Policy Recommendations for Reducing PM 2.5 from Coal Power Plants in Suzhou

Nathan C. Oliver[1]
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[1]Department of Electrical and Electronic Engineering, Xi'an Jiaotong Liverpool University, Suzhou, China 215123

Corresponding email: Nathan.oliver17@Student.xjtlu.edu.cn

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TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

SUMMARY

One of China's greatest threats to its people is air pollution. It is estimated 1.6 million Chinese die every year as a result of polluted air from industry, transportation, and agriculture. The deadliest air pollutant in China is PM 2.5, which has led to the deaths of nearly 1 million people, and 40% of those deaths can be attributed to the burning of coal. Burning coal has been a major driver for economic development in China, in particularly Suzhou. In the city of Suzhou, PM 2.5 levels in 2016 exceeded World Health Organization recommendations by about 4.5 times. It is crucial that the burning of coal be controlled to reduce PM 2.5 in Suzhou. Policies towards coal power plants will have the largest effect on reducing PM 2.5 from coal-burning sources. It is recommended that the Suzhou government implement a policy to require the installation of fabric filters (FF) at coal power plants to reduce PM 2.5 emissions, which will cost $950 million to install. The Suzhou government will have to either subsidize the FFs or provide tax breaks to power plants that install the filters due to the high capital costs of the filters. A $5 billion natural gas (NG) subsidy is recommended to increase and incentivize NG power production in China, and may result in the construction of a NG power plant in Suzhou. Continued investment in solar, wind, and battery storage by the national government is needed to reduce Suzhou's dependence on coal as its main source of electricity. These policies will improve the health of Suzhou's citizens while maintaining proper economic growth into the future.

INTRODUCTION

The World Health Organization estimated that 9 out of 10 people worldwide are breathing "highly polluted air", resulting in the deaths of 7 million people every year [1]. Deaths related to air pollution has been one of the greatest challenges to the country with the largest economy in the world, China. As a result of changes in economic policies since the 1980s, China has transformed from an agricultural economy to industry. This has brought undesirable air pollution to China's densely populated east coast, resulting in 1.6 million premature deaths per year [2]. WHO has established air quality guidelines for gases and particles that negatively impact the health of humans. They have identified four major components of air pollution that result in premature death, which includes sulfur dioxide (SO_2), nitrous oxide (NO_2), ozone (O_3), and particulate matter (PM). PM is considered one of the most hazardous air pollutants to human life as it can enter the lungs and the bloodstream [3], leading to heart and lung issues, and premature death [4]. PM are aerosolized particles that includes soot, dust, smoke, and dirt [3]. PM can be divided into PM 10 and PM 2.5, which is defined as PM less than 10 μm and 2.5 μm in diameter, respectively. PM 2.5 is one of the most dangerous health hazards in China, causing 915,000 premature deaths per year, and the fifth leading cause of death in China [5].

Premature deaths caused by PM 2.5 is a common problem across all major cities in eastern China, including Suzhou. As one of China's fastest developing cities, Suzhou has rapidly increased industrial and commercial development, resulting in air pollution from industry, power plants, and traffic. Figure 1 summarizes the comparison of the WHO air quality guidelines [4] for gases and particles identified as major health risks and the air quality for Suzhou in 2016 [6].

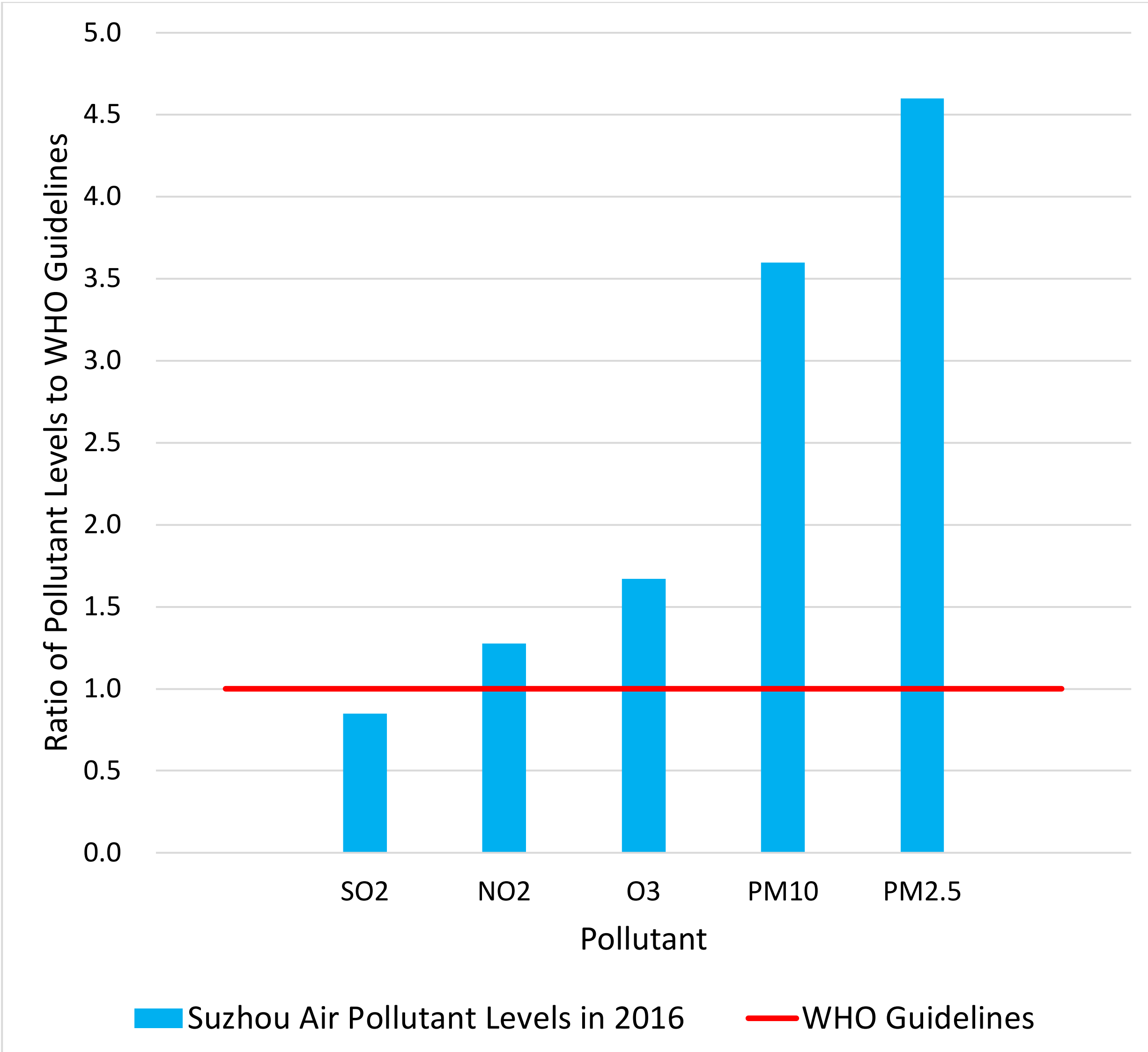

Figure 1: Comparison of WHO air quality guidelines [4][6]

Comparing WHO air quality guidelines and air pollution data from the Suzhou government, average levels of PM 2.5 in 2016 exceeded recommended health standards by 4.5 times. PM 2.5 levels were the most severe for any type of air pollution in Suzhou. It should also be noted that PM 2.5 is a part PM 10, meaning if PM 2.5 levels are reduced, then PM 10 levels will also be reduced.

There are various sources of PM 2.5, including industry, agriculture, transportation and natural sources. In China, the largest source of PM 2.5 comes from coal-burning sources [5]. The Health Effects Institute uses population-weighted measurements to show the amount of PM 2.5

for different provinces of China. Population-weighted is defined as the average PM 2.5 measurements, with each measurement weighted towards the population of each measurement. For example, if two PM 2.5 measurements for two different cities are 50 and 30 ppm, the population-weighted average is not necessarily 40 ppm. The weighted average will be skewed towards the city with the larger population. Figure 2 shows the amount of PM 2.5 coming from coal burning and non-coal burning sources.

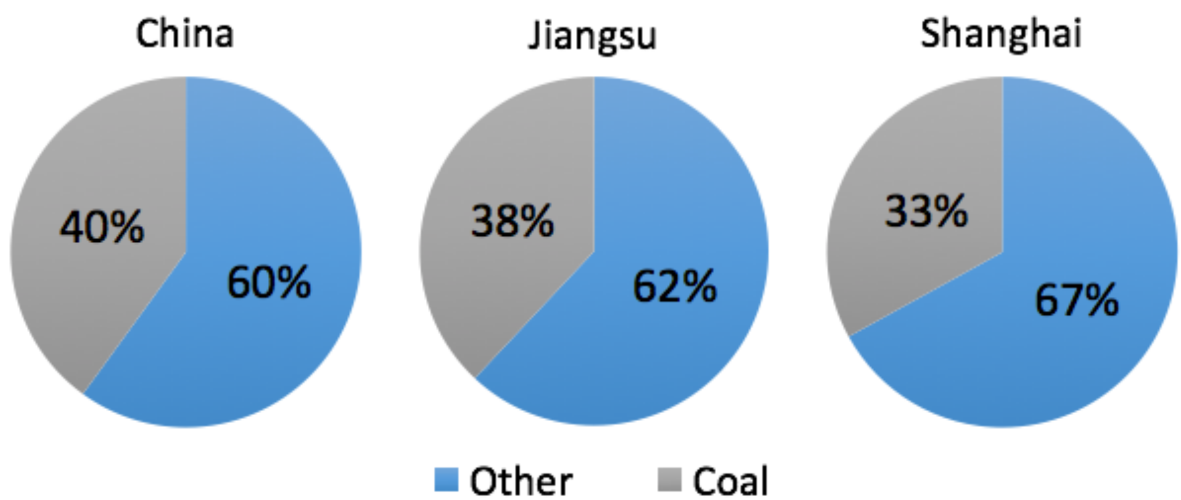

Figure 2: Sources of PM 2.5 in China, Jiangsu, and Shanghai [5]

There is no specific data for Suzhou, but data is available for China, Jiangsu, and Shanghai. Suzhou is a city in Jiangsu province, and Shanghai is a direct-controlled municipality less than 100 km from Suzhou. Although there is no data for Suzhou, PM 2.5 data for these three locations shows that PM 2.5 from coal-burning sources is the leading source of PM 2.5 in Suzhou. 40% of the PM 2.5 in China comes from coal [5]. This also means 40% of the deaths attributable to PM 2.5 are a result of burning coal. This results in 366,000 premature deaths per year in China as a result of breathing PM 2.5 from coal [5]. In China, Jiangsu, and Shanghai, PM 2.5 deaths from coal-burning sources were the 12th, 11th, and 13th leading causes of death, respectively [5].

PM 2.5 coal-burning sources can further be broken down into more specific categories, such as industry, power plants, and residential. Figure 3 summarizes the data for PM 2.5 coal-burning sources for China, Jiangsu, and Shanghai. Industries and power plants that burn coal produce the most PM 2.5. Figure 4 shows that power plants burn 51% of all the coal used in Suzhou [7]. This shows that implementing policies that limit the amount of PM 2.5 released from coal power plants will have a significant impact on the health of Suzhou's citizens. It is expected that by 2030, the number of deaths attributable to PM 2.5 will increase, as can be seen in figure 5 [5]. This is mainly a result of an aging population [5]. Not only will deaths from PM 2.5 increase, the proportion of deaths due to PM 2.5 from coal-burning sources is expected to increase [5], as can be seen in figure 6. In order for deaths caused by PM 2.5 from coal-burning sources to be reduced in the future, it is necessary to implement short and long-term policies that will have an immediate and permanent impact.

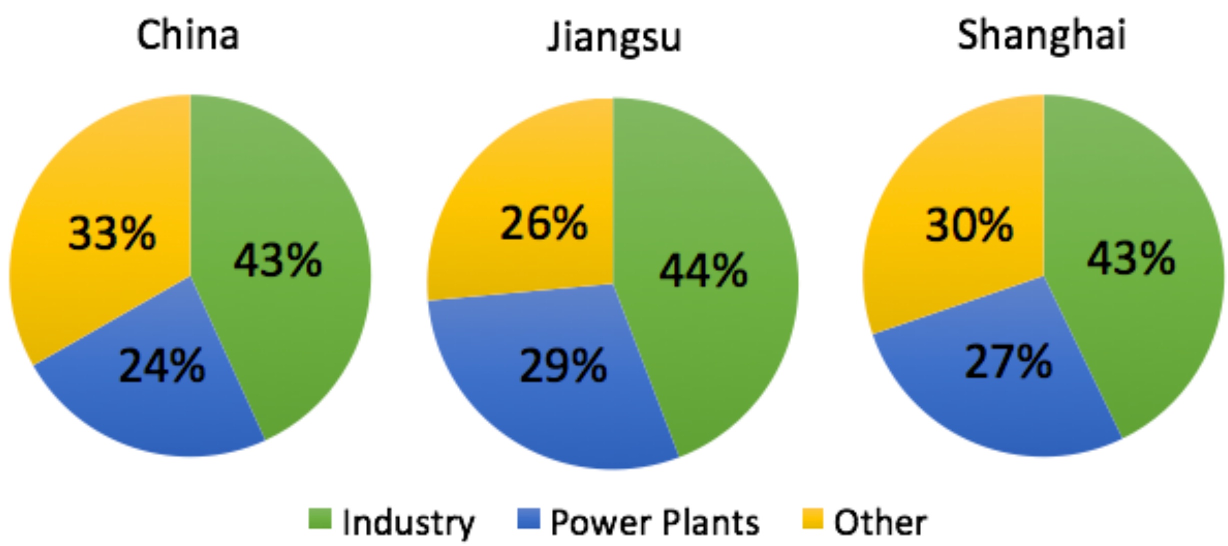

Figure 3: Coal-burning sources of PM 2.5 in China, Jiangsu, and Shanghai [5]

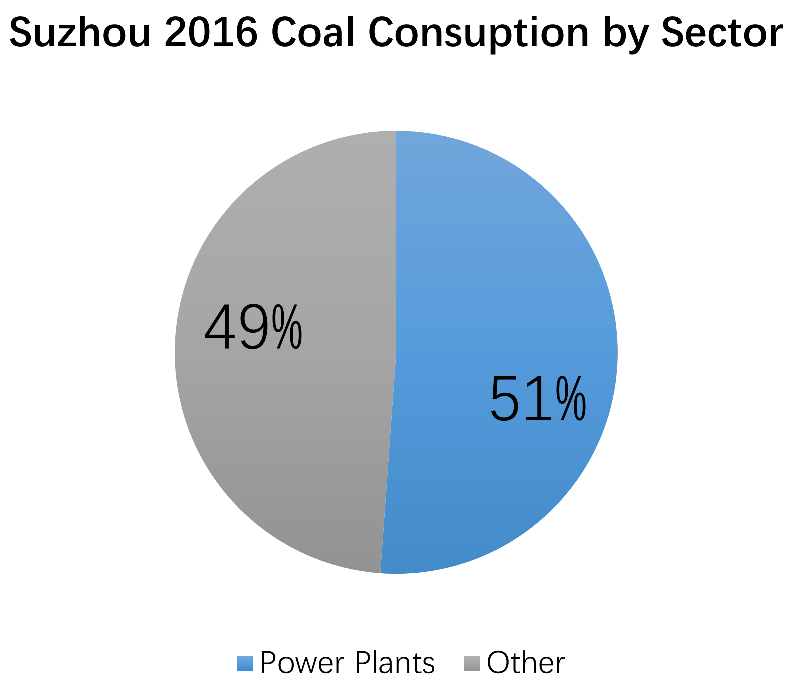

Figure 4: Suzhou 2016 coal consumption by sector [7]

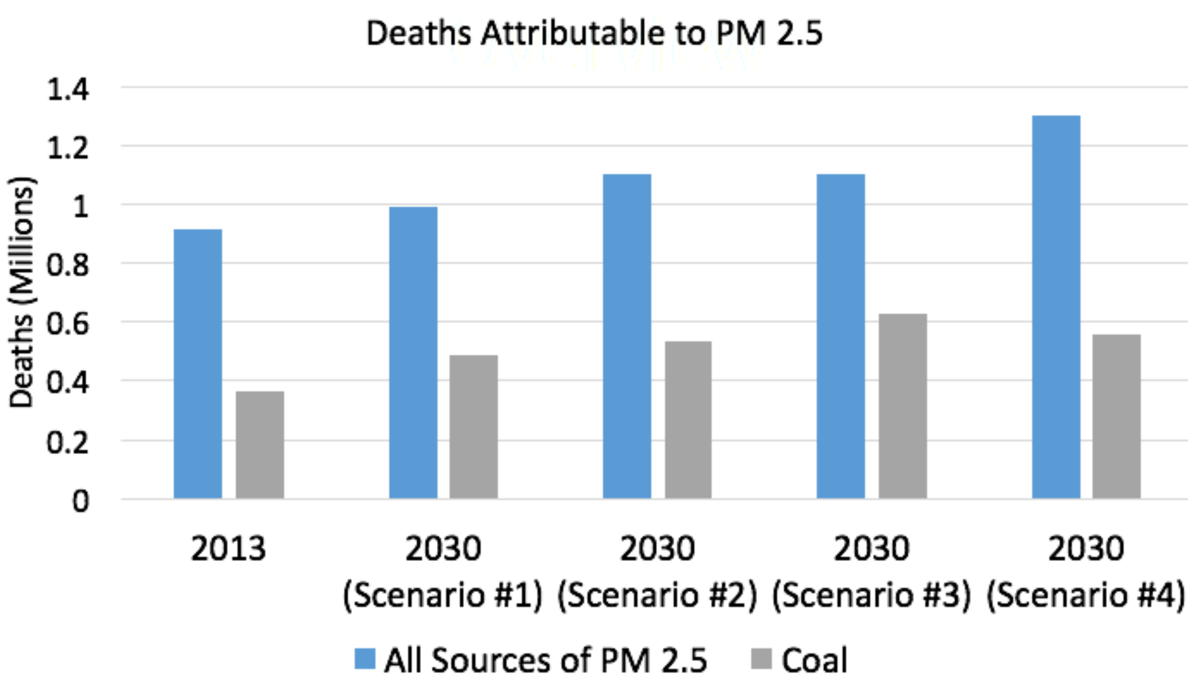

Figure 5: Deaths attributable to PM 2.5 and coal-burning sources [5]

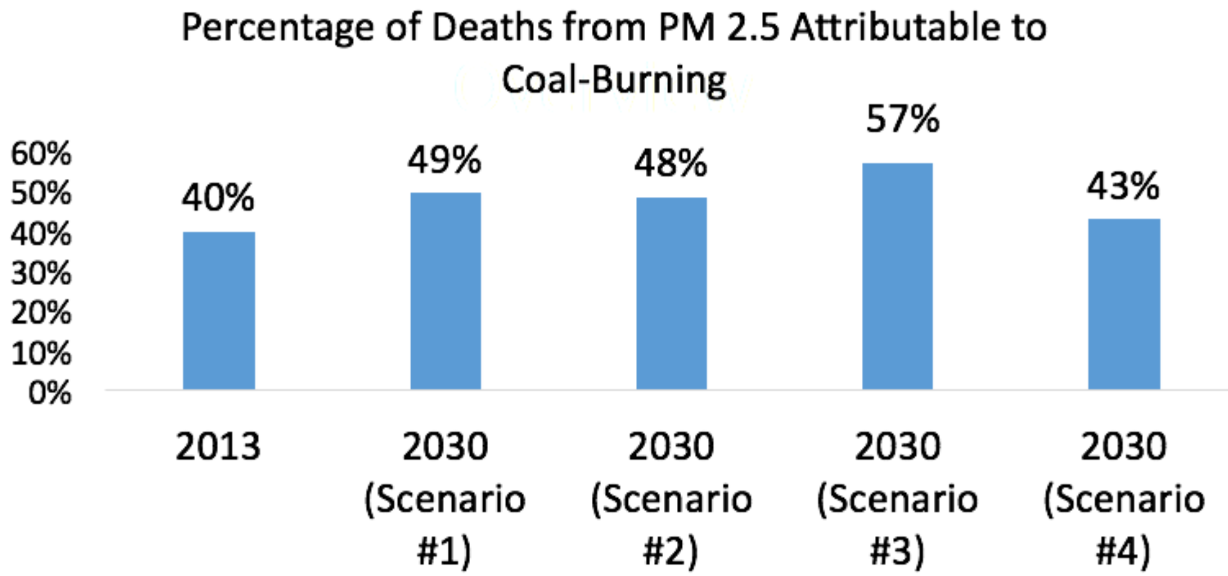

Figure 6: Percentage of deaths from PM 2.5 attributable to coal-burning [5]

POLICY INTRODUCTION

There are various policies that could be used to reduce the amount of PM 2.5 from coal that could have an immediate or delayed impact. Standard policies, as well as new ideas for reducing PM 2.5 are briefly summarized below.

Filters

Coal power plants can use a variety of filters to remove gases or particles from the flue gas before they are released into the atmosphere. Filters can be used to filter out gases and particles listed by WHO as the most detrimental forms of air pollution, including SO_2, NO_2, and PM [8]. Filters can be placed in different locations within the power plant, such as in the smokestack, and at the exhaust of the boiler. Listed below are the most common types of filters used in coal power plants.

Electrostatic precipitators (ESP) is a type of filter placed in the smoke stack of the power plant, and uses electricity to charge particles that can then be attracted by a plate. The accumulated dust on the plates can then be removed [9]. 90% of China's coal power plants currently use ESPs to reduce PM 2.5 emissions, but their removal rate is low [10]. When combined with wet flue gas desulfurization (WFGD), their PM 2.5 removal rate is approximately 98% [10]. The 98% removal rate is not high enough to meet Chinese standards [10]. In the US, ESPs have been mostly replaced with fabric filters (FF) and India is looking to replace ESPs with FFs [10]. Innovations in FFs have made them more efficient and have extended their service life. The costs for FFs are $274/kW for units less than 100 MW, and $141/kW for a unit larger than 700 MW [8].

Typical FFs use tube-shaped filters enclosed in a box with one inlet and two outlets to filter out PM and other particles from the flue gas [11]. The two outlets are for the filtered air and the dust particles removed during filtration. Hundreds or thousands of filters can be used in a single FF. In a small-sized 250 MW coal-power plant, a FF will have 5000 filters with a surface area of 46,500 m^2 [12]. During operation, dust will collect on the surface of the filters, decreasing proper air flow and pressure. Regular intervals of compressed air or water are injected into the filter bags to separate the dust from the filters. The dust collects at the bottom of the container and is removed.

Flue Gas Temperature Reduction

Reducing the temperature of the flue gas is a new idea that could potentially substantially increase the amount of PM 2.5 filtered using current technologies. Condensable particulate matter (CPM) is a type of PM that is a gas as it flows through the smokestack and condenses into a particle once it is released into the atmosphere. One study has shown that 76% of PM 190 emitted from coal-power plants is CPM. This is relevant to PM 2.5, since it is by definition also considered PM 10 [13].

The majority of research and technology has been focused on filterable particulate matter (FPM) which is a particle while inside the power plant and can be filtered using standard practices, as opposed to CPM which cannot. Currently regulations only target FPM. It is suggested that in order for CPM to be filtered using current filters is to cool down the flue gas before it enters the atmosphere. By reducing the temperature, CPM will condense into a filterable particle. It is believed that the largest CPM emissions are from coal-burning sources. Presently, FPM emissions have been substantially reduced, so more focus needs to be placed on CPM research to further reduce PM 2.5 emissions from coal-burning sources [13].

Replace Coal with Natural Gas and Renewables

Renewable energy produces no emissions while generating electricity, and is a natural choice to replace coal power plants. In order to incentivize communities to increase installation of wind Turbines and solar panels, one idea is to implement a feed-in-tariff. This tariff allows home owners to sell excess electricity above the market price [14]. If a home owner installs a solar panel or wind turbine to generate electricity for their home, they may also connect to the local grid to sell excess electricity to the utility company. If the selling price is higher than market value, this may incentivize customers to invest in renewable energy [14].

Renewable forms of energy are expected to be a major part of the Chinese national grid in the future, with 800 to 1000 GW of electricity coming from solar, wind, and other forms of clean energy by 2030 [15]. This is about 50-60% of China's electrical capacity in 2016 [16]. By 2040, it is predicted 40% of China's electricity will come from solar and wind [16]. This 40% would comprise about 78% of China's 2016 electrical capacity [16].

Since renewable energy cannot replace coal overnight, using renewables to replace coal in order to reduce PM 2.5 will need to be a plan that is long-term. Other measures will need to be implemented in the short-term to reduce PM 2.5.

Although natural gas (NG) is a fossil fuel, PM emissions from NG power plants are negligible [17]. Currently, NG power generation in China has been growing at a 10% annual growth rate, and the Chinese Government is using NG power as a way to fight air pollution and climate change [18]. The United Kingdom and the United States have already been transitioning from coal power to NG plants, and China has been increasing NG consumption while slowly weaning its way off of coal [19]. In order for China to reduce coal consumption, the Chinese government has implemented a cap-and-trade policy, but is expected to have negative impacts on natural gas. It is expected that NG will only comprise 4.2% of electricity generation by 2020, much lower than their target of 10% [20]. In order to avoid the reduction in NG power production, a $5 billion NG subsidy can be implemented in conjunction with the cap-and-trade policy to increase NG consumption while decreasing coal use [20]. This policy will drastically reduce PM 2.5 emissions while maintaining the goal of decreasing coal use.

POLICY IMPLEMENTATION

For policies relevant to reducing PM 2.5 in Suzhou, it is advisable that policies relevant to installing FFs at large coal power plants, natural gas subsidies to incentivize construction of natural gas power plants, and the continued installation of wind and solar energy to replace smaller and less efficient coal power plants.

Installation of Fabric Filters (FFs)

Suzhou currently has approximately 9030 MW of installed capacity, and the installation of FFs will be directed at Suzhou's five largest coal power plants [21]. Suzhou has five coal power plants with a capacity over 1000 MW [21], and are listed below.

Table 1: Suzhou coal power plants above 1000 MW capacity

Power Plant	Location within Suzhou	Capacity
Changshu Electric Company Plant	Changshu	1200 MW
Huali Electric Company of Changshu	Changshu	1950 MW
Huadian Wangting Power Plant	Xiangcheng	1200 MW
Suzhou Industrial Park Huaneng Power Plant	Taicang	1200 MW
Zhangjiagang Shazhou Power Plant	Zhangjiagang	1200 MW

These five power plants combine for an installed capacity of 6750 MW. It has been recommended that coal power plants with larger capacities, such as above 600 MW, improve their efficiencies, while smaller, less efficient power plants be shutdown [22]. Due to the massive capital needed to install FFs at power plants, it is advised that a policy be put in place as soon as possible to require the installation of FFs at Suzhou's five largest power plants in order to reduce PM 2.5. Using $141/kW as the cost of FFs for coal power plants larger than 600 MW [8], the capital necessary to install FFs at these five power plants is $950 million. The investment required is enormous, but compared to a new natural gas power plant, wind farm, or solar PV installation, this option is much cheaper. A summary of the investment required to improve or replace coal power plants in shown in figure 6.

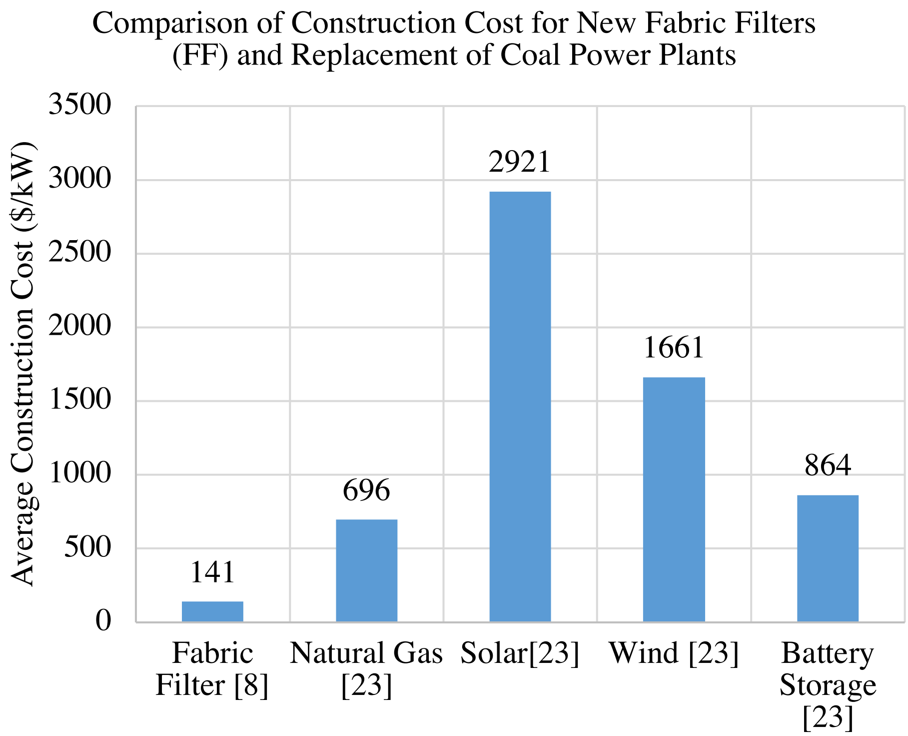

Figure 7: Average construction cost of fabric filters and new power plants [8][23]

A new natural gas power plant that emits essentially no PM 2.5, is almost 5 times as much as installing a FF at an existing coal power plant. Also, it is expected that coal power plants will still comprise 38% of the China's electricity generation in 2040, an increase of 8% of installed coal capacity from 2016. This shows that Suzhou will not be able to completely eliminate coal as a source of electricity, therefore the capital investment of FFs will be vital to improving Suzhou's air quality and reducing PM 2.5. Due to the heavy investment of the FFs, it is recommended the Suzhou government can either subsidize the cost of FFs or provide tax breaks to power plants that install them.

Replacement of Coal Power Plants with Natural Gas

It is recommended that the national government implement a $5 billion NG subsidy in combination with a cap-and-trade policy to increase NG consumption [20]. This may incentivize an electricity company to investment in a natural gas power plant in Suzhou. This policy is not crucial to the sustainability of clean air and continued economic development in Suzhou. This is due to the fact that NG power plants in China are much more expensive compared due to the high price of NG [24]. The United States will be able to use NG power plants as a way to reduce coal consumption, but China will most likely not be able to drastically increase electricity generation from NG in the near future. By 2040, NG will only comprise 7% of China's installed electrical capacity, while wind and solar will comprise 18% and 22%, respectively [16]. Generating electricity from wind and solar will be the ultimate goal for China and the rest of the world to decrease CO_2 emissions, resulting in fewer PM 2.5 emissions. Between now and a world generated primarily by renewable clean energy, cleaner coal power plants will be the short-term solution to reducing PM 2.5 in China. It is expected that existing coal power plants in China will improve their efficiencies and pollute less [22][24]. Using cleaner coal power plants as the solution to reduce PM 2.5 before renewables can be use on a massive scale appears to be the current trajectory for China [24]. As a result of improving efficiencies of existing coal power plants and the expected economic unfeasibility of NG power plants, it is anticipated that coal power will continue to provide the necessary energy generation.

Replacement of Coal Power Plants with Wind and Solar

It is not expected that coal power plants can be replaced in the next 20 years, but instead solar and wind will be used to increase electrical capacity. Due to current projections and the expected decrease in price of renewables, particularly solar and battery storage, it is not recommended to implement a policy with regards to incentivizing the installation of renewable energy sources. Continued investment from the national government will allow solar and wind to occupy a larger share of electrical capacity in China.

Positive and Negative Impacts on Society, the Economy, and the Environment

It is expected that from a sustainability perspective, the greatest impact these policies will have is on society. It is unclear how much of an impact these policies will have on the reduction of PM 2.5, as there is no clear data that can measure this effect, but it is clear that they do reduce PM 2.5. Installing FFs will have a noticeable improvement on the levels of PM 2.5, and other countries such as the United States have already installed FFs in about 36% of their coal power plants [8] due to their high removal rate of PM 2.5 [10]. The positive impact of reducing PM 2.5

outweighs any negative impacts incurred on society, the economy, and the environment because PM 2.5 from coal-burning is one of the leading causes of death in China, Jiangsu, and Shanghai [5].

There are a few negative impacts that may occur as a result of these policies. The massive subsidy from the Suzhou government for installing filters will redirect investment into other areas. This money could be used to invest in the community, such as education. The other impact of these policies is related to the rapid installation of solar, wind and battery storage. One problem that could occur is if they are installed improperly, this could result in a shortage of electricity for periods of time due to the intermittency of power generation from solar and wind. This is unlikely, and it is expected that the national grid will account for this, and install the required amount of battery storage to store electricity when the sun is shining and the wind is blowing, and discharge electricity when needed.

CONCLUSION

It is recommended that the Suzhou government implement a policy as soon as possible to subsidize the installation of FFs for the five largest coal power plants in Suzhou. This is due to the realization that coal will continue to be a major source of electricity in China in the near future, and that large coal power plants will not be able to be replaced. Coal power will become cleaner and more efficient in China, yet filters, particularly FFs, will allow them to reduce PM 2.5 emissions. This policy is crucial for Suzhou to reduce PM 2.5 and allow a generation of children to grow up with cleaner air than their predecessors.

The second recommendation is for the Chinese government to implement a subsidy for NG to incentivize the investment in NG power plants. This is not vital for Suzhou, as it is expected that coal, solar, and wind will be the major sources of electricity in the future. This policy may result in the construction of a NG power plant in Suzhou, but the construction of solar and wind projects, and the installation of FFs at coal power plants will be the most important catalysts for improving the air quality in Suzhou. Once the prices of wind, solar, and battery storage become more cost competitive with coal, then major installations of renewable energy will be able to complement coal as sources of energy.

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