Potential of Premature Death Mitigation through Efficiency Improvements in Coal Power Plants in China

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1. Introduction

Serious Air Pollution in China: Since the 1970s, China has experienced serious air pollution. The average concentration of $PM_{2.5}$ across China was 54 μg/㎥ (in 2013), which is more than five times higher than the WHO standard (i.e., less than 10 μg/㎥). In 2015, $PM_{2.5}$ caused more than one million premature deaths in China and shortened the national average life expectancy by 25 months (IEA, 2016).

Contribution of Coal Power Plants in China to air pollution: The contribution of coal power plants to total $PM_{2.5}$ emissions in China is ~6% (Zhao et al., 2013). <u>However, coal power plants are often located in densely populated urban areas, threatening the health of neighbors (IEA, 2016).</u> According to GBD (2016), the number of premature deaths due to $PM_{2.5}$ emissions from coal power plants will increase to up to 110,000 by 2030.

2. Research Objective

Previous Studies and Our Motivation: The key to mitigate the number of premature deaths is to estimate the current number of premature deaths. For example, HEI (2016; 2019) estimated the "number" of premature deaths due to $PM_{2.5}$ emissions from coal power plants in China. However, the existing studies failed to identify how much "potential" each area has for mitigating premature deaths. <u>To overcome this challenge, our study proposes a novel integrated research framework that combines data envelopment analysis (DEA) with chemical transport simulations and health impact assessments to estimate the premature death mitigation "potentials".</u>

Research Question: <u>Which areas have the potential to mitigate premature deaths due to $PM_{2.5}$ from coal power plants in China?</u>

3. Material and Method

Data Construction: We collected input-output data (Capital, Coal consumed, Electricity produced, SO_2, NO_x, and $PM_{2.5}$) with geographical information for 316 coal power plants in China (40% coverage) from China Electricity Council (2014) and Tong et al. (2018).

Environmental Efficiency Evaluation by DEA : We applied the DEA to the constructed input-output data to estimate the environmental efficiency for 316 power plants. The DEA is a mathematical programming method for estimating the relative production efficiency scores, which are standardized between 0 (lowest) and 1 (highest), of multiple decision-making units (i.e., power plants) based on their input-output data.

Emissions Reduction Potentials Estimation by DEA: Comparing the most efficient technology (i.e., score: 1) with other inefficient technologies (i.e., score: 0-1), the emissions reduction potential for SO_2, NO_x, and $PM_{2.5}$ emissions through efficiency improvements for each power plant can also be estimated. The current emissions from original data are defined as the "baseline" scenario, while the emissions of each air pollutant after the full efficiency improvement of all inefficient power plants are defined as a "mitigated" scenario.

Premature Death Mitigation Potential Estimation: We employed chemical transport models and health impact assessment models to the air pollutant emission data in the two scenarios to estimate the premature deaths by 45㎢ grid in both scenarios. Finally, the mitigation potential of premature deaths by the grid is estimated by differentiating the premature deaths in the two scenarios.

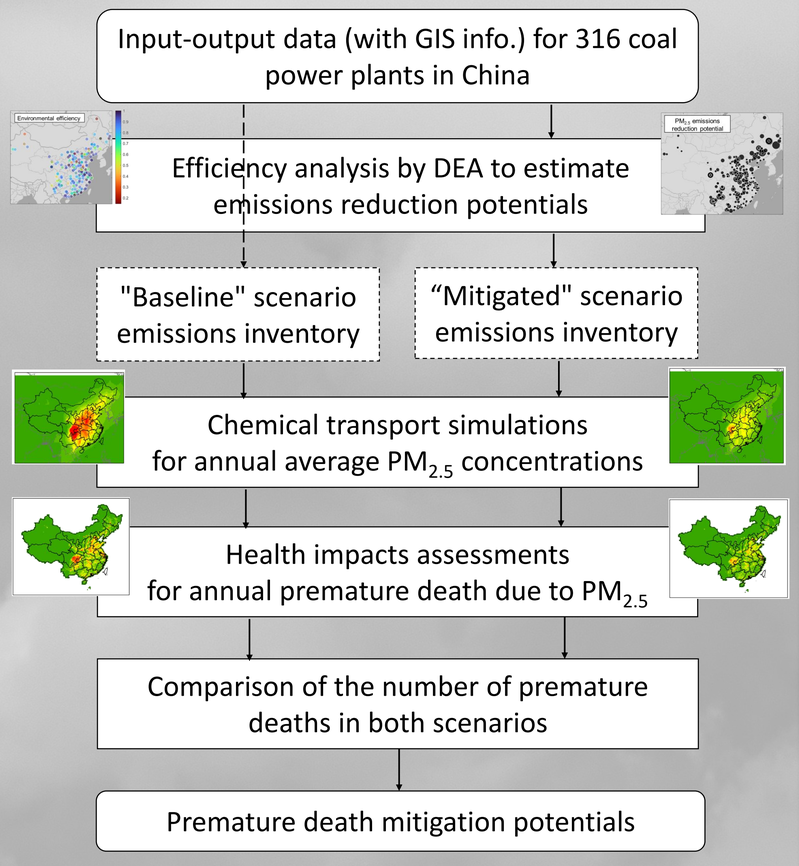

Fig. 1. Research flows

4. Result and Discussion

Environmental Efficiency: There were 15 (out of 316) power plants with the highest environmental efficiency (i.e., score: 1). The average environmental efficiency of all plants was 0.8. The production activities of power plants in the economically developed coastal areas had high environmental efficiency, while those in the northeast and southwest areas had low environmental efficiency.

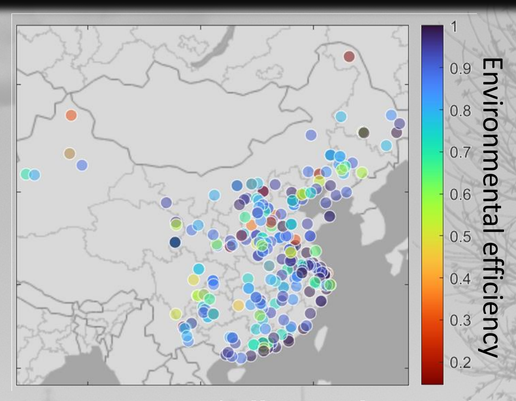

Fig. 2. Environmental efficiency for 316 plants

Emission Reduction potential of air pollutants: The cumulative emission reduction potentials were SO_2: 1685kt (56%), NO_x: 688kt (21%), and primary $PM_{2.5}$: 132kt (48%). There were large emission reduction potentials in the southwest region for SO_2, and in the northeast and middle Yellow River areas for NO_x and $PM_{2.5}$. There was little emission reduction potential in the coastal power plants.

Premature Death Mitigation Potentials: Annual average $PM_{2.5}$ concentrations were highest around the southwestern provinces of Sichuan, Chongqing, and Guizhou. Transboundary pollution to Japan, South Korea, and other neighboring countries was also observed. The current number of premature deaths due to $PM_{2.5}$ emissions from 316 coal power plants in China was ~37,000 ("baseline" scenario), and the number of premature deaths after full efficiency improvements was ~22,600 ("mitigated" scenario). In other words, the mitigation potential for premature deaths due to $PM_{2.5}$ emissions from 316 coal power plants in China was ~14,400 (39%). The 45㎢ grid with the highest premature death mitigation potential was Chengdu with 127 people (49%), and the two adjacent grids also had high premature death mitigation potential. Given this, <u>priority must be given to improving the efficiency of power plants that affect the southwestern region.</u>

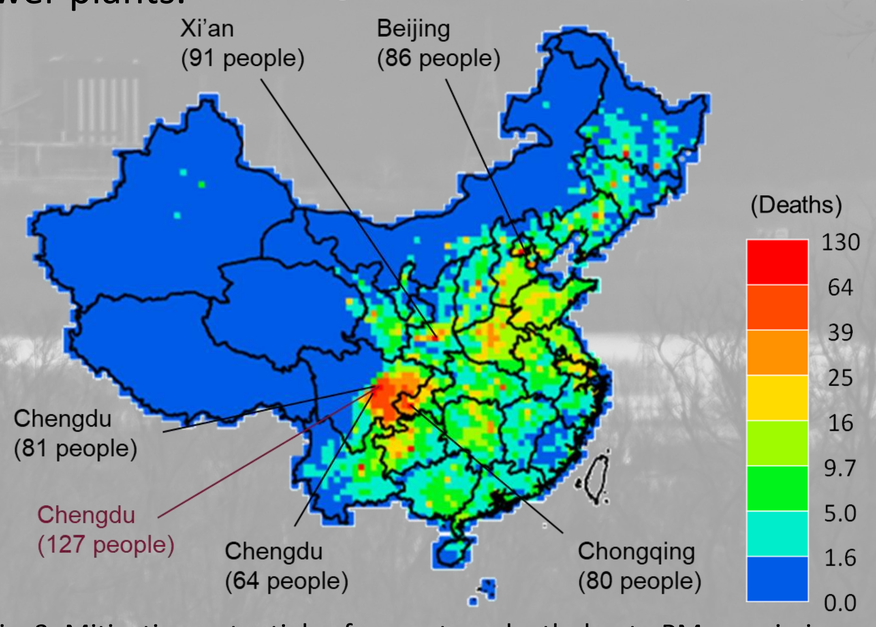

Fig. 3. Mitigation potentials of premature death due to $PM_{2.5}$ emissions