How to Reach Air Quality Standard of $PM_{2.5}$ in China by 2030?

——a numerical simulation discussion based on energy and end-of-pipe control scenarios

Main conclusions:

According to the requirements in the *"Air Pollution Prevention and Control Action Plan"* (Action Plan) released by the State Council in September 2013, and consistent with the Ministry of Environmental Protection's 2013 timetable for reaching national air quality standards, all provinces and cities in China must make middle- or long-term plans and spare no effort to reach the air quality standard by 2030.

In this study, to assess the potential of achieving long-term improvement of air quality in China, we analyzed seven scenarios. The scenarios combined five different potential energy policy pathways, with two different end-of-pipe pollution control strategies. The five energy policy pathways were: a reference 2015 condition (REF); a 'baseline current policy' projection (BASE); and three more ambitious energy policy projections (RCP4.5, SAVE, and DEEP). And the two end-of-pipe strategies were: the 'business as usual' case (BAU), and an enhanced 'best available technology' case (BAT). Combined, the seven scenarios analyzed were: REF-BAU, REF-BAT, BASE-BAU, BASE-BAT, RCP4.5-BAT, SAVE-BAT, DEEP-BAT. In the analysis, the air pollutant emissions inventory and air quality status was simulated for the seven scenarios in China in 2030. The quantitative simulation results were analyzed to judge the effects of different air pollution control measures on the reduction of $PM_{2.5}$ concentrations across 74 key cities in China. This provides a scientific reference-point for China's future air quality policy action.

Simulation results show that:

1. Compared to the reference year (2015), each of the different energy policy scenarios can to some extent reduce $PM_{2.5}$ concentrations in 2030. However, only those more ambitious scenarios which include both significant changes to China's energy system structure, and strengthened end-of-pipe pollution control measures will allow all of the 74 key cities achieve the national air quality standard. Put in terms of the study's scenarios: only the energy policy (SAVE) and (DEEP) scenarios, in combination with stronger end-of-pipe strategies (-BAT) allowed all cities to reach the air quality standard by 2030 (i.e. an annual mean $PM_{2.5}$ concentration of 35μg/m^3, also known as WHO interim-Ⅰ standard).

   Moreover, the simulation results also indicate that for the two most ambitious energy policy and end-of-pipe scenarios (SAVE-BAT and DEEP-BAT), improvement in air quality and reduction in greenhouse gas (GHG) emissions can be achieved simultaneously. For both scenarios, a peak in carbon emissions can be reached before 2030 – with 2030 CO_2 emissions having dropped by 1% and 17%, respectively, as compared to 2015.

   It should be noted however that for the SAVE-BAT scenario, some risk and uncertainty remains in cities being able to meet the national air quality standard: some of the cities in the simulation achieved annual $PM_{2.5}$ concentrations that were only slightly lower than the 35μg/m^3 standard. On the other hand, the more aggressive DEEP-BAT scenario saw all of the key cities reach the standard in 2030. In SAVE-BAT and DEEP-BAT scenarios, percentage of cities reaching the standard in 2025 is 54.1% and 62.2% respectively.

2. Simulation results show that the more aggressive SAVE-BAT and DEEP-BAT can allow more than half of the cities reach the more ambitious level of WHO Interim-II standard (i.e. annual mean PM2.5 concentration of 25μg/m^3). In these scenarios, 50.0% and 56.8% respectively, of the key cities in China could reach the WHO II standard by 2030.

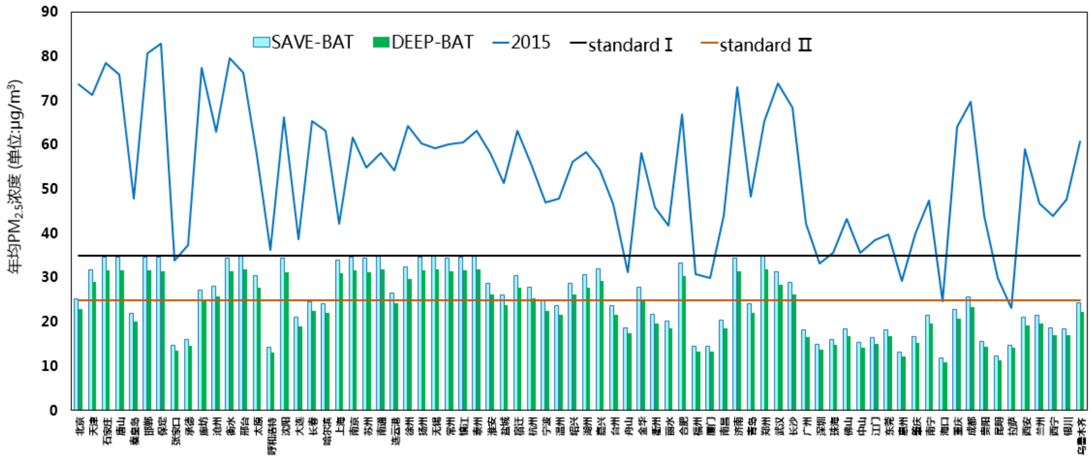

Figure 0-1 Annual mean concentration of $PM_{2.5}$ in different cities in 2030 in SAVE-BAT and DEEP-BAT scenarios

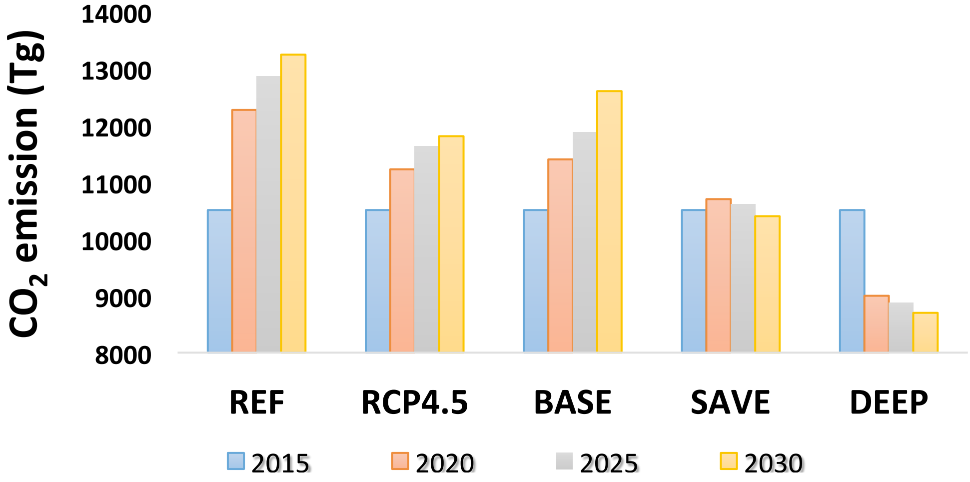

Figure 0-2 CO_2 emission in different scenarios during 2015 and 2030 (unit: Tg)

3. Although the business as usual end-of-pipe pollution control strategies do reduce air pollution constituent emissions, these strategies by themselves will not allow all of China's cities to meet the national air quality standard by 2030. In the simulations of the business as usual end of pipe scenarios (-BAU), SO_2, NOx, and $PM_{2.5}$ emissions were reduced by 30.5%, 5.9% and 27.2% respectively in 2030 (compared to 2015); however, in these scenarios, only 32.4% of key cities in China could meet the air quality standard of 35μg/m^3 as annual mean concentration.

4. End-of-pipe pollution control strategies alone will not be enough to fully meet China's air quality goals; adjustments to the energy structure are also necessary. In the simulated scenarios where enhanced end-of-pipe strategies (-BAT) were applied, but without further adjustment in energy structure (i.e. those REF, BASE, RCP4.5 scenarios), at most only 70.3% of the cities in China would reach the air quality standard in 2030, even though

compared with 2015, scenarios with these policy combinations could reduce SO_2, NOx, $PM_{2.5}$ and VOC emissions in 2030 by approximately 70%, 50%, 50% and 60% respectively. And geographically, over half of the cities in the North China Plain and Yangtze River Delta regions would be at the risk of exceeding the standard. The simulation results show that only those scenarios that include enhanced end-of-pipe measures and energy structure adjustments can allow all cities to meet the goals (see Figure 0-3).

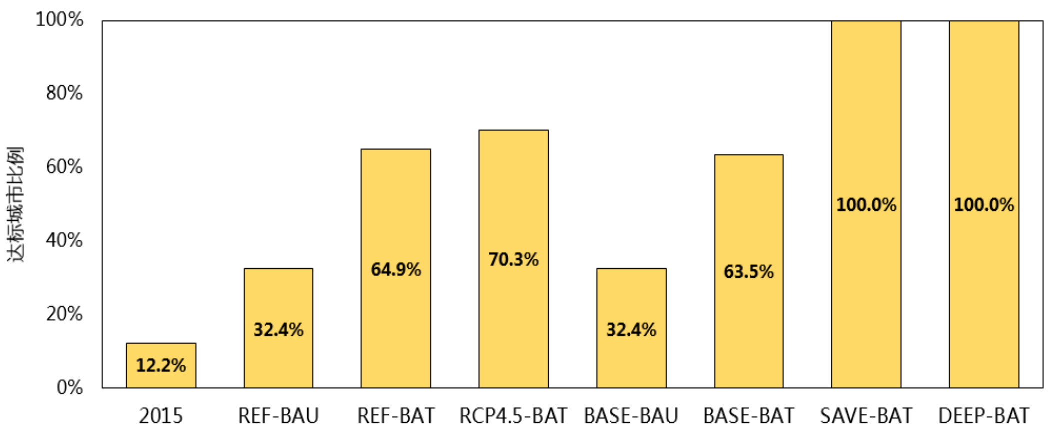

Figure 0-3 Percentage of qualified cities of China in 2030 in different scenarios

Based on the results from the simulations, discussed above, the following changes are recommended in order that all key cities in China achieve the air quality standard:

1. Substantial adjustments to the industrial structure

China's economic development needs to go through the process of middle- to long-term adjustment. High energy consuming industries need to be reduced, and the historic development pattern reliant on heavy industry need to be optimized before 2030. In order to achieve air quality standard, heavy industry production will need to drop by 25% in 2030 (compared to 2015), and energy consumption per unit of product will need to decrease by 20%.

-Development of so-called “double high” industries (i.e. those with both high energy consumption, and high pollutant emissions) need to be restricted. Annual production from key sectors like steel, cement and glass ought to be controlled.

2. Cleaner energy structure

In 2030, coal use in China will need to be reduced to a level lower than 35% of primary energy consumption, while the percentage of natural gas will increase significantly. Policies that shift the energy structure from “coal to electricity” and “coal to natural gas” will need to be promoted so as to replace dispersed coal burning or coal-fired industrial boilers. By 2030, coal would need to be restricted to certain sectors mostly coal power plants. Residential coal use should be fully under control, and all coal with sulfur content more than 0.6% should be completely banned.

3. Full implementation of enhanced end-of-pipe control strategies.

-Ultra-low-emission coal-fired power generation should be fully realized

-Steel enterprises should advance full upgrading and process adjustments, including installing highly efficient dust collectors (such as ‘bag’ or ‘electric-bag’ dust collectors), so that fugitive emissions can be controlled. Further, sintering machines owned by steel enterprises should be equipped with desulfurization devices with desulfurization efficiency higher than 85%.

- Industrial furnaces should be upgraded, aiming for full coverage installation of ‘bag’ or ‘electric-bag’ dust collectors. In the cement sector, electrostatic-bag dust collectors with high efficiency should be fully applied, and fine particles should be collected at an efficiency higher than 99%. Besides implemetation of special emission limits in key regions, places with high risks of failing air quality in 2030 would also need to adopt these more stringent emission standards.

-Middle- and small-seized boilers, as well as old-fashioned boilers should be gradually eliminated; and the remaining large-sized boilers should be fully upgraded to have desulfurization, denitrification, and dust collector equipment installed.

- The average removal efficiency of volatile organic compounds (VOCs) in key sectors like coking, surface coating, and packaging printing in key provinces should not be lower than 70%.

- Control of ammonia emissions should be strengthened. The percentage of farms using slow- or controlled-release fertilizers should be increased to 30% by 2030, and to 80% by 2050. While proportion of modern and centralized breeding of pigs, chickens, cattle, sheep, and horses would need to reach 100% in 2030.

4. Effective control of pollutants from the transport sector

- The quality of gasoline and diesel oil should be fully optimized by 2030, so that all cars in use should reach the strict “National Ⅵ”, or higher, emission standard.

- The number of vehicles in key metropolises and key provinces ought to be effectively controlled. Especially in Beijing and other metropolises, public transport should consist of over 41% of total transportation, with the proportion of energy-saving cars reaching over 50%, and the proportion of electric cars to be over 40% of the vehicle fleet.

Other findings and suggestions:

1. Large adjustments in China's energy structure is essential in order to reach the national air quality standards by 2030.

Results from simulations of different scenarios show that not all key cities in China could reach the air quality standard in 2030 when only enhanced end-of-pipe control strategies are applied. In order to make all cities meet the standard, strong adjustment in both industrial structure and energy structure should be done. In this study, we found that in "SAVE-BAT" scenario, proportion of coal consumption could be reduced to a level lower than 40% due to combination of industrial and energy structure upgrade with best available end-of-pipe control technology. In this scenario, all key cities in China could meet the air quality standard, yet annual mean concentration of some cities are very close to the threshold value. In order to ensure all key cities could be qualified in 2030, "DEEP-BAT" scenario with proportion of coal consumption lower than 35% should be the ultimate goal to pursuit, so that not only all key cities in China could experience annual mean concentrations lower than 35 $\mu g/m^3$, but also nearly 60% of them could reach WHO interim-Ⅱ standard (annual mean concentration of 25$\mu g/m^3$).

2. The second phase of the *Air Pollution Prevention and Control Action Plan* (also known as "Ten Rules of Atmosphere") should be released; and scientifically reasonable plans for air quality should be prepared for all cities and provinces as soon as possible.

In order that the second phase of the "Action Plan" can be announced as early as possible, national goals for middle- and long-term energy structure adjustments, as well as short-term goals for air quality improvement should be further formulated in the immediate future. At the same time, local authorities should carry out systematic management of air quality improvement policies in order to provide feasible measures according to different circumstances in different cities.

3. In different regions, there are different pressures in place, and also different potential to reduce emissions.

Owing to the large territory of China, and the complicated terrain and meteorological conditions, there is great variation in the spatial distribution of emissions, and non-uniformity of air quality across the country. Therefore, different air quality policies should be considered separately in different provinces, municipalities and autonomous regions. In this way, the relevant economic regulations and environmental protections can be balanced to allow a best plan for emission reductions to be implemented locally.

4. Implementation of policies should be strengthened.

It has been observed that when emission reduction plans in China are implemented, the effects tend to be less than expected for a variety of reasons. It is suggested that related scientific studies be carried out according to situations in different places. In this way, the relevant financing and technology requirements can be clearly identified, and feasible supervision programs and emergent rectification measures can be set up.

5. When reducing particle pollutants, attention should also be paid to ozone pollution.

The primary air pollutant in China is currently $PM_{2.5}$, so this report mainly focus on how its annual mean concentration can be reduced to the standard. However, strict regulations on particulate matter, often simultaneously worsen ozone pollution. Therefore, in order to prevent further deterioration in the ozone situation, comprehensive measures for coordinated emission reductions of both particulate precursors and ozone precursors should be thoroughly considered and designed.

6. The environmental protection service sector should be further developed and promoted, including the attraction of capital investment from the private sector.

Implementing the measures outlined in this report will require associated investments in human resources, and financial capacity. Currently, air quality research, management, and legal enforcement are greatly understaffed. Further investment in human resources, as well as funding to support the development of the environmental protection services sector (i.e. third party laboratories, consultancies, etc.) should be enhanced.

7. Emission reduction measures aiming at preventing atmospheric pollution can also bring reductions in GHG emissions.

Only the two more aggressive scenarios of this study (SAVE and DEEP) could ensure that CO_2 emission in 2030 would be lower than that in 2015. In the DEEP scenario, about 17% CO_2 emission can be reduced by 2030 (compared to 2015). And CO_2 emissions could reach their peak before 2030 if the emission reduction measures on the energy structure and industrial structure side are implemented (including “coal to natural gas”, and promotion of non-fossil fuels on the energy side; and reductions in steel, cement, and coke production on the industrial side).