Tackling China's air pollution - Is it driving us to a clean energy future?

—— My takeaway from PUCEG panel discussion on March 14th, 2014

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As smog rolls into many cities in China, air pollution has become one of the top concerns of the public[i]. In response to the problem of air pollution, central and local governments have taken a series of measures. For instance, PM2.5 and ozone have been included in air quality standards since 2013, and hourly air quality data of 74 cities were made available to the public. Another example is Beijing's four-tier alert system, which issues blue, yellow, orange and red warnings corresponding to increasing levels of air pollution and makes recommendations to the public. In addition, activities such as construction work and industrial processes which cause emissions are regulated accordingly.

However, tackling the problem of air pollution requires not only efficient responding mechanisms, but also proactive actions based on a good knowledge of the problem. In order to (1) improve our understandings of the extent, intensity and sources of air pollution in China, (2) explore the possibility of navigating China's energy system to address this issue, and (3) be aware of the opportunities and challenges in doing so, Princeton University China Energy Group (PUCEG) organized a panel discussion entitled "Tackling China's air pollution - Is it driving us to a clean energy future?" We invited world leading experts on atmospheric chemistry, impacts and mitigation of air pollution, as well as energy system analyses. The panelists include Princeton global scholar Professor Tong Zhu from the College of Environmental Sciences and Engineering at Peking University; Professor Denise Mauzerall at the Department of Civil and Environmental Engineering and the Woodrow Wilson School of Public and International Affairs, Princeton University; visiting Professor Avi Ebenstein from the Department of Economics of The Hebrew University of Jerusalem; and Dr. Bob Williams, senior research scientist at the Energy Systems Analysis Group, Princeton University.

Major air pollutants include particulate matter (PM), gaseous chemicals such as $SO_2$, NOx, $NH_3$ and volatile organic compounds (VOCs) that can act as precursors of tropospheric O3 and other secondary pollutants. High concentrations of air pollutants reduce visibility, and more importantly have adverse impacts on ecosystem and human health. For instance, global yield losses due to tropospheric ozone were reported to be 4-15%, 9-14% and 2-6% for wheat, soybean and maize respectively in 2000, and the economic damages amount to $11-18 billion[ii]. Particulate matter, fine particles (PM2.5: diameter smaller than 2.5 μm) in particular, poses great health risks. PM2.5 is inhalable and can penetrate the respiratory systems. Exposure to PM can cause cardiovascular and respiratory morbidity, and trigger premature death associated with cardiovascular and respiratory diseases and lung cancer[iii] [iv]. In 2010, ambient particulate matter pollution ranked the 7th on the leading global risks for mortality and lost years of healthy life, and this risk ranked the 4th in China[v]. The empirical study of Chen et al (2013)[vi] has shown a reduced life expectancy of 5.5 yr for residents living north of the Huai River compared to the south. This reduction was attributed to the higher total suspended particulates (TSPs) level (approximately 250 $\mu g/m^3$ higher) caused by winter heating. They have therefore estimated a reduction of 3 yr in life expectancy with an elevation of 100 $\mu g/m^3$ in TSP concentration.

In 2013, the recorded annual mean PM2.5 concentrations for the 74 major cities in China range from approximately 30 $\mu g/m^3$ to 160 $\mu g/m^3$[vii], all exceeding the World Health Organization standard (10 $\mu g/m^3$)[viii]. The high concentrations are a result of the interplay between emissions of a spectra of pollutants, complicated chemical transformations and meteorological and climate conditions. While the atmospheric chemical transformations and synoptic circulation patterns are unpractical to control, we can reduce our emissions.

Cataloging the compositions of PM2.5 helps us to figure out the emission sources. A study of Beijing[ix] has documented the sources of PM2.5 to be, in descending order, secondary sulphur, vehicle exhaust, fossil fuel combustion, road dust, biomass burning, soil dust and metal processing. The findings indicate large contributions from the energy and industry sector, which implies that to root out the problem some adjustments to the energy system and economic structures are needed. While economic restructuring requires careful planning and small steps in order to maintain economic growth, our energy system may offer some bridging solutions within a relatively shorter timeframe.

Coal has been blamed as the No.1 culprit for air pollution and carbon emission. But currently, China's energy consumption still heavily relies upon coal[x]. An easy solution, at least theoretically, would be to phase out coal. However appealing it sounds, it may prove to be impractical or difficult in the short term, given the relatively large reserves of coal and scarcity of natural gas[xi]. In light of the dilemma, technologies that enhance efficiency and reduces emission of coal use may merit some considerations. One of them is to produce substitute natural gas (SNG) from coal. The idea is to burn coal in oxygen and produce syngas (predominantly $H_2$ and CO) that can be either used to generate electricity or catalytically synthesized into SNG or other clean energy carriers. This chain of processing allows effective removal of pollutants like $CO_2$, $SO_2$, $NO_X$, PM at low cost. Moreover, SNG can be used in buildings or industrial sectors where PM removal is hard to control[xii]. By 2013, China has multiple SNG projects planned and under construction, which will contribute a capacity of $2 \times 10^{11}$ cubic meter/yr. Deployment of SNG alone is not without shortcomings. Researches[xiii] [xiv] have pointed out its large carbon footprint, which implies the necessity of coupling SNG with Carbon Capture and Sequestration (CCS).

Other potential solutions in the energy system include exploration of shale gas and renewable energies. The estimated technically recoverable reserves of shale gas in China are 1,115 trillion $ft^3$, the largest in the world[xv]. However, the economic cost and environmental impacts of shale gas drilling in China still await rigorous examination. Without proper regulations in place, environmental problems associated may arise. China has put a lot of efforts in the development of renewable energies, investing the most in renewable energies in 2012[xvi], and has the largest wind capacity in the world[xvii]. Optimistic projection has shown the potential of having 80% electricity generated by renewables in China at low cost by 2050[xviii]. But large scale deployment of renewable energies still face integration challenges, competition with other land uses, and the need of comprehensive life-cycle assessments.

To summarize, the large adverse human health impacts and economic costs caused by air pollution requires immediate measures be taken. However, to win the war against air pollution requires not only firm resolutions, but also precautions and patience. First, scientific researches on underlying mechanisms are still in need in order to prioritize our actions. For instance, the health impacts of different pollutants may be different. Identifying the one with largest risk helps to provide highest mitigation efficiency. Second, there is no silver bullet for solving the problem. For energy systems, renewable energies, natural gas and technological advancements in coal use should all be evaluated and considered. Third, the problem of air pollution is not isolated from greenhouse gas emissions, economic growth and energy security etc. Therefore, tackling the problem needs a holistic approach, to identify co-benefits that facilitate synergetic solutions and to avoid replacing one problem with another.

[i] PewResearch Global Attitudes Project: http://www.pewglobal.org/2013/09/19/environmental-concerns-on-the-rise-in-china/

[ii] Avnery et al., 2010: “Global crop yield reductions due to surface ozone exposure: 1. Year 2000 crop production losses and economic damage” Atmospheric Environment, 45: 2284-2296.

[iii] Environmental Protection Agency: http://www.epa.gov/pm/2012/fshealth.pdf

[iv] World Health Organization: http://www.euro.who.int/__data/assets/pdf_file/0006/189051/Health-effects-of-particulate-matter-final-Eng.pdf

[v] Health Effects Institute: http://www.healtheffects.org/International/HEI-China-GBD-PressRelease033113.pdf

[vi] Chen et al., 2013: "Evidence on the impact of sustained exposure to air pollution on life expectancy from China’s Huai River policy." Proceedings of the National Academy of Sciences 110.32: 12936-12941.

[vii] Slides prepared by Professor Tong Zhu.

[viii] WHO air quality guidelines for particulate matter, ozone, nitrogen dioxide and sulfur dioxide, 2005, http://whqlibdoc.who.int/hq/2006/WHO_SDE_PHE_OEH_06.02_eng.pdf

[ix] Yu, et al. 2013: "Characterization and Source Apportionment of PM2. 5 in an Urban Environment in Beijing." Aerosol Air Qual. Res 13: 574-583.

[x] EIA report: http://www.eia.gov/countries/cab.cfm?fips=ch

[xi] EIA data: http://www.eia.gov/cfapps/ipdbproject/iedindex3.cfm?tid=3&pid=3&aid=6&cid=ww,CH,&syid=2009&eyid=2013&unit=TCF

[xii] Slides prepared by Dr. Bob Williams.

[xiii] Ding et al., 2013: “Coal-based synthetic natural gas (SNG): A solution to China’s energy security and $CO_2$ reduction?” Energy policy, 55: 445-453.

[xiv] Yang and Jackson, 2013: “China’s synthetic natural gas revolution”, Nature Climate Change, 3: 852-854.

[xv] EIA data: http://www.eia.gov/analysis/studies/worldshalegas/

[xvi] Global trends in renewable energy investment 2013: http://fs-unep-centre.org/sites/default/files/attachments/gtr2013keyfindings.pdf

[xvii] EIA data: http://www.eia.gov/cfapps/ipdbproject/IEDIndex3.cfm?tid=2&pid=2&aid=7

[xviii] Chandler et al., 2014: “China’s future generation: Assessing the maximum potential for renewable power sources in China to 2050”, http://awsassets.panda.org/downloads/chinas_future_generation_report_final__1_.pdf