, increasing the risk of chronic respiratory diseases like asthma, and increasing exposure to allergies are some of the health risks caused by CO_2-caused climate change and global warming (D'Amato *et al.* 2014).

Moreover, increased temperature due to CO_2 emissions causes the ground-level ozone to increase, causing inflammation and damages lung tissue (D'Amato *et al.* 2013).

As figures 1 and 2 depict, China is the largest emitter of carbon dioxide in the world, with an exponentially increasing annual emission level, especially after the country was opened for foreign trade in the 1970s. Sources like coal-based power generation and automobile emissions in China contributed to about 27% of the world's CO_2 emissions in 2019 (Friedlingstein 2020). However, China is proactively taking actions towards reducing CO_2 emissions and the policies and regulations discussed in the later sections of this study reflect on that aspect.

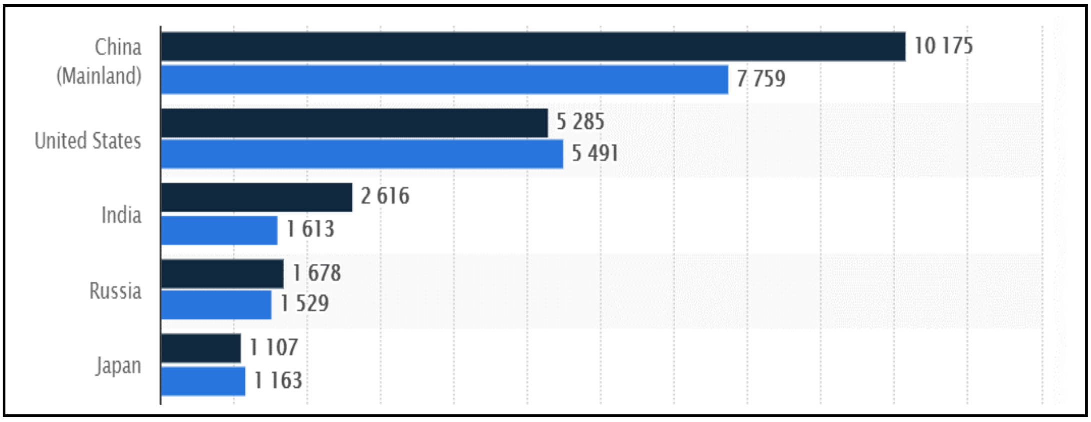

Fig 1: Carbon dioxide emissions in 2009 and 2019, by select country (in million metric tons) (Source: Statista 2021d)

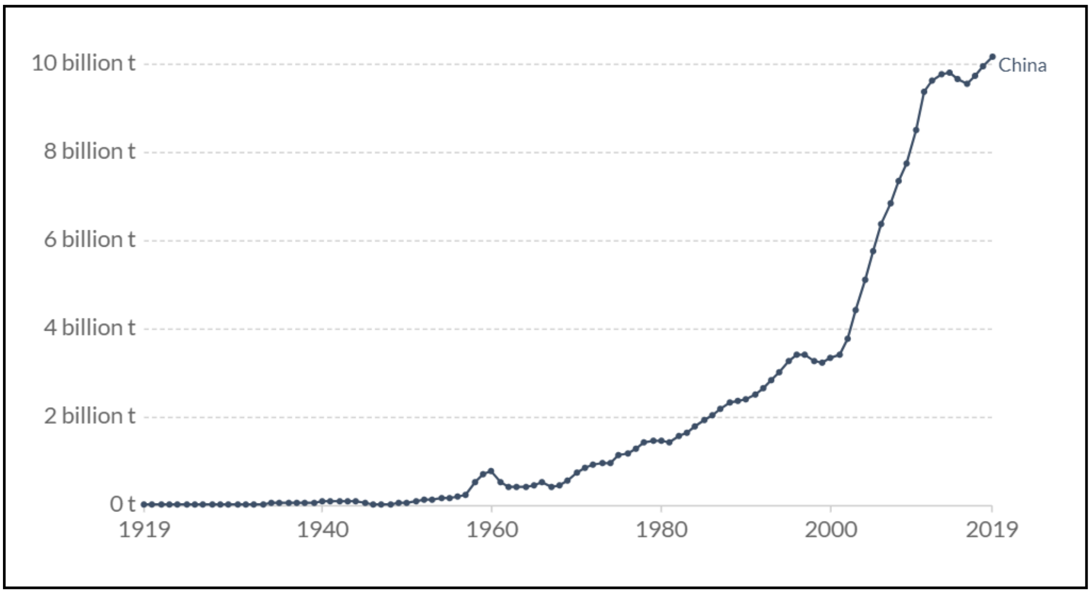

Fig 2: Annual carbon dioxide emissions of China (Source: Ritchie and Roser 2020)

3.1.5. Nitrogen Oxides (NO_x)

Nitrogen oxides (NO_x), including nitric oxide (NO) and nitrogen dioxide (NO_2), are a group of highly reactive, poisonous gases, created by fuel-burning at high temperatures, which also plays a major role in producing smog by reacting with volatile organic compounds (VOC) in hot summer days (EPA 2019). Major sources of NO_x include automobile exhaust, trucks, non-road vehicles such as boats and construction equipment, power plants, industrial boilers, turbines, cement kilns, and others (EPA 2019). The primary National Ambient Air Quality Standards (NAAQS) for NO_x are a 1-hour standard at a level of 100 ppb (parts per billion) and an annual standard at a level of 53 ppb (EPA 2018).

Several epidemiological studies have reported that exposure to ambient NO_2 causes mortality to increase, but there is a debate on whether NO_2 is a direct threat to human health or is only an indicator of other air pollutants (Faustini *et al.* 2014). After an extensive systematic review of literature, Faustini *et al.* (2014) conclude that the "magnitude of the long-term effects of NO_2 on mortality is at least as important as that of PM2.5", emphasizing the importance of discussing the health impacts of NO_2 during health impact assessments. According to the American Lung Association (2020), the major health effects of NO_2 include increased inflammation of the airways, reduced lung function, worsened wheezing and cough, and aggravated asthma. NO_2 also is considered as one of the major reasons for the cause of asthma in children, and also a cause of illnesses in other risk groups like people with lung cancer (American Lung Association 2020). Moreover, new research also links NO_2 to increased cardiovascular diseases, lowered birth weight in newborn babies, and increased risk of premature death as well (American Lung Association 2020).

3.2. Current status and evolution of air quality and pollution in China

Air pollution is one of the major environmental killers, ranking the fifth-highest mortality risk factor in the world in 2017 (World Bank 2019). WHO (2021a) reports that over 4.2 million deaths are caused annually by exposure to ambient air pollution, while 92% of the world's population breathes air that exceeds the WHO air quality guidelines. Combining the number of premature deaths attributable to indoor and outdoor air pollution, it rises to 7 million per year (WHO 2021). Outdoor air pollution is a primary cause of many non-communicable diseases such as stroke, heart disease, lung cancer, and acute and chronic respiratory diseases (WHO 2018).

Out of the millions of premature deaths by ambient air pollution, 91% occur in low- and middle-income countries (WHO 2018). Countries in South-East Asia and Western Pacific regions are disproportionately exposed to outdoor air pollution compared to other regions of the world (WHO 2018). The World Bank (2021a) reports that more than half of the global population lives in very low-quality air (i.e., PM2.5 concentration higher than 35 μgm^{-3}), and the majority are from India and China. As depicted in figure 3, in 2016, China was among the top 5 countries with the highest PM exposure in the world as well (Statista 2021a).

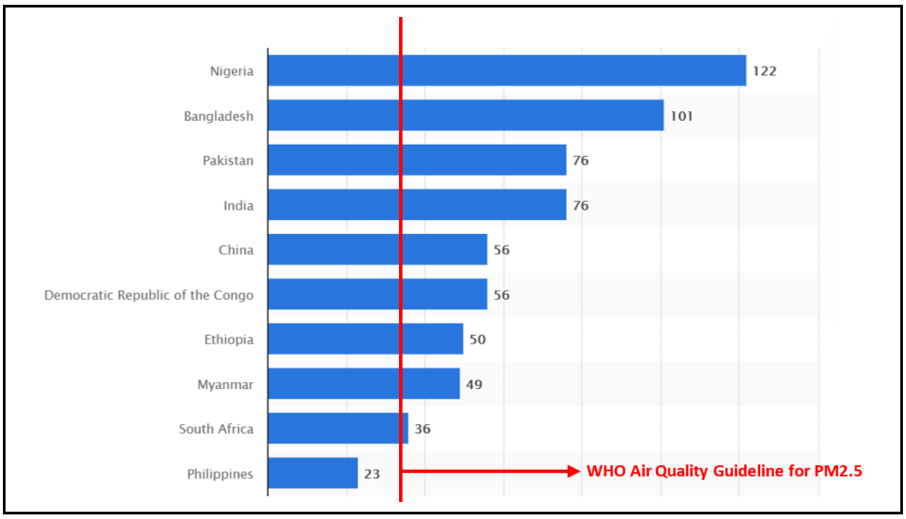

Fig 3:Global PM exposure based on population-weighted concentration by major country in 2016 (Source: Statista 2021a)

In the past few decades, China has been experiencing exponential economic growth. Nearly 40 years ago, China's economy was poor, stagnant, broadly inefficient, centrally controlled, and somewhat isolated from the global economy due to its restricted policies (Morrinson 2019). However, after the initiation of economic reforms and free-market reforms, trade liberalization, and opening up to foreign trade and investment in 1979, China has been in a high economic growth with about 9.5% average GDP growth rate, placing the country among the fastest-growing economies in the world (Morrinson 2019). With the rapid economic growth, China's cities have become more urbanized, leading to a large number of pollution sources being concentrated in a smaller area with dense housing and a large population (Krzyzanowski *et al.* 2014). This, added with the increased traffic and heavy industrialization, has caused China's cities to become hubs for air pollution during past decades (Krzyzanowski *et al.* 2014).

Air quality is measured by using the dimensionless measurement named Air Quality Index (AQI). It is a linear scale running from 0 to 500 where AQI values below 50 representing good air quality while values above 300 representing hazardous air quality (U.S. Embassy and Consulates in China 2021). The safe AQI value may vary from pollutant to pollutant, but generally, AQI values below 100 are thought satisfactory (U.S. Embassy and Consulates in China 2021). Figure 4 shows the AQI basics for particulate matter and ozone pollution.

In the time this paper was written, the real-time air quality visualization map by AQICN showed that 159 cities in China had AQI over 100, where the highest among those having 999 and the lowest having 102 (AQICN 2021). These values are extremely hazardous and not at all suitable for humans to live in. Figure 5 shows the variation of monthly averages of the PM2.5 levels in China from 2015 to 2020. The PM2.5 levels are above the healthy level of AQI for most of each year and it indicates how polluted the air in urban regions of China is.

Air Quality Index Levels of Health Concern	Numerical Value	Meaning
Good	0 to 50	Air quality is considered satisfactory, and air pollution poses little or no risk
Moderate	51 to 100	Air quality is acceptable; however, for some pollutants there may be a moderate health concern for a very small number of people who are unusually sensitive to air pollution.
Unhealthy for Sensitive Groups	101 to 150	Members of sensitive groups may experience health effects. The general public is not likely to be affected.
Unhealthy	151 to 200	Everyone may begin to experience health effects; members of sensitive groups may experience more serious health effects.
Very Unhealthy	201 to 300	Health warnings of emergency conditions. The entire population is more likely to be affected.
Hazardous	301 to 500	Health alert: everyone may experience more serious health effects.

Fig 4: AQI basics for PM and ozone pollution (Source: U.S. Embassy and Consulates in China 2021)

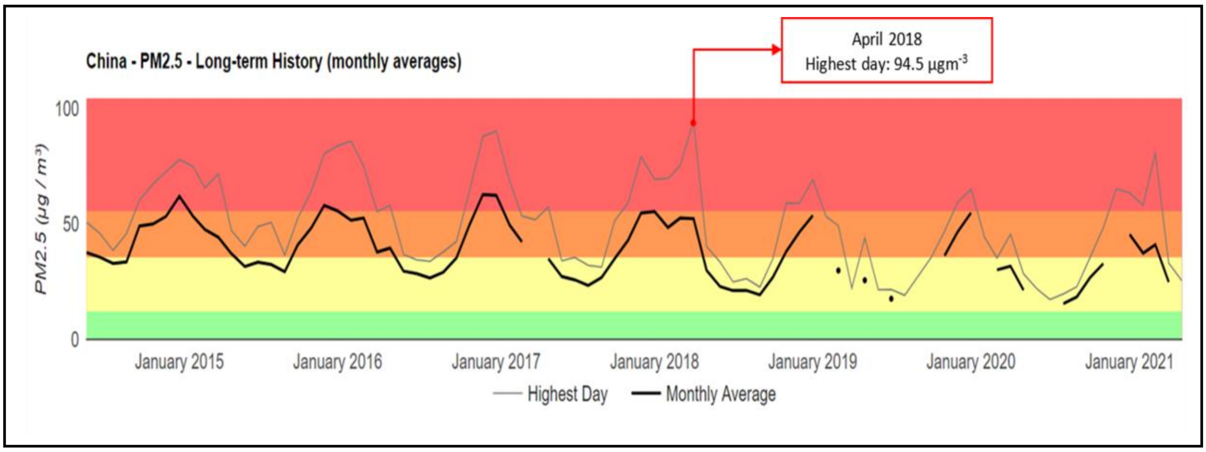

Fig 5: Long-term history of monthly averages of PM2.5 in China (Source: Berkley Earth 2021)

Among all the pollutants, PM2.5 is one of the most hazardous due to its minute size which facilitates an easy penetration into the lung tissues through the respiratory tract. According to several studies where satellite data was used, the PM2.5 concentrations across China have been in an increasing trend from 1999 to 2011 (Peng *et al*. 2016). In-depth empirical data from several other studies show that the PM2.5 concentrations in China have been in a positive trend from 2001 to 2007, and then in a negative trend till 2015 (Ma *et al*. 2016; Lin *et al*. 2018). From 2001 to 2005, i.e., during the time of 10th FYP, the national average of PM2.5 concentration has gone up by 0.04 μgm^{-3} per year (Lin *et al*. 2018). These levels started to decrease from 2006 to 2010 by 0.65 μgm^{-3} per year and from 2011 to 2015 by 2.33 μgm^{-3}

per year, which coincide with the 11th FYP and 12th FYP periods (Lin *et al*. 2018). While these air quality improvements cannot be directly correlated to the mitigation policies in the five-year plans, they might have played a part in it. The correlation between air pollution and the five-year plans will be discussed in later sections of this study. However, the effectiveness of the policies in these plans will not be mainly focused on.

While air pollution is extensive all over the country, Rhode and Muller's (2015) study identifies that south of Beijing, for example, Xingtai and Handan regions has the highest PM concentrations with significant levels extending throughout the interior regions. The map in figure 6 portrays this deviancy for PM2.5, together with the levels of PM10 and O_3 as well. The pollution concentrations in the map are computed using average hourly data and hourly concentration fields over four months in study duration (Rohde and Muller 2015). It is clear from the map that PM2.5 concentrations are way above the healthy levels (colored red) in these regions, compared to other pollutants like PM10 and O_3.

While the air pollution decreased to some extent as a result of the government-mandated lockdown in China to flatten the curve during the COVID-19 pandemic in 2020 (Miyazaki *et al.* 2020), it picked up again after the lockdown is lifted, marking one of the highest air pollution days of all time in 2021. In March 2021, Beijing had one of the worst air pollution days where PM2.5 concentration peaked at 655 μgm^{-3} and PM10 levels at 6,450 μgm^{-3}; the WHO recommended daily averages for PM2.5 and PM10 are 25 μgm^{-3} and 50 μgm^{-3} (The Economist 2021). The sudden limit of transport and industrial activities due to the COVID-19 lockdown caused a drastic reduction in air pollution in China, and this stands to show how big the impact of anthropogenic activities on air pollution is.

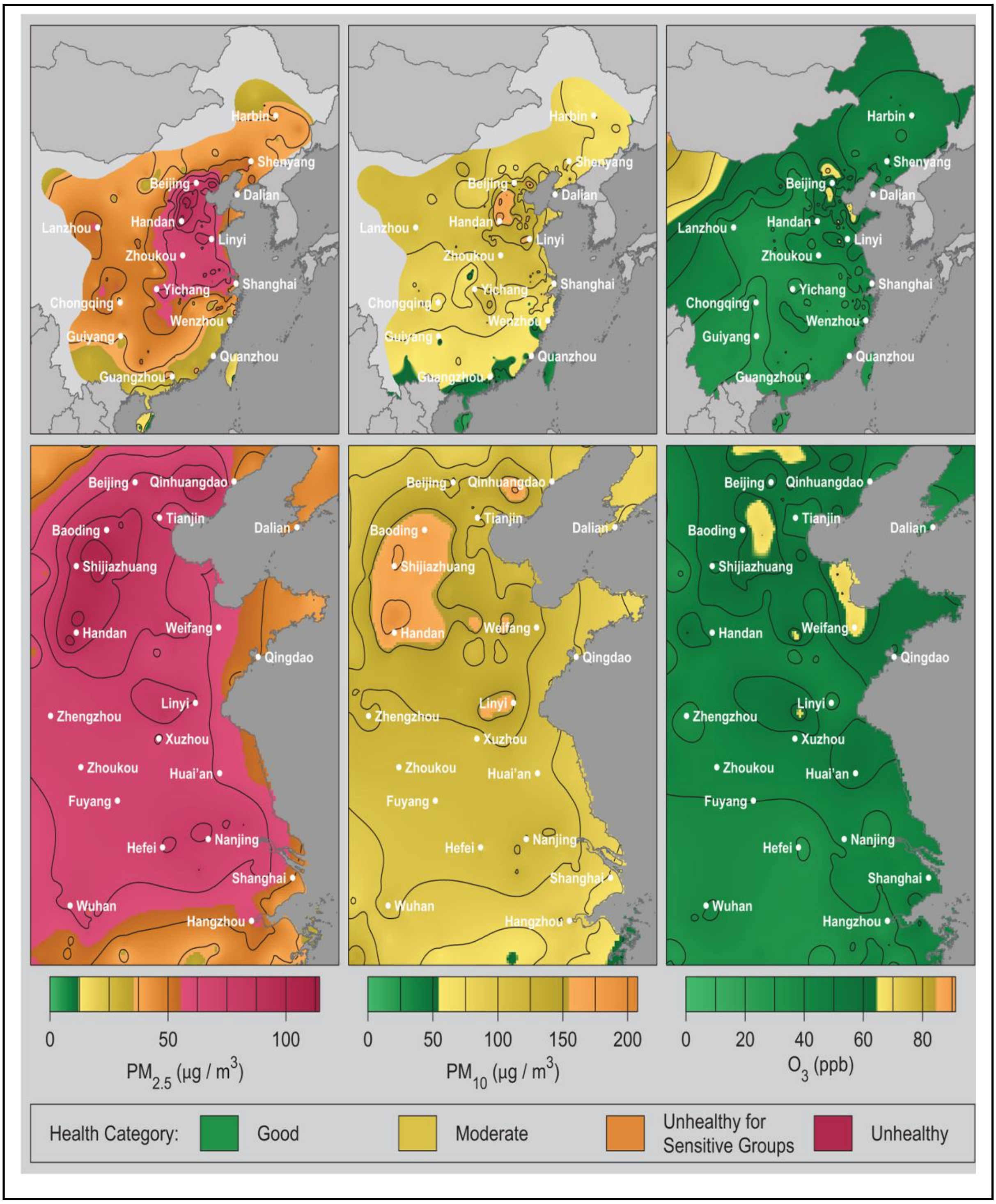

Fig 6: Maps of average pollutant concentration for PM2.5, PM10, and O_3 for eastern China (top row) and the Beijing to Shanghai corridor (bottom row) (Source: Rohde and Muller 2015)

3.3. Sources of air pollution in China

China's air pollution rises from several root causes. While there are 2 parts to air pollution as outdoor and indoor, this paper mainly focuses on the outdoor (ambient air pollution). Here, in this section, the major sources of ambient air pollution in China are discussed.

Among the many sources of outdoor air pollution in China, coal burning, transportation, and industrial emissions take a prime position. Out of these, coal burning contributes to the highest number of air pollution-caused deaths in China with a record of 366,000 deaths in 2013 (Wong 2016). China being the world's largest coal consumer (Hausfather 2020), coal is their main power source to fuel most of the power plants, industries, mines, and other manufactures contributing 69% of the power generation of the country (IEA 2020). Combustion of coal releases carbon dioxide, sulfur dioxide, nitrogen oxides, ozone, soot, dust, and particulate matter into the atmosphere, making the air impure to breathe.

The second highest contributor to outdoor air pollution in China is the transportation sector. According to Rohde and Muller (2015), NO_2 and SO_2 emissions data suggest that transportation fuels contribute to 15-25% of urban air pollution. China underwent a drastic increase in the GDP and this amplified wealth enabled more people to afford cars; hence a directly proportional increase in air pollution is observed with economic growth. As can be seen from figure 7, although the GDP growth reduced after 2009, vehicle ownership continued to increase, causing more tailpipe emissions. It is estimated that approximately 1200 vehicles are added to the roads in China each day (Ye 2015), while the production and sales of vehicles in China exceeded 20 million units in 2013 (Wu *et al.* 2014). Ye (2015) further states that these vehicles have lower emission standards, causing more pollutants to be emitted into the atmosphere compared to their older versions.

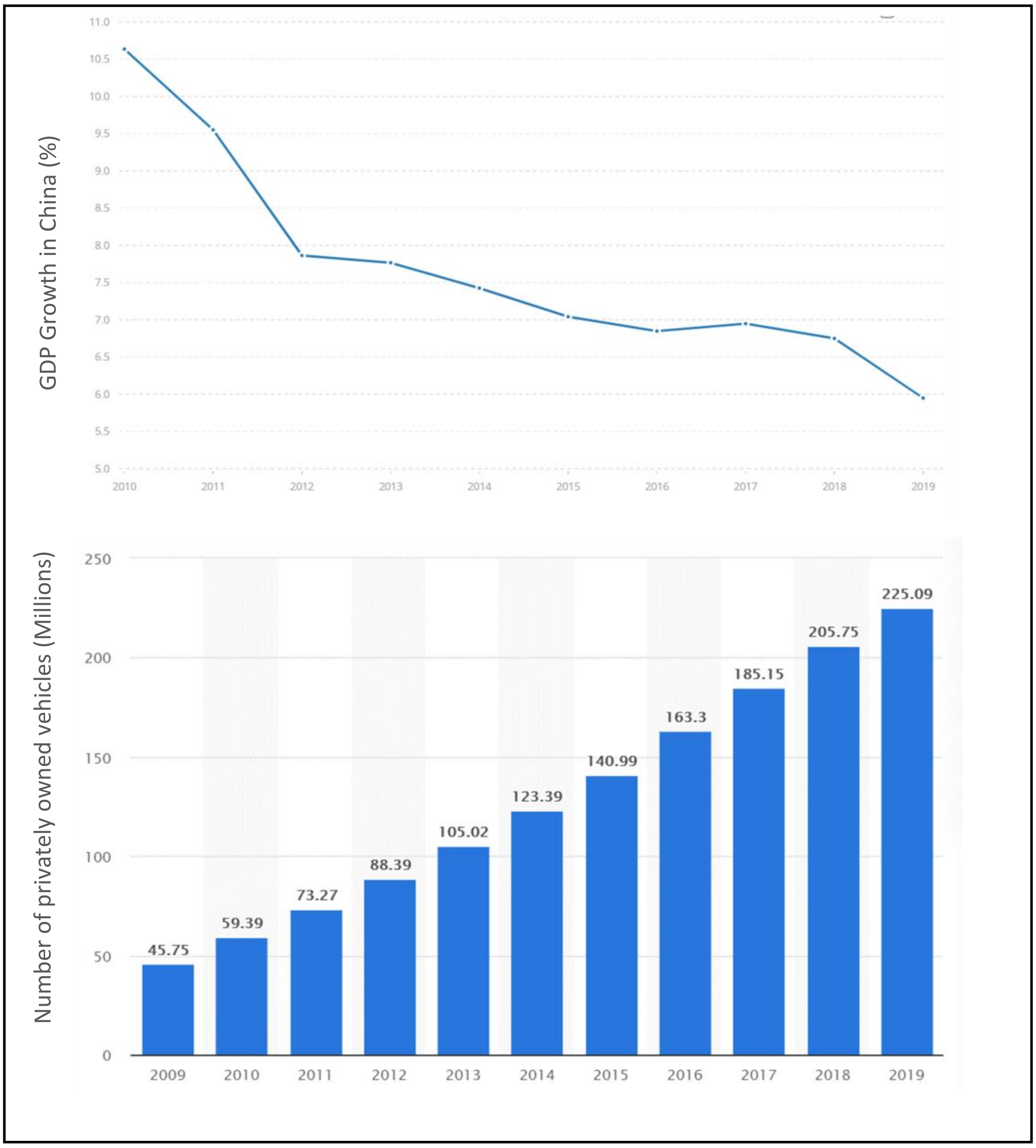

Fig 7: GDP Growth and number of privately owned vehicles in China from 2009 to 2019 (Sources: World Bank 2021b; Statista 2021b)

Metro cities such as Beijing and Shanghai have high levels of traffic congestions in peak hours, which increases the tailpipe emissions by three times than the normal hours (Song 2014). BBC (2016) reported that 50% of the time, the daily air quality of Beijing has been reported to be at an unhealthy level. Traffic congestions not only increase the emissions but also increase the chance of exposure of people to harmful emissions, hence have a direct adverse effect on health as well.

While coal burning, industrial emissions, and motorized vehicles contribute largely to the air pollution in China, the increasing population also is a major cause. Especially in megacities like Beijing, where the population has increased from 11 million to 16 million in 7 years, the pollution is reported to be higher (Ye 2015; Liu and Diamond 2005; Stone 2008). While China is the home to 20% of the world's population, it has increased two-fold during the past century (Liu and Diamond 2005). Although the one-child policy caused China's population growth rate to drop by 1% in recent years, the average household sizes decreased in return, causing an increase of 80 million households in 2000 (Liu *et al*. 2003; Liu and Diamond 2005). Overall, the increased number of households leads to increased power usage and vehicle ownership, which increases the air pollution in the area.

When the population in China increased, a large number of people migrated to urban regions for better life quality. As a result of the opening-up policy and reformations, from 1981 to 2014, China underwent rapid urbanization at a rate of 20.16% (Mou *et al*. 2018). Mou *et al*. (2018) further mention that the urban land area in China increased from 6,720 km^2 in 1981 to 49,900 km^2 in 2014. While there are empirical studies that suggest the urbanization causes a significant reduction in adult mortality rate, under-five mortality, and infant mortality by providing positive health outcomes (Wang 2018), urban regions also contribute to over 78% carbon emissions and a significant portion of airborne pollutants emissions like particulate matter, causing the negative impacts of air pollution to outrank the positive outcomes of urbanization (Liang and Gong 2020). In most urban regions, a large number of people are densely packed in a smaller land area, causing high emissions to cause air pollution and also increasing their exposure to poor quality air.

Apart from these anthropogenic sources, the regional topography of China also affects elevated air pollution. For example, the city of Beijing is surrounded by mountains and it causes high relative humidity, low boundary layer heights, and southerly winds, that ensure the pollutants remain trapped within the limits of the city (Ye 2015; Zhang *et al.* 2018). There are several factories in the outskirts of Beijing and nearby cities, and their inefficient technology and high emission rates contribute heavily to air pollution (Ye 2015; Liu and Diamond 2005). In the spring and summer seasons, the temperature and humidity levels increase, and high winds facilitate the spread of pollutants from heavily industrialized southern regions to cities (Stone 2008).

3.4. Disease and death burden due to air pollution

Air pollution occurs when the air contains toxic chemicals and/or compounds that pose health risks, and detriment the quality of life, by adversely affecting morbidity, disability-adjusted life years (DALYs), and life expectancy (Babatola 2018; Owusu and Sarkodie 2020). Ambient air pollution leads the way to several short-term, chronic, and even fatal non-communicable diseases (NCDs), and children and the aged population are affected the most by it (Owusu and Sarkodie 2020; Liu and Zhang 2009). Combustion of fuel from vehicles, power sources, heating, and indoor sources like cooking, emits airborne fine particles consisting of mutagenic and carcinogenic substances such as polycyclic aromatic hydrocarbons (PAH), nitrated PAH, and nitro-lactones (Lewtas 2007). These chemicals not only cause cancers but also leads to DNA damage that causes reproductive and cardiovascular effects (Lewtas 2007).

Major non-communicable diseases associated with air pollution are ischemic heart disease, stroke, chronic obstructive pulmonary disease (COPD), and lung cancer (WHO 2019). Out of the total number of deaths from those NCDs, a significant portion is attributable to household and ambient air pollution. Figure 8 shows the data related to the deaths from NCDs associated with major environmental risks in 2012, and it is clear that air pollution is the number one cause of those diseases (WHO 2019). Moreover, as can be seen in figure 8, the majority of those deaths are in South-East Asia and Western Pacific region.

Disease and their risk factors	Africa	Americas	Eastern Mediterranean	Europe	South-East Asia	Western Pacific	**World[c]**
Ischaemic heart disease							
Household air pollution [a]	96 000	30 000	51 000	56 000	495 000	366 000	1 095 000
Ambient air pollution [b]	51 000	73 000	91 000	263 000	304 000	297 000	1 079 000
Second-hand tobacco smoke	16 000	27 000	54 000	64 000	113 000	110 000	384 000
Lead	9000	30 000	44 000	56 000	67 000	32 000	239 000
Stroke							
Household air pollution	162 000	27 000	49 000	43 000	498 000	679 000	1 458 000
Ambient air pollution	75 000	37 000	65 000	139 000	273 000	494 000	1 083 000
Second-hand tobacco smoke	9000	7000	14 000	18 000	48 000	78 000	175 000
Lead	9000	13 000	21 000	28 000	47 000	38 000	155 000
Lung cancer							
Household air pollution	4000	6000	3000	10 000	53 000	195 000	271 000
Ambient air pollution	4000	20 000	10 000	69 000	47 000	251 000	402 000
Second-hand tobacco smoke	1000	1000	1000	2000	3000	21 000	28 000
Occupational risks	11 000	62 000	15 000	85 000	42 000	230 000	445 000
Residential radon	3000	8000	3000	26 000	9000	15 000	64 000
COPD							
Household air pollution	30 000	11 000	25 000	8000	493 000	339 000	906 000
Ambient air pollution	4000	3000	9000	7000	126 000	93 000	242 000
Second-hand tobacco smoke	3000	4000	5000	4000	53 000	44 000	113 000
Occupational risks	16 000	23 000	14 000	12 000	181 000	108 000	353 000

Fig 8: Deaths from main NCDs attributable to environmental risks in 2012 (Source: WHO 2019)

The number of deaths attributable to PM2.5 increased significantly from 4.7% in 1990 to 5.3% in 2013 worldwide and this rising trend in deaths after 2000 is largely driven by China, which has some of the most air-polluted cities in the world (Niu *et al.* 2017). In 2017, China identified PM pollution as the fourth leading risk factor for death and DALYs (Yin *et al.* 2020). Several pieces of literature discuss the impact of air pollution on public health, physical health, mental health, and adult and child mortality, in both short-term and long-term in China's context (Chen *et al.* 2004; Wong *et al.* 2008; Kan *et al.* 2009; Liu et al. 2018). While Liu *et al.* (2018) argue that the impact of air pollution on mental health is unclear, several recent studies show that air pollution has a direct impact on mental health. Weir (2012) states that high levels of air pollution may damage the cognitive abilities of children while increasing the risk of adults having cognitive decline which could potentially lead to depression. Moreover, in several country-specific studies in China, it has been found that the mental health of Chinese adults is "strongly and robustly" associated with increased PM2.5 levels (Xue *et al.* 2019). Ali and Khoja (2019) further quote a 2018 study in China where empirical data shows that every

1 standard deviation increase in PM over an average PM2.5 concentration causes an increase of 6.67% in the likelihood of having mental illnesses such as depression.

The number of deaths attributable to air pollution in China is growing at an alarming rate. In 2017, 1.24 million deaths were caused by air pollution, out of which, 712,002 to 990,271 were from outdoor PM2.5 pollution, 67,650 to 286,229 from ambient ozone pollution, and 209,882 to 346,561 from solid fuels used indoors (Yin *et al.* 2020). The same study estimates that in 2017, the age-standardized DALY rate attributable to air pollution in China was 1513·1 per 100,000 while stating that it is significantly higher in males than females (Yin *et al.* 2020). Moreover, Liu *et al.* (2015) study use estimated results of the Global Burden of Diseases Study of 2010 to show that the disease burden attributable to PM pollution increased by over 33% from 1990 to 2010. Song *et al.* (2017) estimate that in 2015, 40.3% of stroke-related deaths, 26.8% of ischemic heart disease-related deaths, 23.9% of lung cancer-related deaths, and 18.7% of COPD-related deaths were caused by PM2.5 pollution. In 2010, the PM2.5 pollution contributed to "35.0% of stroke, 29.9% of ischemic heart disease, 27.2% of lung cancer, and 21.0% of chronic obstructive pulmonary disease" among people over 25 years old in China (Liu *et al.* 2015), and the numbers have been in an increasing trend from 2010 to 2015. Song *et al.* (2017) applied an integrated exposure-response model to estimate the relative risks of disease-specific mortality in China and found out that 15.5% of all-cause deaths were caused by PM2.5 pollution in 2015. These numbers paint a clear image of how bad the air pollution, especially the PM2.5 pollution situation in China is.

3.5. Air pollution prevention policies in China: History and evolution

As a country with a growing economy and population, China has several environmental concerns to think about. Being called the 'manufacturing center of the world', China rose in the ranks of global economies by providing low-cost, good-quality consumer products to the global markets (Chunmei and Zhaolan 2010). However, their economic model being very labor-intensive and resource-intensive, the manufacturing processes leave a lot of pollutants behind, causing several types of environmental risk factors to emerge (Chunmei and Zhaolan 2010).

Jin *et al.* (2016) categorize the environmental policy system in China into five categories as; 1). environmental laws, rules, and standards, 2). national plans in the FYP framework, 3). ten specific regulatory measures, 4). special actions outside the FYP framework, and 5). environment-related state ideologies. This paper majorly focuses on the five-year plan framework, but the overall air pollution prevention policy structures are briefly touched upon.

As a result of heavy industrialization, increased use of motor vehicles, and population growth among many other causes, air pollution has increased, making it one of China's main priorities. While China recognizes air pollution as a major risk factor and has declared war on it, regulating air pollution is a complex issue, as it involves many different pollutant sources, and many institutions across sectors like energy, environment, economic policy, public health, and natural resources (Florig *et al.* 2001; Lu *et al.* 2020). China's central government has been addressing the issue of air pollution since the late 1970s, enacting the Environmental Protection Law in 1979 and many more laws, regulations, and mitigation programs till now (Li and Chen 2017; Hernandez and Renard 2015). In 1987, a more air pollution targeted policy framework named 'Air Pollution Prevention and Control Law' was implemented, which was followed by the 'National Ambient Air Quality Standards' in 1996 and the 'Emission Standards of Air Pollutants for Thermal Power Plants' in 2003 (Chan and Yao 2008; Hernandez and Renard 2015). Table 3 shows a timeline of key legislation and plans on environmental protection and air pollution control in China.

Table 3: Timeline of key legislation and plans for environmental protection and air pollution in China (Data source: Yang 2020)

Year	Law or Action	Brief Description
1979	Establishment of the Trial Environmental Protection Law	Create a legal system for environmental protection
1987	Establishment of the Air Pollution Prevention and Control Law	Introduce control of soot emission from factories in the designated area
1989	Enactment of the Environmental Protection Law	Mark the official start of environmental legislative and institutional building
1998	Establishment of Acid Rain Control Areas & SO_2 Control Area	Introduce measures targeting SO_2 emissions and acid rain caused by coal-burning activities in the designated area
2000	Amendment of the Air Pollution Prevention and Control Law	Focus on SO_2 and PM10 pollution from coal-burning in urban areas
2002	Establishment of the Environmental Impact Assessment Law (EIA)	A first step away from the "pollute first, clean up later" development model to address pollution from the sources
2008	Establishment of the Ministry of Environmental Protection (MEP)	Upgrade status of the State Administration of Environmental Protection to a ministry
2010	Establishment of the Ozone Depleting Substance (ODS) Regulation	Control consumption, trade, and production of ODS
2013	Action Plan for Air Pollution Prevention and Control	Set a "National 10 Measures" road map for air pollution control over 2013-18, including PM2.5 targets for 3-city clusters of Beijing-Tianjin-Hebei and the Yangtze and Pearl River Deltas
2015	Amendment of the Environmental Protection Law	Strengthen penalties for non-compliance, introduce mandatory EIAs for policies & plans, formalize public interest environmental litigation
2016	2^{nd} Amendment of the Air Pollution Prevention & Control Law	Introduce regional co-operation mechanisms and early warning alert systems, place limits on levels of polluting compounds in vehicle fuels, and enhance local government accountability
2016	Amendment of the Environmental Impact Assessment Law	Enhance effectiveness & integrity of EIA for planning & facilities
2018	Establishment of the Ministry of Ecology and Environment	Restructuring of the MEP to give it broader remits
2018	Establishment of the Environmental Protection Tax Law	Replace the decades-old pollution fee system
2018	Action Plan for Winning the Blue Sky War (2018-20)	Considered as the second phase of the 2013 Action Plan, cover more cities including the rustbelt along

In recent decades, air pollution has become a politically prioritized concern of the Chinese government and their air pollution policies have gone through exceptional changes (Jin *et al.* 2016). Compared to the early times, the country has begun to address the air pollution problem head-on through a broad range of policy areas including energy conservation, industrial policies, and technology promotion (Lin and Elder 2014). Although the air pollution control policies made their way into the five-year plans only during the early 11th FYP (Jin *et al.* 2016), those targets and policies got strengthened during the first half of the 12th FYP (Lin and Elder 2014). As depicted in figure 9, Jin *et al.* (2016) categorize China's air pollution control policies into 3 major stages based on the timeline.

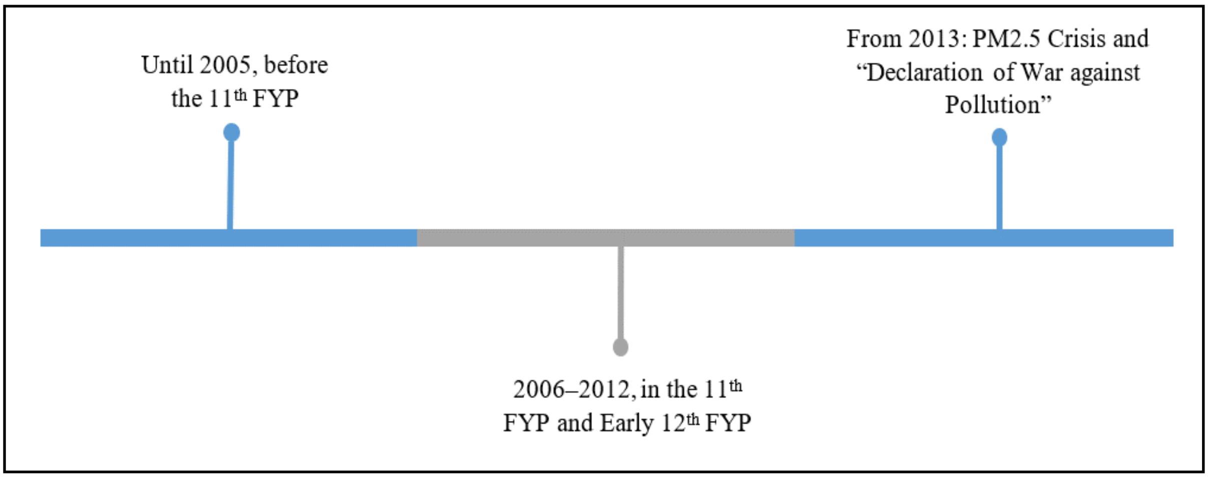

Fig 9: Three Stages of Air Pollution Control Policies in China (Data source: Jin et al 2016)

3.5.1. Stage 1: Until 2005, before the 11th Five-Year Plan

Before 1979, China's policy frameworks mainly focused on economic development, majorly on heavy industries, and pollution was considered a 'non-issue' (Li and Chen 2017). Li and Chen (2017) quote Ross (1988) and emphasize the fact that China's narrow-focused policy structures and political isolation from the western world caused China to miss out on the rising concerns of global pollution in the 1960s. Moreover, the Chinese population back then had low-income levels and poor living conditions; hence the public's focus was on fulfilling basic needs like food and clothes, and environmental protection was seemingly and relatively not a priority (Li and Chen 2017). During the 1970s and 1980s, air pollution control in China was done primarily at the local level, targeting dust emissions (Lu *et al.* 2020). As a result of extensive SO_2 and NO_x emissions by combustion of fossil fuels and others, in the 1980s, acid rain became one of the major serious air pollution issues for China that the government could no longer turn a blind eye to (Lu *et al.* 2020). Chinese policymakers did not figure out the correlation between PM pollution and acid rain immediately, but after following Harvard's Six-Cities Study of USA which led to the establishment of the first PM2.5 National Ambient Air Quality Standards (NAAQS) by the US Environmental Protection Agency, China's researchers started to measure and analyze the ambient PM2.5 levels and chemical compositions (Lu *et al.* 2020; Schwartz 2012; EPA 2020), to figure out its impact on the acid rain.

Due to this lack of understanding about the matter, air pollution was not an urgent social problem before 2005 (Jin *et al.* 2016). According to a satellite-based study on the BTH region (Beijing Municipality, Tianjin municipality, and Hebei province) in China, the most serious PM2.5 pollution with significant deterioration occurred between 2004 and 2007 (Lu *et al.* 2020; Ma *et al.* 2015). Although the government had some positive regulations and jurisdiction-based management schemes in place, the limitations such as lack of general principles of environmental rights and interests, inefficiency in execution, lack of regional coordination, absence of monitoring capacity as a basic regulatory element, and challenged credibility of the law and regulations prevented those frameworks from reaching full potential during that time (Jin *et al.* 2016).

3.5.2. Stage 2: 2006–2012, in the 11th FYP and Early 12th FYP

According to Jin *et al.* (2016), the second stage of air pollution control policies is during the 11th FYP and early 12th FYP, i.e., between 2006 and 2012. Although China had several air pollution control policies before 2005 (Chan and Yao 2008; Hernandez and Renard 2015), since air pollution was not an urgent issue in the country, they were not very effective (Jin *et al.* 2016; Lu *et al.* 2020; Ma *et al.* 2015). Moreover, the 9th and 10th FYPs had initiated national total control policies before 2006, but the implementation and results were total failures, due to reasons such as coal-dominated energy mix (Jin *et al.* 2016; Cao *et al.* 2009).

However, the Chinese government took a serious turn when they included air pollution targets into their most significant policy framework; the five-year plans. 11th FYP and early 12th FYP included a few policies specific to air pollution control, naming 'total emission control on SO_2 and Chemical Oxygen Demand (COD)' and the 'energy saving' policy (Jin *et al.* 2016). The national target for SO_2 and COD was set to reduce 10% from the base level of 2005, and for energy saving, a target of 20% reduction of energy consumption per GDP unit compared to the 2005 base level was set, and these targets were extended and carried out in early 12th FYP as well (Jin *et al.* 2016; CAAC 2013). The policy measures to achieve the above-mentioned targets include "1). preferential de-sulfurization electricity price premium, 2). promotion of high-capacity power generators and phasing out small power generators, 3). regional phase-out deadlines and regional approval restrictions and increased investment in environmental protection, and 4). implemented projects' emission reduction, management and emissions reduction" (CAAC 2013).

Despite all these targets and efforts, the results after the duration were still insignificant, reports Jin *et al.* (2016). According to several studies, some with spatial and temporal distribution data, China experienced its highest annual PM2.5 emissions in 2006, SO_2 emissions in 2007, and NO_x emissions in 2012 (Lu *et al.* 2020; Zheng *et al.* 2018; Zhang *et al.* 2019). The SO_2 concentrations were 2.5 times higher than the 1990 levels, and NO_x and PM2.5 levels were 4.6 and 1.5 times higher compared to the 1990 levels (Lu *et al.* 2020).

3.5.3. Stage 3: From 2013, the PM2.5 Crisis and "Declaration of War against Pollution"

Compared to the previous 2 stages, stage 3 which is after 2013 can be considered as a stage with significant improvement. Over three decades of rapid economic and population growth in China has put huge pressure on the environment due to elevated pollution, and in return causing adverse effects on public health (Yang 2020). After the frequent heavy smog episode from 2010 to 2013, a wave of public displeasure was triggered which forced the government to take action against air pollution, and as a result, in March 2014, China's Prime Minister Li Keqiang declared war against air pollution (Yang 2020; Saikawa 2019). The drastic measures under the 'war on air pollution' included shutting down dirty factories, accelerating the shift to cleaner energy sources, restricting traffic in urban areas, and rebuilding the environmental governance system (Yang 2020). Although the actions were taken to address the air pollution in both the 11th and 12th FYPs, there were no PM2.5 specific targets in those five-year plans until the 13th FYP (Qin 2016). After the infamous 'PM2.5 crisis' in January and February 2013 where several cities and provinces in China were covered by severe haze, the Chinese government initiated a series of action plans to mitigate the issue and also included specific PM2.5 targets in the 13th five-year plan (Jin *et al.* 2016).

On top of the policy targets on PM2.5 pollution control in the 13th FYP, China recently launched a series of movements; short-term movements named 'Ten Actions' in 2013 and 'blue sky defense battle' from 2018 to 2020, and long-term movements named 'the action plan' in late-2013 and 'beautiful China' movement (Jin *et al.* 2016; Lu *et al.* 2020). The 'beautiful China' movement has set targets for 2035 to maintain the annual PM2.5 concentration below 35 μgm^{-3}, the WHO recommended level for PM2.5 (Lu *et al.* 2020). It is noted that since 2013, China has come down hard on pollution control and their environmental legislation has picked up speed, and as also depicted in table 3, this is evident by the fact that about half of all new or revised laws and regulations from 2013 to 2020 occurred in the environmental sector (Yang

2020). The clean air goals for China are set to realize by those revised and added legislations and also measures such as adjustment of industrial structure, decarbonization of energy systems, and implementation of stringent end-of-pipe control measures (Lu et al. 2020).

In conclusion, China is one of the largest countries in the world in terms of both land area and population, and also one of the most powerful in terms of politics and economy as well, making China's a heavily-polluted atmosphere affects the rest of the world negatively, making it a global issue rather than a local one. The former Secretary of State for the United States, Michael R. Pompeo blames China's ruling party for the air and environmental pollution issue, stating in his Twitter account, "too much of the Chinese Communist Party's economy is built on willful disregard for air, land, and water quality and the Chinese people and the world deserve better" (U.S. Embassy in Georgia 2020). The political leaders of the rest of the world see this as a political problem that needs political and diplomatic handling, rather than an environmental issue. It is necessary to understand, solving such a massive problem involves holistic policies that integrate all aspects of the issue; environmental, social, political, and economic, that would initiate interdisciplinary actions against it.

4.0. Discussion

Since the Maoist era, China's government develops a master plan every five years to tackle socio-economic issues in the country and to initiate holistic development in the economic and social aspects (Lin and Elder 2013). These plans are called 'Five-Year plans', or in short, FYP's and they outline the main national development objectives. In general, five-year plans don't start as hard-and-fast rules. Instead, they begin with a master plan that indicates the direction the policies of the next five years should head, and it incorporates many sub-plans for specific aspects. Many FYPs that followed the first five-year plan in 1953 focused on the national development of economic and social aspects of the country. China indeed had significant growth in the economy since the 1970s, especially after implementing the reforms to open the country for international trade. However, it is evident from the increase in anthropogenic environmental pollution in China during the past few decades that this economic growth came with a huge price to pay in the aspect of the environment. Among those environmental problems, air pollution tops the list due to the high number of deaths, diseases, and extremely unhealthy air quality episodes that frequents the Chinese cities.

China initiated several air pollution prevention policies to tackle the issue after it became a concern the government could no longer ignore. According to Lin and Elder (2013), while China's air pollution policies are made of many types of policy measures such as "laws, standards, regulations, and action plans", five-year plans are one of the most important frameworks among them. China's five-year plans did not consider air pollution to be a social concern worthy of political attention until the 11th FYP. Although the 10th FYP had a target to reduce the SO_2 emissions by 10%, the country failed to achieve it by the end of the policy period, and the target was carried to the 11th FYP, with better-structured goals and implementation plans. Moreover, the lessons learned from the 11th FYP helped shape the 12th FYP in regards to air pollution prevention. The 12th FYP consisted of several direct and indirect policy toolboxes to fight air pollution, but targets specific to particulate matter was not recognized until the 13th FYP that was implemented in 2015. The air pollution prevention mechanisms in the 13th FYP were strengthen based on the lessons learned by related targets in the previous FYPs. In the policy documents that are analyzed in this study, air pollution is addressed and underlined in a broad range of areas including energy policy, industrial policy, transportation, urban planning, climate change, and technology.

4.1. 11th FYP: Relevant Chapters and Summary

The 11th five-year plan for national economic and social development in China was implemented in 2006, as a blueprint by the government for the period of 2006 to 2010. In the economic and environmental aspects, the 11th FYP is significantly different compare to the previous plans. While previous plans were instructions-to-be-followed, the 11th FYP was considered more like a strict plan, after the name change from 'Ji hua' (Blueprint) to 'Gui hua' (Strict plan) (Zhang 2006). Moreover, as a result of the private sector dominating the country's economy instead of the state, market forces were supposed to execute the plan as opposed to the government like in previous FYPs (Zhang 2006).

Not only in economic and social development aspects, the 11th FYP is noted as an innovative plan also in environmental aspect. Although the 10th FYP which ended in 2005 had some basic national policies for environmental protection and sustainable development, the goals were not very defined; hence the country was unable to realize all the environmental goals in time. During the 10th FYP, while pollution prevention and ecological protection in respect to protecting people's health was emphasized and were able to make some progress in environmental protection (CGTN 2020), the environment was not the main concern at the time. Moreover, air pollution was not recognized as a serious threat to human health in China in the early decades of five-year plans; hence wasn't included in the five-year plan before 2005. For the first time in a five-year plan, the two major pollution control indicators of sulfur dioxide and chemical oxygen demand were included in the 11th FYP as binding indicators. The tools for air pollution in the 11th FYP included a broad range of measures such as emission standards and limits, mandatory power plant closures, technology mandates, industrial and urban infrastructure restructuring, energy consumption and renewable energy policies, and clean-coal promotion strategies, among others.

Several policy points in the 11th FYP contributed towards air pollution control directly and indirectly in varying magnitudes. The most relevant chapters in the 11th FYP with some kind of an impact on air pollution reduction are chapters 1, 2, and 3 in part 1, chapters 10, 11, 12, and 13 in part 3, chapters 16 and 17 in part 4, and chapters 23 and 24 in part 6. The chapters from the 11th FYP discussed in the upcoming sections of this study are as follows.

- Part 1: Guiding principles and development objective
    - Chapter 1: The critical period of building a well-off society in an all-round way
    - Chapter 2: Implement the scientific concept of development in an all-round way
    - Chapter 3: Major objectives of economic and social development
- Part 3: Push forward industrial structure optimization and upgrading
    - Chapter 10: Accelerate the development of the high-tech industry
    - Chapter 11: Vigorously develop equipment manufacturing industry
    - Chapter 12: Optimize the development of the energy industry
- Part 4: Accelerate the development of the service industry
    - Chapter 16: Widen the productive service industry
    - Chapter 17: Enrich consumption service industry
- Part 6: Construct a resource-efficient and environmentally-friendly society
    - Chapter 23: Protect and remedy natural ecology
    - Chapter 24: Increase environmental protection strength

Chapter 1 in the 11th FYP identifies the existing situation at the time and recognizes the problems that emerged in the 10th FYP. It further discusses the overall achievements of the 10th FYP, such as suppressing the unstable factors occurring in economic operation, defeating the SARS epidemic situation, facing the major natural disasters, and responding to the new changes following the accession to the World Trade Organization in 2001. The 11th FYP recognizes these achievements, some of which were achieved ahead of the schedule, as a solid foundation laid for the development in the 11th FYP period.

Chapter 2 of the 11th FYP mainly focuses on achieving holistic and sustainable development in economic and social aspects. This chapter emphasizes the importance of scientific development and focuses on changing and innovating the development concept and model by keeping the 'human' as fundamentality, to improve the development quality. The major principles outlined in chapter 2 includes accelerating the change of economic growth mode to be more ecologically friendly and sustainable, incorporating science into education to promote independent innovation ability, promoting coordinated development between urban and rural areas, strengthening the construction of a harmonious society by paying attention to the development of economy and society as a whole, and deepening and reforming the opening of China to the outside world. Chapter 2 briefly brush upon the environmental aspect, by incorporating resource conservation and environmental protection into economic development strategies. While that as an overarching goal could consider contributing towards air pollution prevention indirectly by promoting coordination between population, environment, and economy, there is no clear mention of air pollution control in chapter 2.

Chapter 3 of the 11th FYP outlines the main objectives of economic and social development for the duration of 2006 to 2010 in China. The objectives under this chapter focus on a range of areas including economy, infrastructure, energy, regional development, and public service. The major objectives such as the stable operation of a macroeconomy through the realization of additional urban job opportunities, optimization and upgrade of industrial structures to increase the added value to the service industry, enhancing the independent innovation ability, reduction of energy and water consumption, increasing the efficiency of resource utilization, coordinated development of urban and rural regions, reinforcing the public service sector, enhancing the sustainable development, and improving the people's living standards are prominently emphasized in chapter 3 as significant to build a well-off society holistically. This chapter outlines environmental protection as a significant goal under sustainable development and promises to achieve a forest coverage of 20%, a reduction of total discharge quantity of major pollutants by 10%, and to control greenhouse gas emissions notably as well. While this chapter doesn't mention or recognize air pollution as a concern directly, some of the goals such as increase of urban employment, restructuring of industries, and reduction of energy consumption indirectly impact the air pollution both positively and negatively in different magnitudes.

Part 3 of the 11th FYP focuses on optimization and upgrading of industrial structures and consists of 4 air pollution-related chapters; chapters 10, 11, and 12. Chapter 10 has 4 sub-sections that outlines the path to accelerate the development of the high-tech industry by promoting the electronic information manufacturing industry, fostering bioindustry, boosting airspace industry, and developing new material industries like nanometer material, composite material, and high-performance structural material to enhance environmental protection and energy conservation. Air pollution prevention is indirectly incorporated into this chapter by emphasizing environmental protection and energy source remodification using China-specific biological resources for sectors like industries and energy.

Chapter 11 of the 11th FYP consists of 3 sections that touch on the development of the equipment manufacturing industry by working to improve technical equipment, generate high-efficiency clean power, reinforce independent innovation in the automobile industry, and enlarge the strength of the shipbuilding industry. This chapter, however, contributes towards air pollution reduction and prevention to a very limited magnitude, by targeting to improve high-efficiency clean power generation, which would, in turn, reduce the percentage of power generated by coal.

Among the chapters in the 11th FYP, chapter 12 contributes to air pollution reduction to a considerably high magnitude. This chapter is about optimizing and developing the energy industry to become cleaner and more sustainable. The objectives such as developing non-coal renewable power sources like thermal, hydro, natural gas, geothermal, solar, and ocean energy, while pushing forward the power generation with clean coal, directly contribute to the reduction of air pollution.

Section 1 of chapter 12 focuses on the orderly development of coal by strengthening the coal exploration and enhancing coal recovery, which could potentially be a negative impact on air pollution by causing it to increase. However, the policies emphasize measures such as improving clean coal production and utilization and spreading technologies for high-efficiency clean combustion. Although this chapter has direct ties with air pollution reduction, the text neither mentions the terms ‘air pollution’ explicitly nor recognizes air pollution as a concern. Several sections under different chapters consist of targets and objectives that positively and negatively impact air pollution, either directly or indirectly, but there are little to no places that mention air pollution explicitly.

Chapter 16 and 17 of part 4 of the 11th FYP target the development of the productive service industry and consumption service industry. Only section 1 of chapter 16 and section 4 of chapter 17 has any kind of remote relation to the air pollution prevention goal. The above-mentioned chapters prioritize the development of the traffic transport industry strengthening the town's public utility and public transport. The transportation sector is the second-largest source of air pollution in China (See Chapter 3 of this study for elated data and more information) contributing to about 15-25% of urban air pollution. Chapter 16 and 17 outlines the objectives to improve the road network, accelerate the development of rail network, apply information technology to promote transport system management, develop public transit system, and popularize the intelligent traffic transport system to construct a convenient, unobstructed, high-efficiency, and safe integrated transport system while minimizing the traffic in the densely populated urban regions of China. Realizing these targets could greatly help prevent and reduce air pollution in urban China.

Part 6 of the 11th FYP mainly targeted constructing a resource-efficient and environmentally friendly society. Chapter 23 and 24 in this part are significant among all the chapters that are mentioned above. This section directly works towards strengthening atmospheric pollution prevention and control. While chapter 23 is about increasing the forest cover to reduce the carbon levels and to protect and remedy the natural ecology, chapter 24 focuses on increasing the environmental protection strength by preventing pollution. Section 2 of chapter 24 highlights measures such as accelerating the construction of desulfurizing facilities in the coal-fired power plants, constructing new plants according to strict emission standards, and increasing the treatment of smoke dust, fine particles, and vehicular tail pipe emissions in the urban air, which has a significant direct influence on air pollution control in China's cities. Moreover, the government pledges to implement discharge control, clean production audits, environmental labeling schemes, and environmental certification schemes for better control of the emissions. These 2 chapters are the main ones with a direct impact on and recognition of air pollution in the 11th FYP.

4.2. 12th FYP: Relevant Chapters and Summary

The 12th Five-Year Plan for economic and social development in China was a master plan that covers the duration of 2011 to 2015, and it was issued in March 2011 by the Chinese People's Political Consultative Conference and the National People's Congress (Lin and Elder 2014). Compared to previous FYPs, the 12th FYP concentrates on quality rather than the rate of growth. This plan focuses on several key themes like rebalancing the economy, improving the social inequality situation, and protecting the environment. It is a major advancement from previous five-year plans that this one has recognized environmental protection as a key theme.

In terms of environmental protection, this plan has prioritized air pollution as a major environmental issue and includes several measures to address the issue from different approaches and dimensions.

The 12^{th} five-year plan had several goals set regarding air pollution control such as emission reductions for SO_2 and NO_x, natural resource conservation, and energy conservation. As a result of rapid industrialization, a large energy-intensive manufacturing sector, and reliance on coal as the major power source, China has been facing severe environmental degradation, even at the time of the 12^{th} FYP. The major themes of the 12^{th} FYP are intended to counter the negative trend in environmental degradation in China.

The 12^{th} five-year plan consists of several policies that directly and indirectly affected air pollution control in different ways. The 12^{th} FYP is more of an outline for what the development of the duration should look like, and it puts down the foundation for other broader and holistic policies to be formed and implemented. The chapters in the 12^{th} FYP that are most related to air pollution are chapters 2, 3, and 4 in part 1, chapters 10 and 11 in part 3, chapter 20 in part 5, and chapters 21 and 24 in part 6. The chapters from the 12^{th} FYP discussed in the upcoming sections of this study are as follows.

- Part 1: Transforming growth pattern, create a new scenario for scientific development
  - Chapter 2: Guiding principles
  - Chapter 3: Main targets
  - Chapter 4: Policy direction
- Part 3: Transformation and upgrading, enhancing the competitiveness of industrial core
  - Chapter 10: Foster and develop strategic emerging sectors
  - Chapter 11: Accelerate the reform of energy production and utilization mode
- Part 5: Optimizing the structure, accelerating the coordinated regional development and sound urbanization development
  - Chapter 20: Actively and steadily promote urbanization
- Part 6: Green development, energy conservation, and environmentally friendly society
  - Chapter 21: Actively cope with global climate change

- Chapter 24: Intensify environmental protection

Part 1 of the 12th FYP is mainly about the direction and general overarching targets of the policy document. Chapter 1 outlines the pathway to transform the economic growth mode based on a scientific theme, to ensure sustainable economic development throughout the country. It is emphasized that the "fundamental end" of economic transformation is to improve people's lives via different measures like improving the welfare system, job creation, and improving equal access to public service. While economic and social development seems to be a major concern, the chapter points out the importance of building an environmentally friendly and resource-saving society where energy conservation, GHG emission reduction, and active tackling of climate change are considered instrumental. Moreover, chapter 2 pledges to develop low-carbon technologies to reduce carbon emissions as well. While this chapter doesn't mention air pollution as a concern, many of the targets that are mentioned above could greatly help reducing air pollution.

Chapter 3 focuses on the main targets of the plan, and among them, resource conservation and environmental protection take a prime position. The targets such as increasing non-fossil fuel resources up to 11.4% of primary energy consumption, decreasing energy consumption per unit of GDP by 16%, and decreasing CO_2 emissions per unit of GDP by 17% have a great positive impact on the prevention and control of air pollution by CO_2. Moreover, the third chapter in the 12th FYP specifically pledges to make significant reductions in the total emissions of major pollutants such as COD, SO_2, and NO_x. Those targets were set to achieve by decreasing Chemical Oxygen Demand (COD) and SO_2 emissions by 8%, and ammonia and nitrogen oxide by 10%, during the five years.

Chapter 4 describes the policy direction which states clear-cut goals such as expanding domestic demand, optimizing investment structure, promoting industrialization and urbanization, agricultural modernization, social management, accelerating the growth of urban and rural income, and accelerating the coordinated and interactive regional development, that navigates the policies towards a major economic and social development. The target to promote industrialization and urbanization, if let out of hand, could negatively impact the air quality situation and cause an increase in air pollution due to high emissions. However, chapter 4 also pledges to improve the incentive mechanism for emission reduction, which would contribute towards emission reduction immensely.

Part 3 of the 12th FYP is mainly about emerging industries and technologies. While this sector seemingly has no connection with the air pollution issue at hand, it is important to understand that, revamping the industrial sector to use more renewable energy sources instead of coal can be a major air pollution reduction measure. Chapter 10 of this part emphasizes the importance of developing new energetically strategic, energy-saving, and environmentally-friendly industries such as information technology, biology, high-end equipment manufacturing, new materials, new-energy automobile, and new energy sources. Moreover, the new-energy industry goal targets to promote the development of renewable energy sources like solar, photovoltaic, photo-thermal, wind, and biomass. Similarly, under the new-automobile industry goal, the development of plug-in hybrid electric vehicles, pure electric vehicles, and fuel-cell automobile technologies is recognized as significant. Tail-pipe emissions are one of the largest contributors to air pollution in China, and by reverting the carbon-based fuel vehicles to hybrid or electric, the emissions could be cut down by a significant portion.

Chapter 11 of part 3 narrows down the reformation of energy production targets even more. While this chapter pledges to develop renewable sources like hydropower, nuclear power, solar energy, biomass energy, and geothermal energy to promote the development of a diversified clean energy mix, it also has targets to improve energy production from coal. Although this could be perceived as a negative impacting target on air pollution, it is important to improve coal extraction to minimize occupational casualties, and to ensure employees' safety. Chapter 11 has mentioned targets such as developing safe and efficient coal mines and large coal enterprise groups, promoting the integration of the coal resources, merging and recognizing coal mine enterprises and promoting industrialization. While it is apparent that these targets could possibly contribute towards increasing air pollution, it is necessary to understand that, compared to previous five-year plans, the 12th FYP is aiming to gradually and slowly move away from the high-emission energy generation methods and industries.

Part 5 of the 12th FYP mainly focuses on the urban and regional development within China. Chapter 20 has several sections with goals that are targeting to transform agricultural population to urban population, in order to promote urbanization. Although urbanization could be a triggering factor to elevate air pollution due to the increase of population and traffic, some targets focus on population management, so it supposedly balances out. While the chapter continues to explain the targets to increase urbanization, some sections outline targets such as defining the borders of the city, restructuring the urban plan, and enhancing the population density, to prevent and cure the "city disease". In short, chapter 20 focuses on increasing the urban population, which could increase air pollution, while improving the urban structure, which could contribute towards reducing air pollution. Although the two themes of chapter 20 are seemingly contradictory, having such an integrated approach is necessary to reduce the negative impacts of urban development.

In the 12th FYP, part 6 contains the chapters that are directly connected to air pollution. Chapter 21 of part 6 focuses on tackling global climate change actively, and one of its main units is controlling greenhouse gas emissions. Major targets to fight climate change include reduction of energy consumption intensity and reduction of carbon dioxide emissions, and the policymakers anticipate that these kinds of massive reductions could reasonably restrict energy consumption, and decrease the growth of industries of high-energy consumption while increasing energy efficiency. Moreover, the targets to reduce air pollution include revising energy consumption structures, increasing the use of non-fossil energy resources, increasing the forest cover, volume, and carbon sequestration, accelerating low carbon application and research, and establishing a carbon emission trading market as well. Another important goal under this plan is to establish and improve the statistical monitoring system of GHG emissions, energy savings, and emission reductions, and it signifies the importance of monitoring the situation and gathering data for pollution control. Chapter 24 of part 6 further emphasizes the overall commitment of the 12th FYP to limit air pollution through emission reduction, strict control of pollutant discharge, and implementation and supervision of emission standards.

4.3. 13th FYP: Relevant Chapters and Summary

The 13th five-year plan was the most recent, completed five-year plan in China. It was initiated in March 2016, for the period of 2016 to 2020, and it acted as the central government's blueprint for China's long-term social and economic policies. This Master plan was created around five major themes; innovation, coordinated development, green growth, openness, and inclusive growth (Koleski 2017). Although economic growth is at the core of the 13th FYP, environmental protection has graduated from a sub-theme to a major theme. By the time of implementation, the Chinese government has left its "growth at any cost" mindset, and focused on attempting to clean up the severe environmental degradation. This five-year plan also has instrumental air pollution control targets which were built on the foundation laid by the 11th and 12th FYPs. Among all the FYPs implemented before, this is the first five-year plan that included specific targets to reduce PM2.5 in the air. Through 13th FYP, China has taken an integrated approach towards tackling air pollution and climate change, while strongly focusing on economic growth and livelihood improvement.

The national 13th five-year plan of China consists of several chapters that contain targets that contribute towards air pollution control positively or negatively to various magnitudes. Some of the targets directly address the air pollution issue, while some others indirectly impact air pollution. The most relevant chapters in the 13th FYP with a connection to air pollution prevention and control are chapters 29 and 30 in part 7, chapter 38 in part 9, and chapters 44, 46, and 48 in part 10. The chapters from the 13th FYP discussed in the upcoming sections of this study are as follows and each chapter consists of several sections that narrow down the targets, even more, to address the issue more holistically.

- Part 7: Modern Infrastructure Networks
    - Chapter 29: Develop Better Modern Comprehensive Transportation Systems
    - Chapter 30: Build a Modern Energy System
- Part 9: Push Development Coordinated between Regions
    - Chapter 38: Promote the Integration of Beijing, Tianjin, and Hebei
- Part 10: Accelerate the Development of Service Industry
    - Chapter 44: Step-up Comprehensive Environmental Governance
    - Chapter 46: Respond to Global Climate Change
    - Chapter 48: Develop Green and Environmentally Friendly Industries

Part 7 of the 13th FYP focuses on the infrastructure network, transport system, and energy system in China. Chapter 29 outlines the importance of efficient, low-carbon, and modern transportation services and provides the plans for the period of the 13th FYP. With the economic growth, vehicle ownership increased significantly, adding a large number of new vehicles to China's road each day, making the transportation sector the second largest contributor to air pollution in the country. Dust and particulate matter emissions from tail-pipes are very high in traffic-congested urban regions like Beijing, and one of the major measures to reduce traffic and the number of vehicles in the urban regions is to improve public transport. Chapter 29 emphasizes measures China was planning to initiate to improve public transportation modes such as rail transit, bus rapid transit, and other mass transportation systems. Moreover, the chapter mentions the plans to encourage the public to use eco-friendly transportation systems to get around, which could largely contribute toward reducing air pollution by limiting tail-pipe emissions. Section 4 of chapter 29 focuses on the efforts to develop low-carbon modes of transportation by taking measures to use resources intensively and economically, promoting energy-efficient transport systems, and developing smart transport modes.

Among the transportation projects highlighted in this chapter increasing capacity around heavily congested sections of expressways in the Beijing-Tianjin-Hebei (BTH) region and Yangtze Economic Belt would help reduce air pollution due to traffic congestions in the BTH region significantly. Moreover, chapter 29 outlines the goals of the Chinese government to ensure smooth traffic flow in urban roads, and busy entrances and exits of outbound highways, which would further help control air pollution to some extent.

Chapter 30 of part 7 is focused on building a modern energy system that is low-carbon, clean, efficient, and safe, which would ensure the energy security of the country. One of the major highlights in this chapter is the pledge to coordinate the development of clean renewable energy sources such as hydropower, wind, photovoltaic, solar thermal, and coastal nuclear. Moreover, the plan outlines the efforts to efficient and clean use of coal for power generation, and also to limit coal resource development according to region, for example; restrictions in the east, limitations in the central and northeast, and optimization in the west of China. Coal is still the main energy source of China and contributed to 58% of the total energy consumption in 2019 (Standaert 2021). The coal and fossil fuel-based thermal power plants of China are the major sources of air pollutants contributing to approximately 0–23%, 16–39%, and 19–51% of anthropogenic particulate matter, SO_2, and NO_x respectively, from 2010 to 2017 (Tang *et al.* 2020). Therefore, it is significantly important to focus on alternative, clean energy sources for power generation, to reduce the percentage of power generation by coal; hence reducing the air pollution by coal-based emissions.

The major energy development projects in chapter 30, that had a direct or indirect impact on air pollution control that was put into work during this five-year time were naming, 1). high-efficiency smart power systems, 2). clean and efficient coal utilization, 3). renewable energy, 4). nuclear power, and 5). unconventional oil and gas. Under these projects, several initiations such as the development of ecologically sound hydroelectric power plants and natural gas peaking power plants, carrying out solar thermal energy demonstration projects, implementing an action plan for energy conservation and emissions reductions in coal-based power generation, upgrading all the coal-fired power plants in the country, limiting the average coal consumption in the power plants, and promoting and developing the nuclear power generation sector were planned to make the energy system in China clean, efficient, and safe.

Beijing-Tianjin-Hebei (BTH) region also known as Jingjinji Metropolitan Region or Jing-Jin-Ji in short is a densely populated economic hub which considered the national economic capital of China. BTH region is a major urban area with high economic activity and traffic congestion, therefore it is a very important region for air pollution control in China. Chapter 38 in part 9 mainly targets to promote the integration of the BTH region, intending to develop a world-class city cluster, leading the development of the surrounding region. One of the main targets under chapter 38 in the 13th FYP is to lower the population density of the main districts of the BTH area, which could significantly contribute to air pollution control in the area. Moreover, section 4 of chapter 39 outlines the targets to reduce the total pollution emissions in the BTH region, coordinate efforts to prevent and control air pollution, implement gasification projects in key areas of heavy air pollution, and reduce the concentration of particulate matter by at least 25%. This is the first time a target specific to the control of particulate matter is outlined in a five-year plan in China.

Chapter 44 in part 10 directly addresses the environmental governance issues and section 1 of this chapter outlines several air-pollution-specific targets. The section highlights the policies such as formulating a plan to ensure air quality standards in the cities are met, enforcing strict obligatory targets to air pollution control, maintaining the cities at and above the prefectural level to achieve a 25% reduction in the number of days with heavy air pollution, and increasing efforts to reduce the PM emissions in key regions. Moreover, the plan includes measures such as establishing a monitoring system to ensure the achievement of environmental protection standards for vehicles, watercraft, and fuel oils, strengthening the monitoring of windblown dust from unpaved roads, and prohibiting open straw burning, which could highly contribute towards the reduction of air pollution in the country.

Section 2 of chapter 44 focuses on the reduction of industrial emissions, which is a major source of air pollution in China. In this section of the 13th FYP, the commitment of the government towards the cause is highlighted through planned actions such as ensuring that all industrial polluters meet emissions standards, improving the existing emission standards, strengthening the monitoring of the industrial pollution sources, and publishing a blacklist of industries that fails to meet the standards. Moreover, strict measures such as relocating, upgrading, or shutting down all the heavily polluting enterprises in the urban districts, conducting a national survey of pollution sources, and reforming the total emissions control system for major pollutants to cover more pollutants are identified to ensure a better emission control. There are targets specific to pollutants such as VOC (Volatile Organic Compounds) where the plan pledges to control the total emissions of VOCs in chief regions to reduce the nationwide emissions levels by 10% by the end of the period in question. Other targets to reduce air pollution in China under chapter 44 include replacing small and medium coal-fired facilities with alternative clean-energy in urban villages and urban-rural fringes, controlling the total nitrogen emissions in the cities, and transforming the chief industries to achieve cleaner production. It is important to emphasize that this 13th FYP is the first plan to recognize air pollution as a serious concern and initiate a significant portion of the plan to the related targets.

Chapter 46 in part 10 is attending towards responding to global climate change by adapting to it while trying to slow down the impacts. One of the major initiatives highlighted in this chapter is to control GHG emissions through a series of measures such as effectively controlling carbon emissions in power, steel, building materials, chemicals, and other major carbon-emitting industries, promoting low-carbon development in key sectors like industry, energy, transport, and construction, demonstrating the establishment of near-zero carbon emission zones, controlling emissions of non-CO_2 greenhouse gases, and expanding the use of low-carbon products and technologies. Moreover, this plan emphasizes improving emission standards by various measures such as promoting the establishment of national carbon emissions trading scheme, implementing systems for carbon emissions reporting, inspection, and verification, managing quota for major carbon emitters, and improving the statistical accounting, performance evaluation, and accountability systems with regards to carbon emission standards. In addition, the Chinese government pledges to support leading development regions in becoming the first to reach their carbon dioxide emissions peak, to promote the reduction of carbon emissions among major industries.

Chapter 48 focuses on the development of green and environmentally-friendly industries, where the development of green service providers and expansion of the use of environmentally friendly products are highlighted. The measures to achieve this target include, improving the environmental credentials management system for enterprises, development of professional services for energy conservation and environmental protection, promoting energy performance contracting, and furthering third-party governance of environmental pollution. Moreover, the government intends to promote the use of mature and applicable technologies for industries, for example, integrating high-efficiency flue gas dust removal, to improve the industries to become more environmentally friendly. These measures could indirectly contribute towards the control of air pollution to various extents.

4.4. Evaluation and Comparison: 11th FYP vs 12th FYP vs 13th FYP

While previous five-year plans (1st FYP to 10th FYP) didn't recognize 'air pollution' as a critical social and public health concern, starting from 11th FYP, air pollution became a point of interest in the five-year plans. 11th FYP contains several policies that affect air pollution prevention and control indirectly via policing the sectors like energy and transportation. Moreover, there is a section in chapter 24 of the 11th FYP that outlines the policies to strengthen atmospheric pollution prevention and control. The major policies under that section target the coal-based energy industry and the transportation sector. This section is the only place in the 11th FYP that recognizes the issues 'air pollution', 'carbon emissions', and 'GHG emissions', and highlights what is the plan to combat it. In contrast, the 12th FYP contains several chapters that are mainly targeted towards environmental protection and climate change combat but have the above-highlighted issues as major points of interest. In addition, several other sections that have policies with an indirect contribution towards air pollution control also recognize and highlight these issues as concerns. 13th FYP on the other hand has more refined and narrowed-down policies that directly contribute to prevention and control of air pollution, compared to 11th and 12th FYPs. The 13th FYP has several targets that specifically aimed to reduce different types of pollutants such as PM, CO_2, SO_2, NO_x, VOC, and others, instead of targeting all air pollutants under the blanket term 'emissions'.

From 11th to 12th to 13th five-year plans, the air pollution targets have improved, narrowed down, and become specific, which is a great achievement in fighting China's 'war on air pollution'. In this section, the precise policies of 3 FYPs are categorized into 4 themes and then into 12 sub-themes, and have analyzed their contribution to the prevention and control of air pollution in China.

4.4.1. Analysis of Themes

Energy Sector

- Energy consumption
- Renewable energy and clean power
- Coal in energy

Industrial Sector

- Emissions, GHG, and pollutant discharge
- Low-carbon technology in industries
- Standards and schemes

Transportation Sector

- Traffic and road network
- Public transport
- Vehicle emissions

Urban Development

- Employment
- Population
- City development

Fig 10: Themes and sub-themes of the air pollution targets in the 11th, 12th, and 13th five-year plans

In this section, the themes and sub-themes of the 11th, 12th, and 13th FYPs are discussed. During the analysis of the 3 five-year plans, 4 common themes where there are 3 sub-themes under each of them were found among the air pollution targets in the plans. The themes and the sub-themes are sorted and categorized clearly in figure 10.

In China, coal being the main source of fuel (Muller *et al.* 2015), the coal-based emissions from power generation and the industries are the number one contributor of air pollution, emitting large levels of particulate matter, CO_2, and SO_2 to the air. Therefore, it is important that a significant amount of the policies in the five-year plans are targeted towards regulating the coal industry. The second major sector that has a great effect on air pollution is the transportation sector, where rising vehicle numbers in the recent decades have caused an uprise of vehicular tail-pipe emissions, especially NO_2 levels (Muller *et al.* 2015). High traffic congestions in mega-cities like Beijing not only increases the levels of emissions but also increases the exposure of the public to the bad air. The 11th, 12th, and 13th five-year plans contain several policies that target to reduce traffic congestions, regulate vehicular emissions, and develop public transport services, which greatly contribute towards reducing the contribution of the transportation sector for air pollution. Apart from these causes, urbanization is another major cause of air pollution, especially in large, dense, and fast-paced metro cities like Beijing and Shanghai. Studies have found that the urban regions have higher concentrations of particulate matter and many other health-damaging pollutants compared to the rural regions (Krzyzanowski *et al.* 2014). In urbanized cities, the dense housing, high traffic congestions, and industries become major sources of air pollution, and the adverse effects become higher if "the pollution control lags behind the city growth" (Krzyzanowski *et al.* 2014). According to the air quality data from the AQICN, many of the Chinese cities are or close to become hubs for air pollution, so the government must include air pollution combat as the main focus in as many as possible policy documents in the country. The major themes and sub-themes I have selected for this study reflect on the above-mentioned issues.

The policies in the 3 FYPs were analyzed using the logic model explained in the methodology section of this paper, presented the analysis in tables 4 to table 15, and discussed the tables in the coming sections.

4.4.2. Energy Sector

4.4.2.1. Energy Consumption

Energy consumption as a sub-theme was seen in some policies in 11th FYP and many in 12th FYP. However, it is not a major focus in the 13th FYP. The policies that are relevant to this sub-category are mentioned in table 4*Table 4* and have been further analyzed according to the chosen logic model. The only policy related to energy consumption in the 11th FYP is the pledge to reduce the energy consumption per unit GDP by 20%. The 11th FYP fails to mention the exact activities or the pathway that should be followed to achieve this target.

In contrast, the 12th FYP has many elaborate policies to reduce and maintain energy consumption. The policy to transform the economic development through scientific development to achieve an environmentally friendly society that saves energy mainly focuses on the research and development of renewable energy sources and identifying and restructuring of environmentally unfriendly sectors to become energy efficient. Moreover, the 12th FYP highlights the policies to improve the incentive mechanism of energy conservation and emissions reduction, which would need inputs such as high-budget and an accurate incentive calculation system. This policy was not present in the 11th FYP and is a new addition to the 12th FYP. Another policy that was added to the 12th FYP, but was absent in the 11th FYP is the target to optimize the energy consumption structure and to make structural adjustments to the industries to save energy and to improve energy efficiency. The main stakeholders in this would be industries, and it is important to note that the 12th FYP has several policies to make major structural adjustments to the country's industries to make them more eco-friendly and less polluting. Although 13th FYP is more advanced with better targets towards this aspect, it does not contain any direct policies aiming towards energy consumption. While there are other targets in the 13th FYP that may impact this sub-theme indirectly, this can be considered a drawback of the 13th FYP compared to the 11th and 12th FYPs.

By realizing the policies under this sub-theme in 11th and 12th FYPs, the long-term outcomes such as lessening the energy consumption in the long run, reducing the emissions by power generation, and minimizing the dependence on coal for power generation, and the short-terms outcomes such as lessening the coal consumption can be achieved. While none of the policies under this sub-theme mentions or recognizes the impact of these policies on air pollution reduction, it can be considered and noted as a major externality of these policies. Although many complicated relations are attached to these 2 issues, it is necessary to highlight that by working to reduce energy consumption, the emissions could be reduced, in turn preventing and reducing air pollution.

Table 4: Policies under the sub-theme 'energy consumption'

<table>
<tr><th>Policies on 11th FYP</th><th>Policies on 12th FYP</th><th>Policies on 13th FYP</th><th>Inputs</th><th>Outcomes</th><th>Activities</th><th>Aims</th><th>Impacts</th><th>Externalities</th></tr>
<tr><td rowspan="2">Energy consumption per unit GDP is reduced by 20%</td><td>Transform economic growth mode via scientific development, to build an environmentally friendly society to save energy and tackle climate change</td><td rowspan="6">N/A</td><td>Budget/ R&D team</td><td rowspan="6">Long-term: Minimize the dependence on coal for power generation/ Increases use of renewable energy

Short-term: Lessen the coal-consumption

Individual: Strict measures for the public to conserve energy, Industries may need to restructure to their optimal energy consumption</td><td rowspan="2">Research and development into renewable energy sources

Identify the sectors that are not environmentally friendly and restructure them better</td><td rowspan="6">Energy conservation

Increased energy efficiency</td><td rowspan="6">Decreased energy demand

Minimized dependence on coal</td><td rowspan="6">Less coal usage - decreased carbon and other GHG emissions

Air pollution reduces and air quality increases</td></tr>
<tr><td>Energy consumption per unit GDP will decrease by 16%</td><td>Industries/ powerplants/ households</td></tr>
<tr><td rowspan="4"></td><td>Improve incentive mechanism of energy conservation and emission reduction</td><td>Budget/an incentive calculation system</td><td>Provide incentives to encourage energy conservation and emission reduction</td></tr>
<tr><td>Optimize energy consumption structure</td><td>Industries/ powerplants/ households</td><td></td></tr>
<tr><td>Structural adjustments to industries to save energy and improve energy efficiency</td><td>Industries</td><td>Restructuring industries</td></tr>
<tr><td>Regulate total energy consumption levels

Reduce the intensity of energy consumption</td><td>Regulators/ inspectors</td><td>Regulate energy consumption</td></tr>
</table>

4.4.2.2. Renewable Energy and Clean Power

Renewable Energy and Clean Power is another major sub-theme that was noticed in policies related to the energy sector in all 3 five-year plans. The policies that are relevant to this sub-category are mentioned in table 5 and have been further analyzed according to the chosen logic model. Out of the 3 plans, the 11th FYP has the most significant set of policies regarding this. Policies such as exerting China-specific biological energy sources, research and development of high-efficiency clean power generation, power transmission and transformation, and optimal development of renewable energy sources are prominent in favor of air pollution reduction. According to He (2015), "Decarbonizing energy mix is the fundamental countermeasure to reduce CO_2 emissions without endangering energy supplies" and a policy that compliments this statement came into play in 12th FYP is the increment of the percentage of non-fossil fuel resources in the primary energy mix to 11.4% by the end of 2010, compared to the 6.8% in 2005 (He 2015). This policy target is further carried on with the aim to increase the proportion of non-fossil fuel in the primary energy mix to 15% by 2020, and to 20% by 2030 (He 2015). This policy is not specified in the 13th FYP, but according to He (2015), China has plans and policies in place to achieve the 20% target by 2030.

11th FYP recognizes the major renewable energy sources like thermal power, natural gas, hydropower, nuclear power, solar energy, geothermal energy, and ocean energy, and signifies the activities that are planned to do in order to develop and promote these energy sources. This policy is improved and carried into the 12th FYP and then to the 13th FYP as well. Compared to the 11th FYP, the 12th FYP has policies to develop biomass energy and photovoltaic power, apart from the above-mentioned energy sources. However, only the 11th FYP mentions and recognizes natural gas as a resource that should be explored the strength of. Natural gas is also a fossil fuel, but compared to coal and oil, it is cleaner, more efficient, and has a CO_2 intensity of energy 40% less than that of coal (He 2015). Therefore, accelerating the exploration strength of natural gas can be considered an important approach to decarbonize the energy system (He 2015). Moving onto hydropower, while all 3 FYPs have mentioned the measures to develop hydropower optimally, only the 13th FYP has signified the importance of working on ecological conservation during hydropower generation. It can be considered a major improvement from the 11th to the 13th FYP. Moreover, the 13th FYP also has a target to exploit tidal power, which was not recognized as a renewable energy source in previous FYPs.

These policies require inputs of high-quality, in-depth research and development, a considerable amount of budget, and intersectoral collaborations. One of the major outcomes of improving the renewable energy sources and concentrating on clean power is minimizing the dependence on coal for power generation. While carbon (Eg: black carbon, CO_2, and CO) is the main pollutant group emitted during coal-based power generation, other pollutants such as particulate matter, dust, SO_2, and NO_x are also emitted in large amounts. One of the main aims of this policy in all 3 FYPs is to reduce the carbon, GHG emissions, and other air pollutants from power generation, and that aligns with the outcomes of the policy; reduction of the proportion of carbon-based fuel used in power generation. Major positive externalities such as lessening the CO_2, SO_2, NO_x, and PM emissions, improving the air quality in the vicinities, and reducing air pollution can be gained by realizing these policies. Therefore, these policies play a main role in the prevention and control of air pollution. However, in my perspective, it is very important to properly and methodically strategize the transition from coal and fossil fuels to non-fossil fuel energy sources, to not compromise the energy supply flow of the country.

Table 5: Policies under the sub-theme 'renewable energy and clean power'

Policies on 11th FYP	Policies on 12th FYP	Policies on 13th FYP	Inputs	Outcomes	Activities	Aims	Impacts	Externalities
Exert China-specific biological energy sources and environmental protection Research and develop high-efficiency clean power generation and power transmission and transformation Optimally develop thermal power, properly develop natural gas power generation, and orderly develop hydropower Actively push forward nuclear power construction, and actively develop and utilize solar E, geothermal E, and ocean E. Accelerate the exploration strength of petroleum and natural gas resources	Non-fossil fuel resources will rise to 11.4% of the primary energy consumption Develop hydropower, nuclear power, wind power, solar energy, biomass energy, geothermal energy Focus on the development of new-generation nuclear energy, wind power, and solar energy, photovoltaic power.	Development of hydropower with ecological conservation Attention to wind, photovoltaic power Provide support for solar thermal energy Focus on building a coastal nuclear power plant belt Accelerate the development of biomass and geothermal energy Actively exploit tidal power	Research Budget Employment	Minimize the dependence on coal for power generation Clean energy production Fewer emissions by coal	Research and development into renewable energy sources	Minimize the coal consumption in power generation	Reduce the carbon and other GHG emissions by coal-based power generation	Lessened emissions of CO_2, SO_2, and PM Air quality improves Air pollution reduces

4.4.2.3. Coal in Energy

Coal contributes to the highest portion of the primary energy mix in China. As coal is an abundant and cheap energy source, China's economic growth benefits from using it as the main source of energy (Tang *et al.* 2015), while the country's air quality suffers immensely. According to the Statistical Communique on National Economic and Social Development of China for 2020, released by the National Bureau of Statistics, 56.8% of China's total energy consumption in 2020 is attributed to coal (Zhou and Liang 2021), and coal-based power generation is a major source of air pollution in China. Considering these factors, the importance of policies that are directed to reduce the coal consumption and emissions from coal-based power generation in the five-year plans should be highlighted. The policies that are relevant to this sub-category are mentioned in table 6*Table 6*.

All three five-year plans contain some policies that can be categorized under this sub-theme. However, not all these policies have a positive effect on the prevention and reduction of air pollution. But as a country, it is necessary to develop existing energy sources to make them more reliable and safer in order to make the energy supply smoother. Therefore, it is to be understood that the coal-related policies with a negative effect on air pollution reduction, would be acting as trade-offs in air pollution reduction.

Clean coal production is a major policy concern in the 11th FYP. In clean coal production, coal by fossil fuel is refined with chemicals to become environmentally friendlier (Mclaughlin 2018). As lucrative as this option looks, there are controversies surrounding clean coal production. After a series of experiments using refined coal, the electric giant, Duke Energy Corp found that their clean coal is failing to deliver its environmental promises (Mclaughlin 2018). Moreover, there have been several ecological hazards due to chemicals used to refine the coal to make them 'clean' (Mclaughlin 2018). In contrast, as shown also by the 11th FYP, China is working on strengthening the clean coal production and utilization, as a technology that improves the environmental performance and efficiency, compared to the current state-of-the-art in coal-fired power plants (Buchan and Cao 2004; Tang *et al.* 2015). The standard technology to reduce localized pollutants such as SO_x, NO_x, and particulate matter (PM10, PM2.5) is to use desulphurization, NO_x-reduction, scrubbing, and filtering (Tang *et al.* 2015). These techniques are used in conventional power plants, but Tang *et al.* (2015) state that similar outcomes are included in clean-coal technologies, while the power generation through clean coal is much more efficient than conventional power plants.

Although the 11th and 13th FYPs are pushing towards strengthening the clean coal production and improving cleaner and more efficient coal usage, both FYPs contains detailed policies that highlight the standard, conventional pollutant reduction techniques.

Policies like 'accelerating the construction of desulfurizing facilities in the existing coal-fired power plants and installing desulfurizing devices according to emission standards in all newly built coal-fired power plants' in 11th FYP, and 'carrying out nationwide upgrades of coal-fired power units, maintaining the average coal consumption per kilowatt-hour of the coal power plants under pre-determined rates, and ensuring that boilers with a capacity of 35 tons or greater are equipped with desulfurization, denitration, and dust purification technologies' in 13th FYP provide examples for this. Aims such as reduction of SO_2 and NO_x emissions, achieving ultra-low emissions and energy efficiency, and improving coal-based power generation can be achieved through realizing these policies. China's five-year plans after 2005 have given similar attention to both conventional and modern techniques of reducing emissions from coal-based power generation, and it can be considered a major improvement from five-year plans before the 11th FYP.

Out of all 3 five-year plans in context, the 13th FYP has the most detailed policies under this sub-theme. Through the 13th FYP, China planned to categorize and limit the coal-based power generation according to regions. The policy restricts coal resource development in the east (Shanghai municipality and others) of the country, limits it in the central (Henan, Hubei, and Hunan provinces) and northeastern (Manchuria) regions, and optimizes it in the west (Chongqing Municipality). During the rapid development phase of China after the reformation, the western region has been lagged, while the rest of the country developed (Mission of the People's Republic of China to the European Union 2004). Moreover, the western region has many advantages like rich natural resources, high market potential, and substantial labor power, compared to the eastern region (Mission of the People's Republic of China to the European Union 2004); hence it is profitable and strategic to optimize coal resource development in the western region. However, these limitations according to the region, have a high potential to limit the emissions in heavily polluted areas in China, causing a positive impact on air pollution reduction. In addition, air pollution is higher in Beijing and nearby cities in the northern region of China due to the topography (refer to section 3.3 in Chapter 3). Therefore, limiting the industrial activities to western China would help reduce the air pollution in topographically disadvantaged regions in the country as well.

Although the above-mentioned policies positively contribute towards air pollution control and prevention, there are several policies in all 3 five-year plans, especially in the 11th and 13th FYPs that may have adverse effects on air pollution to certain extents. For example, the policy to strengthen the coal resource exploration, enhance coal recovery, and construct large scale coal bases' in 11th FYP and policy to 'increase the proportion of coal used for power generation' in 13th FYP can be considered as trade-offs in air pollution reduction. However, it is my perspective that these types of actions are necessary to balance the impact of the policies against coal-based power generation, to ensure that the energy supply of the country is not disrupted. Especially for a heavily industrialized country like China, the energy supply must be maintained steady. Therefore, reduction of dependence on coal in the primary energy mix should be done very slowly over a long period to avoid any energy catastrophe.

Table 6: Policies under the sub-theme 'coal in energy'

Policies on 11th FYP	Policies on 12th FYP	Policies on 13th FYP	Inputs	Outcomes	Activities	Aims	Impacts	Externalities
Strengthen the coal resource exploration, enhance coal recovery, construct large scale coal base Strengthen the clean coal production and utilization	Develop safe and efficient coal mines and large coal enterprise groups Promote the integrity of coal resources and the merger and reorganization of coal mine enterprises	Ensure the cleaner and more efficient use of coal	Budget Safety regulators Safety training New facilities Constructors	Coal consumption increases but becomes safer	Improve the coal industry R&D into clean coal production	Improve the coal-based power generation and reduce the CO_2 and SO_2 emissions by coal	Increase the clean coal use	Plans to explore coal resources more could lead to increased coal consumption and increase emissions
		Restrict coal resource development in the east of the country, limit it in the central and northeastern regions, and optimize it in the west		Reduce the coal-based emissions in key regions	Limit the coal production by region		Reduced coal-based emissions from major regions	Regional air quality improvements
Accelerate the construction of desulfurizing facilities in the existing coal-fired power plants Newly built coal-fired power plants must install desulfurizing devices according to emission standards				Reduce SO_2 emissions by coal-based power generation	Construction of desulfurizing facilities in coal power plants		Desulfurizing facilities would clean the discharge to an extent, so the emissions are not as polluting as usual	SO_2 emissions reduce and air quality can be improved

		Carry out nationwide upgrades of coal-fired power units to achieve ultra-low emissions and energy efficiency		Increase energy efficiency and reduce emissions	Industrial restructuring and upgrading	Reduce emissions and increase energy efficiency		Emission reduction
		Ensure average coal consumption per kilowatt-hour is kept below 310 grams in existing power plants and below 300 grams in new power plants			Regulate according to specific targets for power plants	Reduce coal consumption	Fewer carbon emissions	Lowered air pollution
		Increase the proportion of coal used for power generation		Increased coal proportion in power generation		Higher coal consumption		High carbon emissions
		Implement the upgrading action plan for energy conservation and emissions reductions in coal-based power generation		Emission reduction	Implement energy conservation and emission reduction plans	Reduce emissions		Lowered air pollution
		Promote the use of alternative clean energy in urban "villages" and urban-rural fringes, and replace small and medium coal-fired facilities.		Clean energy usage increases Reduce coal consumption	Promote clean energy alternatives/ Replace coal facilities	Reduce coal consumption		
		Ensure that boilers with a capacity of 35 tons or greater are equipped with desulfurization, denitration, and dust purification technologies		Less pollutant discharge	Regulate the treatment of emissions before discharge	Reduce pollutant emissions		
		Work to eliminate coal-fired steam boilers with a capacity of ten tons or lower in all cities at or above the prefectural level across the country		Low coal consumption	Eliminate coal-fired boilers below capacity standard	Reduce coal consumption		

4.4.3. Industrial Sector

4.4.3.1. Emissions, GHG, and Pollutant discharge

The industrial sector is one of the major contributors to air pollution in the world. While greenhouse gas emissions are the most commonly-known pollutant from industries, other air pollutants like particulate matter, SO_2, NO_x, CO_2, and dust particles are also emitted by many industries. The 11th, 12th, and 13th five-year plans have several policies and targets, that are directed towards reducing emissions to different lengths, by treating pollutants before discharge and restructuring the industrial system. The policies that are relevant to this sub-category are mentioned in table 7.

11th FYP has 2 major targets regarding this sub-theme; 1). reduction of total emissions of major pollutants to annual average growth of 10%, and 2). advance the comprehensive treatment of SO_2 in iron and steel, ferrous metal, chemical, and building material industries. Compared to the 11th FYP, where the reduction of emissions is mentioned under the umbrella term 'pollutants', the 12th FYP has targets where significant reductions for each pollutant CO_2, SO_2, COD, Ammonia, Nitrogen, and NO_x are highlighted separately. This is a significant improvement from 11th FYP to 12th FYP. To ensure a considerable development in achieving the targets, it is important to have narrowed-down and specific policy targets than targeting change under general conditions.

There is a common policy that is presented in both the 11th and 13th FYPs. The policy in the 11th FYP targets to reduce SO_2 emissions in several industries naming, iron, and steel, ferrous metal, chemical, and building material. A similar policy is in the 13th FYP targeting to bring carbon emissions in power, steel, building materials, chemicals, and other major carbon emitters under control. Although 2 policies in 2 FYPs target different pollutants, it is significant to notice that both involve industry and system restructuring, and both identified what specific industries to target. While this kind of policy is not in the 12th FYP, it has several generaltermed policies that would need industry restructuring as a major step to achieve. Examples of such targets in 12th FYP are ‘effective regulation of GHG emissions’, ‘assignment of target responsibilities for emissions reduction’, and ‘strict control of the pollutant discharge’. It is also important to observe that all three above-mentioned policies have similar outcomes.

Two major improvements that came into play in 13th FYP, but were absent in both 11th and 12th FYPs are recognition of non-CO_2 GHG emissions and emission reduction in the BTH region. Beijing-Tianjin-Hebei region is a major hub for air pollution in China, and recognizing it and adding a location-specific policy for the 13th FYP is a great improvement moving forward. It can be considered a major improvement from the preceding five-year plans. The other policy that is related to non-CO_2 GHG emissions is equally important, as non-CO_2 GHGs were not specifically recognized in previous FYPs. While CO_2 bears a major focal point when policies about GHG emission reduction comes to play in the context of air pollution, other greenhouse gases such as methane, fluorinated gases, and NO_x also heavily contribute to air pollution. For example, methane is a major precursor for ground-level ozone, which has several adverse health impacts such as worsened bronchitis and emphysema, triggered asthma, and permanent damage to lung tissues. Similar to carbon dioxide, non-CO_2 greenhouse gases also have a large impact on air pollution and public health; hence adding targets to reduce those pollutants to the 13th FYP is a clear advancement in air pollution prevention and control.

Apart from the above-mentioned improvements, there are several other policies in the 13th FYP, that involves major industrial restructuring. 13th FYP planned to relocate, upgrade, or shut down all heavily polluting enterprises located within urban regions, according to the emission laws. Moreover, the total emissions control system is reformed to add and recognize more pollutants to mitigate. These policies aim to achieve a clean urban atmosphere by removing polluters from the densely populated urban areas and by controlling more pollutants. Apart from these, several other policies try to stop all heavy-pollution projects that violate the state industrial policies, and ensure the steel and cement industries' machines are equipped with desulfurization and denitration technologies respectively. These policies make sure that the industries comply with the state standards, and having such hard and fast policies has a positive impact on air pollution control and prevention. Overall, it has been observed that there have been gradual and significant improvements from the 11th FYP to the 12th FYP and then to the 13th FYP, in the context of the sub-theme 'emissions, GHG, and pollutant discharge'.

Table 7: Policies under the sub-theme 'emissions, GHG, and pollutant discharge'

<table>
<tr><th>Policies on 11th FYP</th><th>Policies on 12th FYP</th><th>Policies on 13th FYP</th><th>Inputs</th><th>Outcomes</th><th>Activities</th><th>Aims</th><th>Impacts</th><th>Externalities</th></tr>
<tr><td>Reduction of total emissions of major pollutants to annual average growth of 10%</td><td rowspan="2">CO_2 emissions per unit of GDP will decrease by 17%

Reduce CO_2 emission intensity

COD and SO_2 emissions reduce by 8%

Ammonia nitrogen and nitrogen oxide emission reduce by 10%

Effectively regulate GHG emissions

Assign target responsibilities for emissions reduction

Strictly control the pollutant discharge</td><td rowspan="2">Bring carbon emissions in power, steel, building materials, chemical, and other major carbon-emitting industries under effective control

Control total emissions of VOCs in chief regions and industries to bring about a nationwide drop in total emissions of over 10%.

Control the emissions of non-CO_2 greenhouse gases.</td><td rowspan="3">Emission regulators

Industries

Power plants</td><td rowspan="2">Major emission reductions</td><td rowspan="2">Assign emission targets

Regulate emissions according to standards

Restructure industries to reduce emissions</td><td rowspan="2">To reduce CO_2, SO_2, NO_x, and VOC,</td><td rowspan="3">Air quality improves

Contribute to fighting climate change

Reduced emissions in the city

Fewer emissions</td><td rowspan="3">Less air pollution in urban regions

Better air quality</td></tr>
<tr><td>Advance the comprehensive treatment of SO_2 in iron and steel, ferrous metal, chemical, and building material industries</td></tr>
<tr><td></td><td></td><td>All heavily polluting enterprises located within urban districts will be either relocated,
upgraded, or, by the law, shut down</td><td>The clean urban atmosphere and environment</td><td>Relocate or shut down heavy polluters in urban areas</td><td>Improve the city conditions
and other GHG emissions</td></tr>
</table>

		Reform the total emissions control system for major pollutants so that more pollutants are covered		Control emissions for more pollutants	Reform the total emissions control system	Identify and cover a wide range of pollutants		
		Support leading development regions in becoming the first to reach their carbon dioxide emissions peak. Put a stop to all projects that cause heavy pollution in violation of state industrial policies. Ensure that steel industry sintering machines are equipped with desulfurization technology and that the cement industry adopts denitration technology. Promote the use of mature and applicable technologies (Eg; integrated high-efficiency flue gas dust removal and waste heat recovery, high-efficiency heat pumps, semi-conductor illumination, and waste recycling)		Reduce emissions from heavy-polluting industries	Strict regulations and monitoring Incentivize emission reductions Identify and stop heavy pollution violation projects	Reduce industrial emissions		
		Reduce total pollutant emissions in the BTH region		Reduce air pollution in the BTH region	Monitor and reduce pollutant emissions in the BTH region	Cleaner air quality in the BTH region		

4.4.3.2. Low-carbon technologies in industries

High-carbon emissions from industries can be considered as one of the major causes of air pollution in heavily industrialized developing countries like China. Low-carbon technologies in industries have been in the talks for transforming environmentally-friendly industries for years, for example, the 'Sustainable Industry Low Carbon (SILC) Initiative' that supports industries to develop and transform into low-carbon technologies through EU grants (European Commissions 2021). However, only after the 12th FYP, low-carbon technologies made their way into the five-year plans for national and social development in China. The policies that are relevant to this sub-category are mentioned in table 8

There is no mention of any specific low-carbon technologies in the 11th FYP. Even in the 12th FYP, the policy only mentions the development of low-carbon technologies, without any specific activities to achieve it as a target. On the other hand, the 12th FYP has several policy targets that would indirectly cause negative impacts on air pollution. The policies that aim at carrying out research and development demonstration of coal-based natural gas, coal-based liquid fuels, and coal-based co-production, and also at the promotion of industrialization steadily could be of reason to alleviate air pollution in the country. While it is apparent that China as a country cannot phase out 'coal-based industries' completely as of yet, having policies that promote industrialization without any specification on how it can be sustainable or less polluting, can be considered as a drawback in this FYP. Such policies could cause negative externalities such as increased carbon, GHG, and other air pollutant emissions by industries, causing air quality to degrade even more.

When comparing to 11th and 12th five-year plans, 13th FYP tops in this category as well. The low-carbon technologies are recognized in several places within the document, and the policies are more context-specific compared to the 12th FYP. The 13th FYP has policies that aim to 'promote low-carbon development in industry, energy, construction, transport, and other key sectors', 'push forward pilot programs for low-carbon development and demonstrate the establishment of near-zero carbon emissions zones', and also to 'step up efforts to expand the use of low-carbon technologies and products. One major improvement from 11th FYP to 12th FYP is the recognition of low-carbon technologies, and from there, a great leap can be seen when it comes to low-carbon technologies in 13th FYP. 13th FYP not only recognizes the sector, but also specifies which industries these new technologies should be added, and emphasizes and highlights the efforts to research, develop, and utilize the low-carbon technologies. To realize this target, inputs including research and development teams and specific ministries are necessary. While recognizing more specified targets to promote low-carbon technologies can be considered a great advancement from 11th and 12th FYPs to 13th FYP, in my perspective, China still has a long way to go before implementing them in industries. However, specifying policies like 'pushing forward pilot programs for low-carbon development and demonstrating the establishment of near-zero carbon emissions zones' has put a foundation to carry out better-formed policies concerning this sub-theme in the future FYPs.

Table 8: Policies under the sub-theme 'low-carbon technologies in industries'

Policies on 11th FYP	Policies on 12th FYP	Policies on 13th FYP	Inputs	Outcomes	Activities	Aims	Impacts	Externalities
N/A	Develop low carbon technologies Advance on low-carbon pilot projects Accelerate research, development, and application of low carbon technologies . Carry out R&D demonstration of coal-based natural gas, coal-based liquid fuels, and coal-based co-production orderly	Promote low-carbon development in industry, energy, construction, transport, and other key sectors Push forward pilot programs for low-carbon development and demonstrate the establishment of near-zero carbon emissions zones. Step up efforts to expand the use of low-carbon technologies and products. Chief industries will be transformed to achieve clean production.	R&D teams Ministries	Reduce carbon emissions by coal-based industries	Research and develop low-carbon technology	Promote low-carbon tech and reduce dependence on carbon products	Increased use of low-carbon technologies Lowered emissions	Lessened carbon emissions lead to reduced air pollution
				Use of new coal-based fuels	Research and develop new coal-based energy sources			High carbon emissions from coal-based products
	Promote industrialization steadily			Increase GDP Increase employment		Increase industrialization	Increased industrialization leads to increased employment	High industrial emissions lead to increased air pollution

4.4.3.3. Standards and schemes

The third sub-theme under the main theme 'industrial sector' is 'standards and schemes'. The policies that are relevant to this sub-category are mentioned in table 9. While the 11th FYP lacked any policies related to standards and schemes that would directly or indirectly address air pollution, both the 12th and 13th five-year plans had such policies. 12th FYP has a smaller number of policies on this matter, compared to the 13th FYP. It has several context-specific and narrowed-down policies on the promotion and establishment of standards, schemes, and systems to reduce emissions from industries and enterprises. This can be considered a great achievement from 11th to 12th to 13th FYP in this sector.

One of the main standards recognized in the 12th FYP is related to low-carbon technologies. During the categorization of policies, it was difficult to put the policy in question into one of the 2 sub-themes under the industrial sector; low-carbon technologies in industries and standards and schemes. However, since the policy 'research into the development of low-carbon product standardization, labeling, and authentication systems is directly related to the sub-theme 'standards and schemes' than the low-carbon technologies, it was categorized under that. This policy is one of the most important improvements on the matter from 11th FYP. By allocating inputs such as research and development teams, budget, and analysts into developing standardization systems for low-carbon technologies, the industries can be encouraged to adopt them and become more environmentally friendly.

Moreover, the 12th FYP has other standards-related emission control policies that are aimed towards the establishment of an effective system or GHG emission statistics calculation, creation of a carbon emissions trading system, implementation of standards for pollutant discharge, and evaluation of the effect of such standards on the environment. These are not generalized policies, but ones with specific targets, so if implemented strictly and immediately, the outcomes such as control of industrial carbon emissions and gradual transition to low-carbon technologies in industries could be realized within the period of the five-year plan.

While the 12th FYP had a lot more standards-and-schemes-related policies than the 11th FYP which had none, the 13th FYP has even better policies in this matter compared to the 12th FYP. The 12th FYP has the policy to create a carbon emissions trading system gradually, and this specific policy was improved and carried onto the 13th FYP. The 13th FYP not only highlights the promotion of the establishment of a national carbon emissions trading scheme, but also further instructs to implement systems for carbon emissions reporting, inspection, verification, and quota management for major carbon emitters. Moreover, this FYP consists of policy to transform enterprises in steel, cement, plate glass, papermaking, printing and dyeing, nitrogenous fertilizer, and sugar refining industries that cannot meet emission standards. These policies directly recognize the impact of major carbon emitters in the country such as coal-based energy production and industries like cement and steel. Figure 11 shows all the GHG emitters in China for the year 2016, which shows that electricity and heating, manufacturing, and construction are the highest contributors of GHG emissions in China. Therefore, it is extremely important that the 13th FYP recognizes these heavy polluters and takes actions towards reducing the emissions from them and reduce the impact on air quality, before the consequences of industrial pollution become irreversible.

Figure 12 shows the extreme increase of CO_2 emissions from 2000 to 2019 from fossil fuels for the energy and cement industry in China. While there was a high growth from 2000 to 2011, after 2011, the growth rate of CO_2 emissions slowed down. Different factors may have had a hand in this decrease, yet the policies that targeted this outcome in 13th FYP would be one of the reasons for this achievement. The policies such as this in China's five-year plans complement the country's pledge to promote a low-carbon economy to reduce global warming and fight climate change by addressing "energy, industry, low carbon cities, circular economy, and low carbon technology, afforestation and carbon sink, the carbon emission trading market and carbon emission reduction targets" (Yang *et al.* 2019).

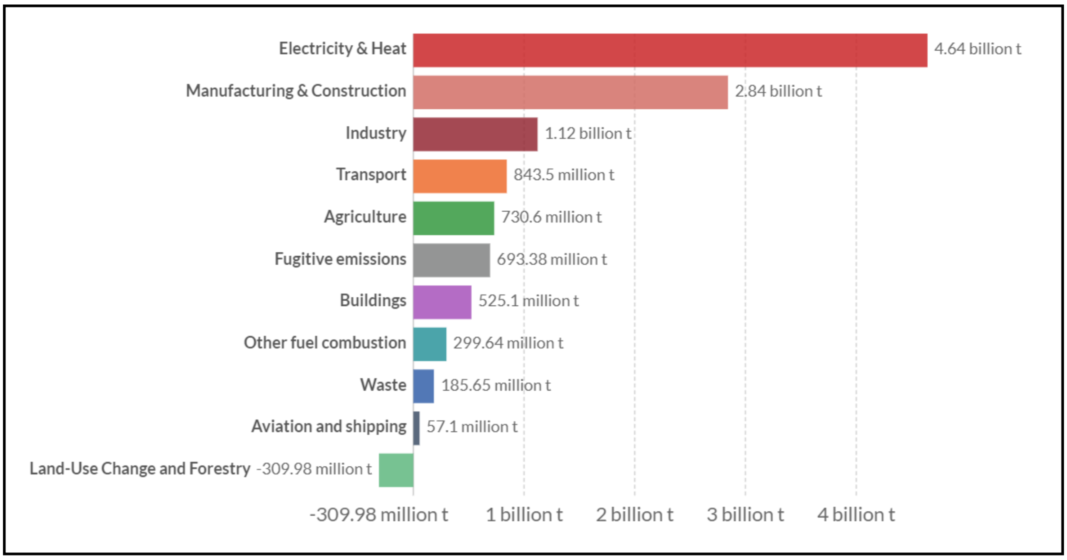

Fig 11: Greenhouse gas emissions by sector in China in 2016 (Source: Ritchie and Roser 2020)

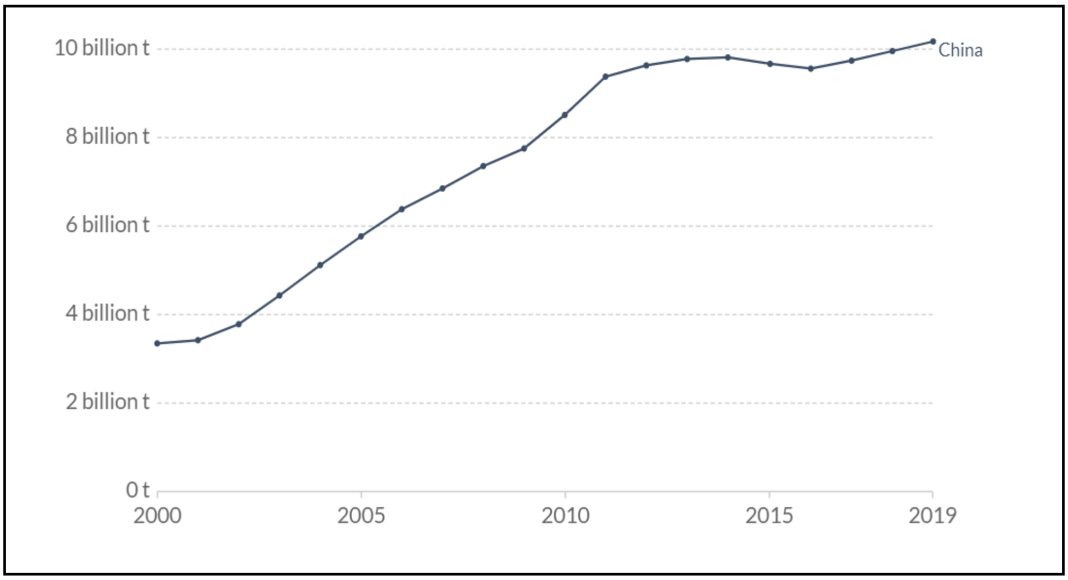

Fig 12: Carbon dioxide (CO_2) emissions from the burning of fossil fuels for energy and cement production in China (Source: Ritchie and Roser 2020)

13th FYP further has policies with several outcomes that directly and indirectly help prevent and control air pollution in China. Improving carbon emission standards, carrying out performance evaluations, and improving statistical accounting are some of such policies. They further highlight and signify the actions that should be taken to strengthen the standards and schemes to reduce emissions by major emitters in the country. Moreover, the 13th FYP contains stricter policies addressing industrial polluters. They target to ensure that all industrial polluters meet improved emissions standards, strengthen the supervisory monitoring of industrial pollution sources, and publish a blacklist for industries and enterprises that fail to meet the mandated standards. These kinds of strict policies on industrial polluters were not seen in either the 11th FYP or 12th FYP, therefore, it is important to note that this is a huge improvement during the implementation of the 13th FYP.

Having such hard-and-fast policies like this forces the heavy industrial polluters to take immediate actions to cut their emissions, causing positive impacts on air pollution prevention and control.

Table 9: Policies under the sub-theme 'standards and themes'

Policies on 11th FYP	Policies on 12th FYP	Policies on 13th FYP	Inputs	Outcomes	Activities	Aims	Impacts	Externalities
N/A	Research into the development of low-carbon product standardization, labeling, and authentication systems Establishment of an effective system for calculating GHG emission statistics The gradual creation of carbon emissions trading system. Implement standards for pollutant discharge and emissions and evaluate their effect on the environment	Promote the establishment of a national carbon emissions trading scheme, and implement systems for carbon emissions reporting, inspection, verification, and quota management for major carbon-emitters Improve statistical accounting, performance evaluation, and accountability systems as well as carbon emission standards Ensure that all industrial polluters meet emissions standards, improve emissions standards, strengthen supervisory monitoring of industrial pollution sources, publish a blacklist of enterprises that fail to meet emissions standards, and require such enterprises to make corrections within a stipulated time frame	Standardization systems Regulators Inspectors Analysts	Spread of low carbon technologies Control carbon emissions	Research and development into low carbon technologies Standardize low-carbon tech usage and emissions Improve standardizing systems Regulating the industries and strict control for them to meet the standards Put the failed ones on a blacklist	Promote low carbon technologies and reduce carbon emissions To maintain carbon emissions according to the standards	Reduce harmful emissions Reduce carbon emissions	Promoting low-carbon tech reduce the emissions Reduce air pollution by carbon-based products Improve air quality
		Transform enterprises in the steel, cement, plate glass, papermaking, printing and dyeing, nitrogenous fertilizer, and sugar refining industries that cannot consistently meet emissions standards			Transform the industries that don't meet emission standards			

4.4.4. Transportation Sector

4.4.4.1. Traffic and roads

The transportation sector is the second-largest contributor to air pollution in China. With its fast-economic growth, China's people got to enjoy a higher disposable income, increasing vehicle ownership, which altogether has led to severe traffic congestions in the Chinese cities (World Bank 2018). According to the 2016 Yearbook of China Transportation & Communications, the car ownership of China rose to 488% in the past decade, reaching 290 million vehicles (Mou *et al.* 2018). When people sit in the traffic for hours, the level of exposure to air pollutants increases largely, causing negative consequences on their health and wellbeing. Therefore, it is of importance that any policy framework that targets to mitigate air pollution includes policies to reduce traffic congestions in the country's major cities. The policies that are relevant to this sub-category are mentioned in table 10.

Among the three five-year plans, only the 11th and 13th FYPs have policies targeting control of traffic congestions. 11th FYP focus more on improving the road network and distributing the traffic network to construct a 'convenient, unobstructed, high-efficiency, and integrated transport system'. This is narrowed down in some contexts to an extent but still needs to be worked on the specific action plan to achieve it. From the 11th FYP to the 12th FYP, there is degrowth in policies in this sector. Although the policy in the 11th FYP is somewhat generalized, the plan recognizes the issue and highlights the importance of reducing traffic congestions in the cities of China. However, the 12th FYP does not contain any traffic-related policies.

13th five-year plan has 2 main context- and region-specific policies that would help reduce the traffic congestions. Beijing-Tianjin-Hebei is a region with heavy air pollution and the 13th FYP's policy to improve the service and increase the density of expressway networks in the Yangtze Economic Belt and the BTH region aims to increase the capacity around heavily congested sections of the expressways. This FYP further pledges to take actions to ensure smooth traffic in busy areas like urban roads, and entrances and exits of outbound highways. Moreover, the 13th FYP plans to initiate the construction of ring roads in the cities where the conditions are suitable. Ring roads can decentralize the traffic movement from heavily congested roads in the city center by providing alternate routes to direct the traffic flow and relieve the pressure on inner-city areas (Arndt *et al.* 2019). Putting foundation to plan and construct ring roads could reduce several daily unnecessary traffic congestions in high-density cities in China.

Inputs that are necessary to approach these policy targets include road regulators, traffic control, construction, and road development planning, among others. The actions such as constructing a well-planned road network and linking up transportation means could help achieve the main aim of the policy; increasing the efficiency of transportation by reducing traffic congestions. A positive externality that can be achieved by realizing this policy is to reduce the amount of time a vehicle idles in traffic, which cuts down the vehicle's emissions and also reduces the exposure of the public to harmful vehicular emissions. Improving the road network and focusing traffic reduction measures on high-traffic hubs can be considered a great place to start achieving these aims.

Table 10: Policies under the sub-theme 'traffic and road network'

Policies on 11th FYP	Policies on 12th FYP	Policies on 13th FYP	Inputs	Outcomes	Activities	Aims	Impacts	Externalities
Unified plan and rationally distribute traffic infrastructure Carry out the mutual link-up of various transportation means Exert the combination efficiency, and construct a convenient, unobstructed, high-efficiency integrated transport system	N/A	Increase the density and improve the service of expressway networks in the Yangtze Economic Belt and the Beijing-Tianjin-Hebei region Increase capacity around heavily congested sections of expressways	Road regulators/ traffic control/ construction/ road development planning	Improved road network Reduced traffic	Construct a well-planned road network Link-up transportation means	Increase efficiency of transportation Reduce traffic congestions	Less time on the road - less traffic efficient and quick travel times	Vehicular emissions by traffic congestions reduce Better air quality
Further, improve the road network		Ensure smooth traffic flow on urban roads and at busy entrances and exits of outbound highways; and in cities, where conditions permit, plan and construct ring roads.						

4.4.4.2. Public transport

As explained in section 4.4.4.1, the more the number of private vehicles on the road, the more the air pollution. When there is no improved public transport or when the public transport cannot reach certain places, the need for privately owned vehicles is heightened. As the capacity of a public transport vehicle (for example, bus, train, tram, or light rail) is much higher than that of a small private vehicle, promoting the public to use public transport will largely reduce the number of single vehicles coming into the city. Therefore, a country must have a good, convenient, and affordable public transport system. The policies that are relevant to this sub-category are mentioned in table 11.

Similar to the traffic-related policies in the above section, the 12th FYP does not have any policies addressing public transport as well. Although both the 11th and 13th FYPs contain policies targeting to improve the urban public transportation system and public transit sites and stations, they are generalized and not very specific. These policies just brush over the matter, without focusing in-depth on the actions that need to be taken to realize this target. 13th FYP for that matter, however, has mentioned an aim to speed up the development of urban rail transit and bus rapid transit, yet does not mention the actions to be taken to do that. The main aim of these policies is to promote and develop public transportation and if done right, can result in the positive externalities of air pollution reduction by lowered vehicular emissions.

Although the five-year plans do not focus much on public transport, China's government has taken other measures to ensure the improvement of public transport as a way to reduce traffic congestions. China took a grant from the 'Global Environment Facility for the Large City Congestion and Carbon Reduction Project' to initiate a project that promotes a comprehensive approach to improve the efficiency of public transport and services in China's cities (World Bank 2018). However, even with these kinds of projects, it is my conclusion and perspective that China must include integrated and comprehensive policies under this sub-theme in their most important development plan, the five-year plans.

Table 11: Policies under the sub-theme 'public transport'

Policies on 11th FYP	Policies on 12th FYP	Policies on 13th FYP	Inputs	Outcomes	Activities	Aims	Impacts	Externalities
Give priority to the development of public transit Improve urban road network structure and public transit site and station	N/A	Development of public transportation Speed up the development of urban rail transit, bus rapid transit, and other Improve urban public transportation systems	Transportation-related ministry and institutions Developers Constructors Public vehicles	People use public transport more - less traffic	Develop urban rail and bus systems	Promote public transportation	More people use public transport leads to less vehicle circulation in the city, resulting in fewer traffic congestions	Lower the vehicular emissions and air pollution

4.4.4.3. Vehicular emissions

On-road vehicular emissions are one of the largest emitters of pollutants such as particulate matter, black carbon (soot), carbon monoxide, NO_x, and formaldehyde (Behera and Balasubramanian 2014; EPA 2019). Most of the vehicles are traditionally powered by fossil fuels, and the incomplete combustion of fossil fuels releases those air and climate pollutants, degrading the air quality of cities mainly. The policies that are relevant to this sub-category are mentioned in table 12.

All 3 five-year plans have a certain type of policy addressing the reduction of vehicular emissions to different lengths. The focus is on which aspect of vehicular emissions varies from one FYP to another. The policies in the 11^{th} FYP target to increase the treatment strength of urban smoke-dust, dust, fine particulate, and vehicle tail gases, while the ones in the 12^{th} FYP focus on the development of plug-in hybrid electric vehicles, pure electric vehicles, and fuel cell automobile technologies. 13^{th} FYP on the other hand has several policies that integrate vehicles, technology, energy, and emission standards. This can be considered a great improvement in this aspect, from 11^{th} and 12^{th} FYPs to 13^{th} FYP. The 13^{th} five-year plan highlights several policies targeting to develop low-carbon transport, establish a monitoring system for emission standards for vehicles, and increase the proportion of natural gas users in cities. These policies aim to regulate and reduce vehicular emissions and promote eco-friendly transportation means, to achieve outcomes such as better air quality in cities.

The transport sector is the second largest contributor to air pollution in China. Yet, the five-year plans for national economic and social development in China include some generalized policies that briefly touch upon the transport sector without including many specific actions, actors, or aims to initiate those policies. It is my perspective that the policies under this main theme need more improvements that would narrow them down and make them more actionable.

Table 12: Policies under the sub-theme 'vehicular emissions'

<table>
<tr><th>Policies on 11th FYP</th><th>Policies on 12th FYP</th><th>Policies on 13th FYP</th><th>Inputs</th><th>Outcomes</th><th>Activities</th><th>Aims</th><th>Impacts</th><th>Externalities</th></tr>
<tr><td></td><td>Focus on the development of plug-in hybrid electric vehicles, pure electric vehicles, and fuel cell automobile technologies</td><td>Make head-way to develop low-carbon transport</td><td rowspan="3">Treatment facilities and techniques

Vehicle production

Regulators</td><td>Eco-friendly vehicles

Less vehicular emissions</td><td>Develop hybrid and electric vehicles
R&D into low-carbon tech in transport</td><td rowspan="2">Reduce vehicular emissions and promote eco-friendly transportation means

Regulate vehicular emissions</td><td rowspan="2">Low vehicular emissions</td><td rowspan="2">Less air pollution and better air quality</td></tr>
<tr><td></td><td rowspan="2"></td><td>Establish a monitoring system to ensure that environmental protection standards for vehicles, watercraft, and fuel oil are achieved</td><td>Regulate the transportation sectors to ensure that they meet the standards</td><td>Establish a monitoring system to ensure that environmental protection standards for the transport sector achieved</td></tr>
<tr><td>Increase the treatment strength of urban smoke dust, dust, fine particulate, and vehicle tail gases</td><td>Increase the proportion of natural gas users in cities</td><td></td><td>Regulate and standardize tail-pipe emissions and emissions from other main sectors</td><td></td><td></td><td></td></tr>
</table>

4.4.5. Urban Development

4.4.5.1. Employment

Urbanization is another major cause of air pollution. The increase of urban employment opportunities has a large impact on people moving to cities from rural areas, increasing the population density in the city. Higher the population, other aspects like the number of vehicles on the road, and the per capita carbon footprint also increases accordingly. The policies that are relevant to this sub-category are mentioned in table 13.

11th FYP has a rigid policy under its chapter for economic and social development, where the government targets to realize 45 million additional urban jobs to transfer the rural labor force to the cities. The main intention of this policy is to reduce the registered urban rate of unemployment and control it at 5%, while it also aims to achieve 7.5% growth in the annual average GDP. While the 13th FYP doesn't have any direct policies in this aspect, the 12th FYP plans to push the transformation of the diverted agricultural population into town population, to push forward the urbanization.

Among the long-term outcomes of these policies, an increase in urban population density, environmental deterioration, expansion of city margins, and land-use change are prominent. Studies report that China's urban land area saw a 644% increase where it increased to 49,900 km^2 in 2014 from 6720 km^2 in 1981 (Mou *et al.* 2018). The main reason for this drastic land area increase is China's implementation of reform and opening-up policy (Mou *et al.* 2018), but the addition of policies on increasing urban employment to the 11th FYP may have had a role in that. Mou *et al.* (2018) further explain that the expansion of city borders invades prime agricultural and resource lands, leading to "fragmented and piecemeal land development patterns". Due to increased population, land/cover change, and high traffic congestions caused by urban growth directly associated with the air quality, degrading the air quality significantly. Apart from these long-term outcomes, an immediate surge of population in cities, housing shortage, and increase of vehicles on the urban roads increasing vehicular emissions fall under the category of short-term outcomes, which cause degradation of the quality of life for the public while deteriorating the air quality in the cities. Moreover, the individual outcomes for the public due to the realization of this policy may include high rent payments and increased living costs compared to rural areas.

The realization of new urban employment is to be done by taking actions such as the creation of new industries and expansion of existing industries. When employment is given by increasing the industrial capacity, industrial pollution affects adversely the air quality of the city as well. This can be considered another indirect impact on air pollution by increasing urban employment. Although the impacts include an increase in GDP and a decrease in urban unemployment, there are several negative externalities of this policy. Among them, the increase in traffic congestions, carbon footprint, energy consumption, coal consumption, and power demand are the ones that would impact air pollution adversely over time.

Table 13: Policies under the sub-theme 'employment'

Policies on 11th FYP	Policies on 12th FYP	Policies on 13th FYP	Inputs	Outcomes	Activities	Aims	Impacts	Externalities
45 million additional jobs will be realized	Steadily push the transformation of the diverted agricultural population into town population	N/A	Industries Employers Additional budget,	**Long-term:** Population density increase/ land use change/ city margins expands **Short-term:** Immediate surge of urban population/ High number of vehicles and increase vehicular emissions **Individual:** High rent and living cost in cities compared to rural	Creation of new industries Expansion of industries	Annual average growth of GDP by 7.5%	Increased GDP Reduce urban unemployment	Increase in urban population Increased traffic congestions Increase in carbon footprint Increase of energy usage - increases the demand for power Increased coal consumption in urban areas

4.4.5.2. Population

Population growth affects air quality in different ways. Especially in highly populous countries like China, the exponential population growth can cause many negative and irreversible impacts on the air quality of the country. A study from NASA has found out that the contribution of surface-level NO_2 to air pollution in each region doubled when the population increased from 1 million to 10 million, while in China it increased by a factor of five (Hansen 2013). It is a strong indicator that population correlates with air pollution to a great length. The policies that are relevant to this sub-category are mentioned in table 14.

11th FYP briefly recognizes the importance of sustainable development and consists of a policy objective to control the country's national population at 1.36 billion. Currently, in 2021, the population of China peaks at 1.39 billion, but the exponential population growth that was observed in the past decades has been slowly reducing in recent years (World Bank 2021a). However, the 11th FYP does not mention an actual policy regarding this aspect.

The 12th FYP on the other hand contains several policies that are directed towards population control. As also mentioned briefly in section 4.4.5.1, the 12th FYP plans to steadily push the transformation of the agricultural population into the urban population, fully respecting the wishes of farmers and the rural labor force. The plan further explains and highlights the importance of proper population management and aims to strengthen and improve the management of the increasing urban population to absorb the migrant population better. Compared to the 12th FYP, the 13th FYP has one policy that intends to lower the population density of Beijing, as a step to relieve Beijing of functions nonessential to its role as China's capital.

All these policies revolve around inputs such as employment, family planning, awareness campaigns, and strict laws. The impact of employment on population growth was discussed in the above section. While the policies in the 11th and 13th FYPs focus on population management and reduction of population density, the policies in the 12th FYP mainly focus on increasing urbanization and enhancing the population density of the newly constructed cities. Although they may negatively impact the air quality of the cities to some extent, it is necessary to point out that urbanization is a major way to develop a country. The key is to carry on with development, without compromising the resources and environment for the current and future citizens of the country. By focusing on population management as a part of the country's master plan for national economic and social development, China's authorities can create a positive impact on air quality. However, in my perspective, the lack of an action plan for these policies is a drawback and hindrance to initiating them effectively within the five years.

Table 14: Policies under the sub-theme 'population'

<table>
<tr><th>Policies on 11th FYP</th><th>Policies on 12th FYP</th><th>Policies on 13th FYP</th><th>Inputs</th><th>Outcomes</th><th>Activities</th><th>Aims</th><th>Impacts</th><th>Externalities</th></tr>
<tr><td></td><td>Steadily push the transformation of the diverted agricultural population into town population</td><td>Lower the population density of main districts of BTH region</td><td rowspan="3">Employment

Family planning

Workshops

Awareness

Laws</td><td rowspan="3">Increased urban employment

High urban density

Population control</td><td rowspan="3">Providing employment</td><td rowspan="3">Improve urbanization

Reduce population density

Maintain population and reduce the growth</td><td rowspan="3">High consumption

High urban emissions</td><td rowspan="3">Increased air pollution in urban regions due to high population

High household and vehicular emissions in urban regions

Population percentage exposed to bad air quality increases</td></tr>
<tr><td>The total national population is controlled at 1.36 bn</td><td>Strengthen the population management</td><td rowspan="2"></td></tr>
<tr><td></td><td>Enhancing the population density of the newly constructed districts</td></tr>
</table>

4.4.5.3. City development

After China reformed its policies and opened up the country for foreign trade, the economic sector saw exponential growth. Together with that, urbanization rose to higher levels as well. Figure 13 represents the degree of urbanization in China from 1980 to 2020, and it shows a very drastic escalation in urbanization from 1995 to 2010, and since 2010 till now, it has been on more slow and steady growth. With the increasing urbanization, the city structure should improve, revolutionize, and become sustainable to support the increasing urban population and activities without compromising the environmental and social conditions of the city. The policies that are relevant to this sub-category are mentioned in table 15.

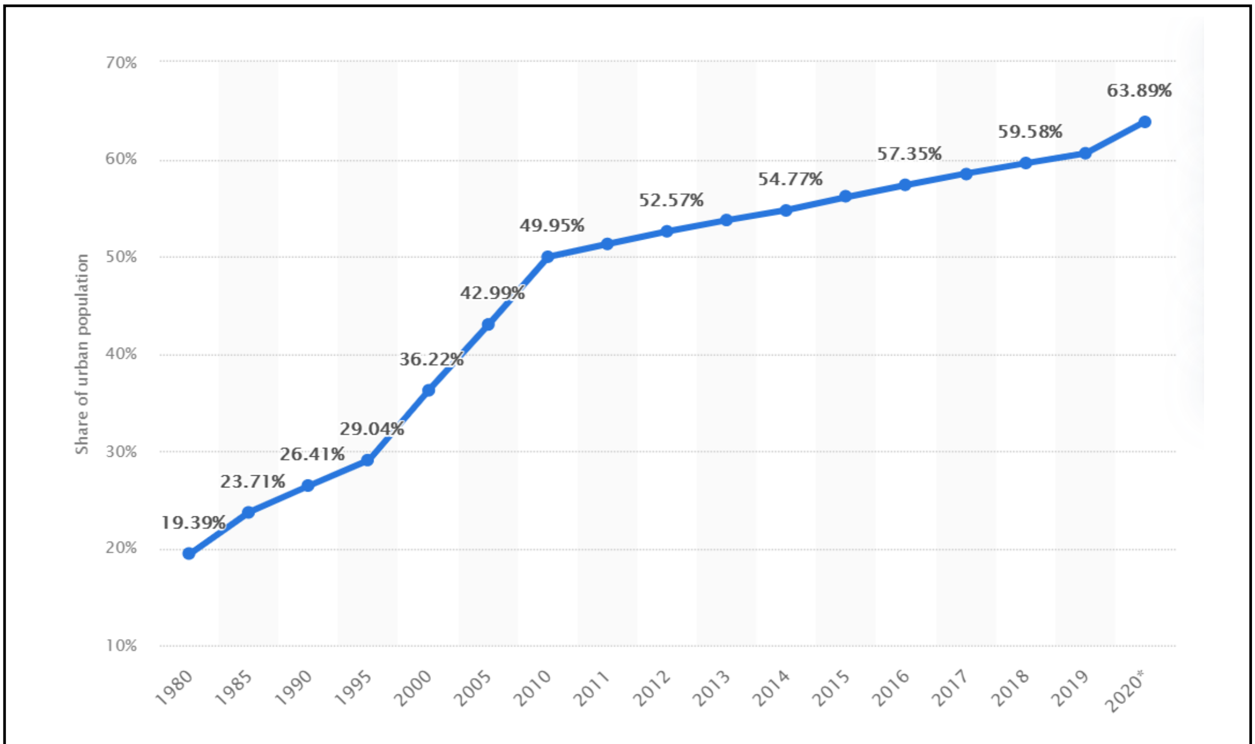

Fig 13: Degree of urbanization in China from 1980 to 2020 (Source: Statista 2021c)

The 11th FYP does not mention any policies or objectives concerning this sub-theme. However, the 12th and 13th FYPs have several policies that are directed towards air pollution mitigation through the development of city structures in major cities in China. As also explained in section 4.4.5.1, expansion of city borders causing many negative consequences like environmental deterioration, land use/cover change, and loss of agricultural lands are some of the major externalities of urbanization. The policies in 12th FYP such as defining the borders of the city development, regulating the construction of the new towns and districts, and preventing over-expansion of super large cities directly aims to manage the unhealthy over-expansion of cities, and it can lead to better city structures with fewer traffic congestions and lesser harmful impact on the environment.

Both the 12th and 13th five-year plans contain policies that are directed to control and prevent air pollution in the city and to alleviate the air quality. While the 12th FYP briefly mentions limiting air and noise pollution, it lacks a specific path to realize that. The related policies in the 13th FYP are better formulated with percentage targets and context-specific directions. The policies under this sub-theme in the 13th FYP include;

- formulating a plan for ensuring air quality standards in cities are met,
- strictly enforcing obligatory targets,
- ensuring that the cities at and above the prefectural level achieve a 25% reduction in the number of days of heavy air pollution,
- channeling greater effort into reducing fine particulate matter emissions in key regions,
- implementing gasification projects in key areas of heavy air pollution, and ensuring that the concentration of fine particulate matter concentration is decreased by at least 25%, and
- strengthening monitoring of windblown dust from unpaved roads and construction sites and prohibit open straw burning,

aimed at better coordination of efforts to prevent and control air pollution.

The major outcomes of these policies are better planned and structured urban regions that conserve energy and are sustainable, improved air quality, and reduced PM pollution. It is important to reiterate that the 13th FYP is the first five-year plan in China that included a well-defined policy addressing PM pollution, with a target to reduce the number of days with heavy PM2.5 levels and also the PM concentration in key areas by 25%. Given that over 4 million premature deaths in the world (Burrows 2021) and 1.24 million in China (Yin *et al.* 2020) are attributable to PM pollution, specifically to PM2.5, it is of great importance that all the major policy frameworks for development in China contain specific PM reduction targets. Five-year plans for national development are the key master plan for the country's development and having such narrowed-down and context-specific policies with well-defined targets are important to control and prevent air pollution.

Table 15: Policies under the sub-theme 'city development'

Policies on 11th FYP	Policies on 12th FYP	Policies on 13th FYP	Inputs	Outcomes	Activities	Aims	Impacts	Externalities
N/A	Define the borders of the city development Regulating construction of the new towns and districts Preventing over-expansion of super large cities		Engineers Regulators Developers City development-related institutions	Planned cities	Define the city borders and prevent the over-expansion of city limits/ Limit air and noise pollution	Maintain better quality cities	Better quality of life in urban areas	Less air pollution and better air quality due to better city planning
		Better coordinate efforts to prevent and control air pollution		Improve air quality	Coordinate efforts to prevent air pollution Well-planned PM targets	Improve air quality in key regions	Reduced air pollution	
		Formulate a plan for ensuring air quality standards in cities are met, see that cities at and above the prefectural level			Plan to ensure the air quality standards of the city are met	Reduce the number of bad air quality days	Better air quality in cities	
	Limit air and noise pollution	Reduce fine particulate matter emissions in key regions Achieve a 25% reduction in the number of days of heavy PM pollution		Reduce PM pollution	Develop plans with PM targets in focus	To reduce PM levels in major regions	Reduce PM pollution	

		Implement gasification projects in key areas of heavy air pollution Ensure that the concentration of fine PM is reduced by at least 25%.						
		Strengthen monitoring of windblown dust from unpaved roads and construction sites and prohibit open straw burning		Reduce dust pollution	Monitor the windblown dust from different sources Prohibit open straw burning	Reduce the dust pollution and improve air quality	Improves the air quality Reduce dust particles in the air	

5.0. Recommendations

There are many policy frameworks that are directed towards the prevention and control of air pollution in China. However, as national five-year plans carry great weight in the approaches for the social and economic development of China, air pollution mitigation policies in the five-year plans must be detailed, well-defined, and context-specific. While it is true that five-year plans started as an outline to produce more defined policies as the implementation occurs, given that the dynamics surrounding these five-year plans have changed along with the global political, economic, social, and environmental changes, I believe that the plans should be upgraded to an action-plan more than just an outline. My perspective and recommendation for future policy formation are that the documents need to specify the actions that should be taken to realize the policy targets and highlight what authority is responsible for achieving each target. Identifying a responsible authority in the FYP itself would encourage the respective authorities to achieve the target within the time specified. I believe these kinds of changes would increase the effectiveness of the policies and also smooth the implementation process.

When discussing air pollution policies in the five-year plans of China, agriculture is a sector that is missing altogether. Agriculture is one of the largest sources of short-lived climate and air pollutants, such as methane. Methane is the second-highest contributor to the greenhouse effect, after carbon dioxide, and the agricultural sector is the highest anthropogenic source of methane emissions in the world. United Nations Environment Programme and the Climate and Clean Air Coalition state (CCAC) that cutting down methane emissions can significantly help slow down climate change (UNEP 2021). Methane itself has less impact on human health, but it acts as a precursor for tropospheric ozone, which causes over 1 million premature deaths of respiratory diseases worldwide (CCAC 2021). Therefore, detailed policies to control emissions from the agricultural sector must be included in the national five-year plans. It could greatly help reduce the ozone-related death and disease burden and also cut down on smog occurrences as well.

Moreover, I have observed that these five-year plans lack discussion and focus on the issue of transboundary air pollution as well. China being a large country in the Asian continent with huge geographical influence over the countries in the Asia-Pacific region mainly, its air pollution issues largely impact on neighboring countries. Liu *et al*. (2020) draw data from a number of reports and state that air pollution can travel long distances towards downwind regions, and that air pollutants such as O_3 and particulate matter can travel on intercontinental scales. Several other empirical studies recognize China as the main source of transboundary air pollution as well (Liu *et al*. 2020; Yoshitomi *et al*. 2011; Gao *et al.* 2014; Jung *et al.* 2017). While since the 1990s, there has been some progress in establishing cooperative schemes among Japan, China, and South Korea, intending to tackle transboundary air pollution, Yarime and Li (2018) state that these schemes and initiatives have not contributed towards "establishing effective international regimes to tackle transboundary air pollution across East Asia". Considering these cases, policies regarding international collaborations to control transboundary air pollution are another necessary addition that I recommend for the five-year plans of China.

Another one of my recommendations drawn from this study is that China's government should include policies to reduce the use of highly polluting raw materials with cleaner and high-quality raw materials for industries and other sectors like transportation, to their FYPs. Kumar and Gupta (2016) provide some of the examples from previous studies for the use of alternative materials in highly polluting sectors, suggesting to use of alternative raw materials in place of high-sulfur containing materials in electric utilities and use of fuels like natural gas, propane, and ethanol to reduce polluting vehicular emissions.

Policies to mandate and maintain the filtering and refining of the discharge from industries is another important step to control emissions from the industrial sector. While all 3 discussed policy frameworks highlight the importance of filtering the discharge, they still lack a proper action plan. Therefore, this area should be improved going forward.

6.0. Conclusion

Air pollution is a major cause of death and disease in the world with over 7 million deaths a year attributed to the cause. Exponential population growth, rapid urbanization, and heavy industrialization, together with many other economic, political, and social factors have driven the air quality of the planet to become worse each year. The rapid air quality improvements across the globe due to the strict lockdowns resulted from the recent COVID-19 pandemic stand to show evidence of the harmful impact human activities have on the earth's atmosphere. Apart from being a cause for the deterioration of public health, air pollution also drives climate change, causing many climate crises such as global warming, sea-level rise, crop loss, weather pattern change, and ice melting.

China, having the largest population and one of the fastest-growing economies in the world, is one of the biggest environmental polluters in the world. It is the largest carbon emitter in the world, contributing to more carbon emissions than all of the developed nations combined. Many of China's cities are among the highest air-polluted cities in the world as well. Coal-based power generation and carbon-emitting industries are the largest sources of air pollution in China, with the fossil fuel-based transportation sector being the second. Major metro cities in China including the capital city Beijing, have highly polluted air with air qualities deemed 'unhealthy', for most of the year. China has proactively understood the criticality of this issue and considered air pollution an enemy of the state and has declared a war on air pollution to mitigate the problem.

China has several policy frameworks, some directly target to mitigate heavy air pollution in the country, for example; the Blue-Skies policy. This study mainly focused on discussing the evolution of air pollution-related policies in 11th, 12th, and 13th five-year plans for national social and economic development in China. Three documents were read-through vigorously, and all the policies that have a direct or indirect impact on air pollution were categorized into 4 themes; energy sector, industrial sector, transportation sector, and urban development. The policies were further boxed into 12 sub-themes under those main themes and were analyzed according to a logic model detailed in the methodology section of this study. According to the analysis of this study, several overarching conclusions can be drawn.

- The air pollution mitigation policies have profoundly changed, in most cases, positively, from 2005 to 2020.
- Aspects of air pollution covered in national five-year plans have increased proactively from the 11th FYP started in 2005 to the 13th FYP ended in 2020.
- Air pollution mitigation and environmental protection have become a major focus with one or more separate chapters dedicated to it in latter FYPs compared to previous ones.
- While the policies addressing air pollution in all the 4 discussed sectors have improved significantly, the industrial sector is observed to have undergone the largest improvement while the transport sector has the least improvement among all 4.

Five-year plans for national social and economic development are one of the major blueprints of economic development in China. The initiative started in 1953 and so far, 13 FYPs have been implemented every five years. Currently, China is following the 14th FYP that was launched in 2021. While the five-year plans mainly focused on economic development until 2005, after the 11th FYP, environmental issues like air pollution gradually came into the spotlight in the plans. While 11th FYP didn’t have many detailed policies related to air pollution mitigation, the plan recognized air pollution as a concern and pledged to take action to mitigate it. The air pollution-related policies in the 11th FYP were improved and carried on to the 12th FYP, and several positive additions could be seen in the aspect of air pollution mitigation in the 12th FYP. The policies were detailed and context-specific compared to the 11th FYP, yet they still needed many improvements. Some of the aspects of air pollution that were not addressed in the 11th FYP were however addressed in the 12th FYP. Compared to the 11th and

12th FYPs, the 13th FYP contained some well-defined, context-specific, and actionable air pollution mitigation policies. 13th FYP also recognized particulate matter (PM2.5) as a major hazard for the first time and introduced strict and defined targets to reduce PM pollution in China. This can be considered a major improvement in air pollution policies in the history of five-year plans, given a large number of China’s annual death and DALYs lost are caused by PM pollution. One of the major reasons for having much improved and refined air pollution mitigation policies in 13th FYP, compared to 11th and 12th FYPs could be the public health impact and the backlash due to frequent heavy smog episodes from 2010 to 2013, which forced the government to take strict actions to reduce air pollution in China. This led the ruling part to include well-developed, context- and pollutant-specific policy targets in the 13th FYP in 2015, targeting to reduce highly harmful pollutants such as PM2.5. Jiang Yifan, a reporter for China Dialogue quotes the minister of ecology and environment in China, Huang Runqiu stating that targets for reducing PM2.5 pollution in the 13th FYP period (2015-2020) had been met and exceeded (Yifan 2021). Therefore, it can be deduced that the policy targets in the 13th FYP were effectively implemented in the past 5 years.

While the current 14th FYP has not been extensively discussed in this study, it is important to note that it contains many improved policies related to air pollution and climate crisis mitigation. The 14th FYP is the first five-year plan that was published after China committing to carbon neutrality, so the climate, energy, and air quality targets are being closely monitored. During the period of the 13th FYP, the Chinese government tackled air pollution and climate change vigorously and received a lot of public support for the cause (Yifan 2021). With all the developments in the related policies in 14th FYP, this synergy is expected to be carried out over the next five years successfully. If implemented effectively, these policies have the potential to improve the quality of air, soil, and water successfully in the near future.

It is my conclusion and perspective that the air pollution-related policies in China's national five-year plans have evolved greatly during the 15 years from 2005 to 2020, and the current FYP stands to prove that. While it is a great outcome, the ambitious goals can only be achieved through strict impose of these policies in all the sectors and monitoring the implementation closely to prevent any corruption in the implementation. Industries have been caught ignoring these policies and continuing to work at full capacity by faking records, and the government needs to impose strict punishments for any such violations to ensure that the protocols are being followed. Given China is one of the largest, fastest-developing, and most powerful nations in the world, their environmental quality including soil, air, and water, and climate greatly impact the whole world. China, taking better actions to improve the environmental and climate conditions may improve the whole world's condition to a great length.

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