Health and Economic Benefits of Developing Renewable Energy under 2 ℃ Target in China

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23rd AIM International Workshop, November 27-29, 2017

Introduction

- Climate change is becoming an essential issue in this century globally. Climate mitigation through renewable energy development could not only reduces the CO2 emission and slow down the climate change, but also bring air quality co-benefits, especially for China.
- Chinese government set up target on GHGs emission according to Paris Agreement. China also released the China Renewable Energy Outlook 2017(CREO 2017), recently.
- This study aims to quantify the health and economic benefits from air quality improvement due to the development of renewable energy in China, and assess the costs of developing renewable energy and carbon reduction costs under 2 ℃ target.
- Taking into account the all the costs and benefits of renewable energy development, policy suggestions are provided to the government for future renewable energy policy.

Method and scenario

This study uses the renewable energy projection from **CREO 2017**, combines the EDO model, LEAP model, GEOS-Chem model, health assessment model and CGE model to evaluate the air quality and health benefits and social cost of carbon from development of renewable energy under the 2℃ target in China toward 2050.

- **EDO** (Electricity and District Heating Optimisation) model and **LEAP**(Long-range Energy Alternatives Planning) model are used to project future energy consumption by fuel and by sector based on the Chinese government energy projection.
- **GEOS-Chem** model use the air pollutants emissions data and simulate $PM_{2.5}$ and ozone concentration.
- **Health assessment** Health model is an integrated health impact assessment model. It can quantify the air pollution-related mortality, morbidity, work time loss, health expenditure and value of statistical life (VSL).

Scenario

This study sets up Stated Policies scenario and Below 2 ℃ scenario to evaluate the benefit from renewable energy. Stated Policies scenario is the BaU scenario, while Below 2 ℃ scenario has more intensive target on renewable energy development. Table 1 and 2 show the different assumptions in two scenarios.

- **Stated Policies scenario** : The carbon emission constrains is based on China's current carbon emission intensity target table 1. The renewable energy development follows the same speed as before.
- **Below 2 ℃ scenario** : The carbon constraints for the energy system on several different simulations from the IPCC AR5 database with more than fifty percent chance of staying Below 2℃ warming. Large-scale renewable energy can substitute fossil fuel and be used to mitigate the climate change.

Scenario	Parameter	2020	2030	2050
Stated Policies	Carbon intensity	40-50	60-65	-
Below 2 ℃	Carbon cap(Mt Co2)	9000	8000	3000

Table 1: Carbon constraints in two scenarios.

Scenario	2017	2020	2030	2040	2050
Stated Policies	30	50	100	100	100
Below 2 ℃	30	50	100	200	200

Table 2: Carbon constraints in two scenarios.

The CO2-development pathway for the two scenarios is subdivided into a cap for power and district heating(DH) sector and a cap for other sectors.

Scenario	2020	2030	2040	2050
Carbon budget for the energy sector	9000	8000	5500	3000
Power and DH carbon budget	2862	2748	1798	1282

Table 3: Carbon budget for the Below 2℃ scenario (million ton).

Energy consumption

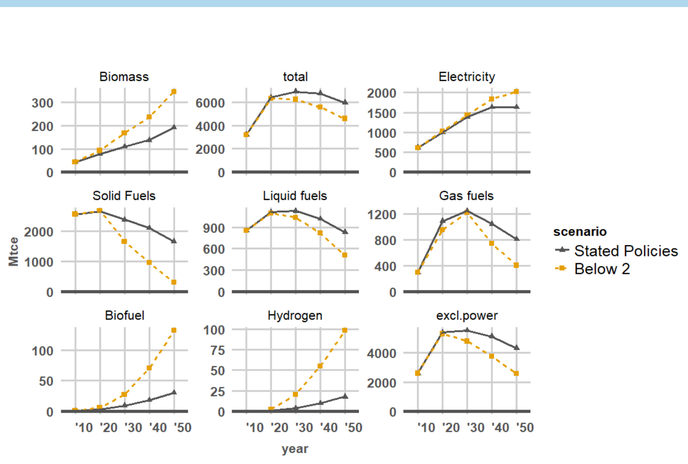

Figure 1: Energy consumption by source in two scenarios.

- This study uses the energy demand assumption for the future from CREO 2017.
- Figure 1 shows the energy consumption projection by source under two scenarios. The total energy consumption is lower in Below 2 ℃ than Stated Policies scenario.
- Solid fuels, Liquid fuels and Gas fuels is higher in Stated Policies and lower in Below 2 ℃ scenario.
- Renewable energy consumption, such as biomass, biofuel, hydrogen will increase absolutely in the future.

Emissions

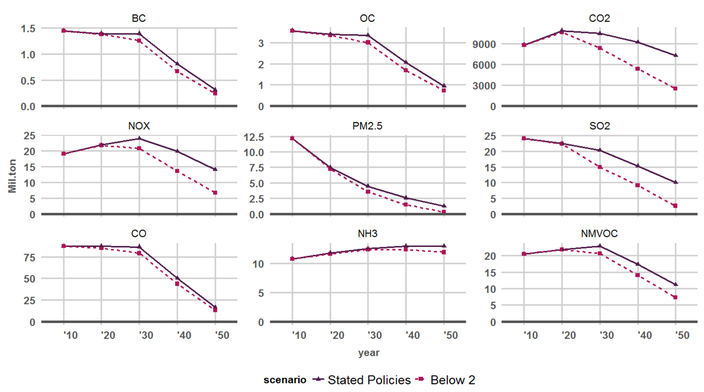

Figure 2: Air pollutants and GHGs emission in two scenarios in China

- Air pollutants and GHGs emission in Below 2 ℃ scenario is lower than in Stated Policies scenario after 2020.
- Comparing with Stated Policies scenario, CO2, NOx, SOx and NMVOC decrease faster in Below 2 ℃ scenario.
- CO, $PM_{2.5}$ and NH3 decrease slowly in in Below 2 ℃ scenario. Residential sector is the main contributor on CO and $PM_{2.5}$ emissions. Agriculture is the main contributor on NH3 emission.
- The primary air pollutants emission data is used by GEOS-Chem model to simulate concentration.

Concentration

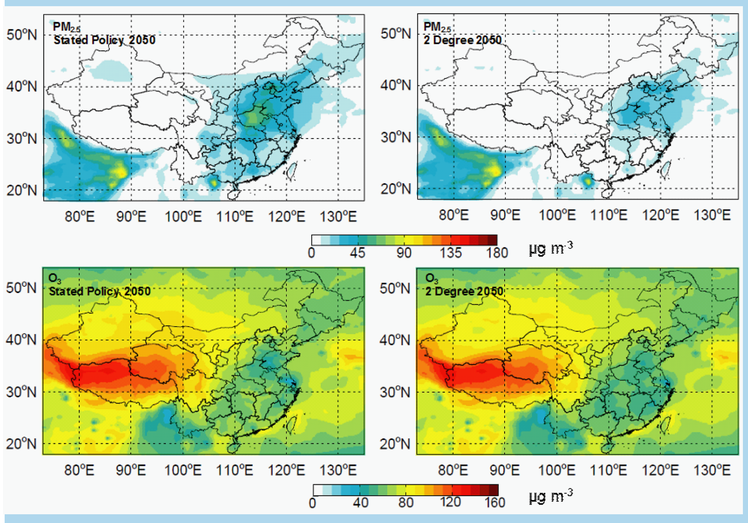

Figure 3: $PM_{2.5}$(top) and ozone(bottom) concentration in two scenarios in 2050.

- Figure 3 shows the $PM_{2.5}$ (top) and ozone(bottom) concentration in Stated Policies scenario and Below 2 ℃ scenario in 2050. Air quality is much better in Below 2 ℃ scenario.
- This study also simulates $PM_{2.5}$ (top) and ozone(bottom) concentration. In 2030, air quality improvement is very limited. $PM_{2.5}$ reduction is upto 20 ug/m^3 and ozone reduction is upto 5 ug/m^3.
- In 2050, $PM_{2.5}$ reduction is upto 40 ug/m^3. North and East part of China will have higher $PM_{2.5}$ reduction. Ozone reduction is upto 15ug/m^3 and south of China will have most reduction. For some regions, such as Beijing, Shanghai and Guangdong, ozone concentration is higher in Below 2 ℃ scenario.

Health impact

Figure 4 shows the avoided premature death from development of renewable energy. Renewable energy development could reduce 0.3 million in 2030 and 0.5 million in 2050 premature death due to the air quality improvement in China. Most of the premature death is from $PM_{2.5}$ pollution. At the provincial level, the most avoided premature death is found in Henan (37 and 85 thousand in 2030 and 2050, respectively), Shandong (15 and 38 thousand), Hebei (18 and 36 thousand), and Anhui (14 and 37 thousand) provinces. Most of these provinces are in the east and central of China.

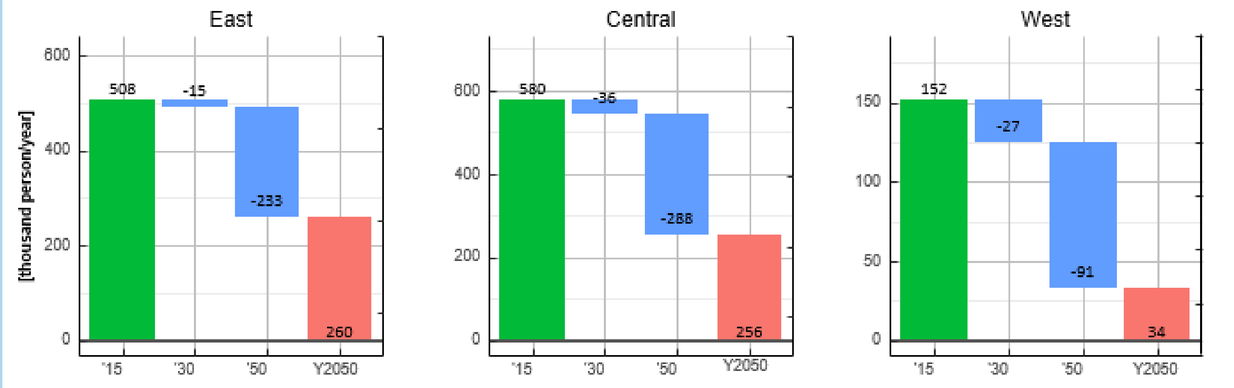

Figure 4: Avoiled premature death in Below 2 ℃ scenario in China.

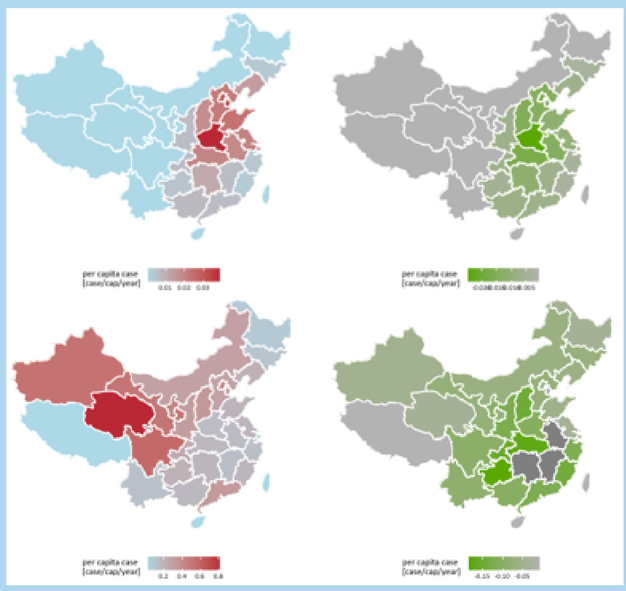

Figure 5: Health impacts (left) and benefit (right) on risk of morbidity from $PM_{2.5}$ (top) and O3 (bottom) in 2050.

- In 2030, the national total avoided morbidity is 34 million cases per year, whereas it increases to 140 million cases in 2050.
- In the Stated Policies scenario, Qinghai, Sichuan, Beijing, Gansu and Tianjin are among the regions with highest health impacts from $PM_{2.5}$ and ozone pollution.
- In the Below 2℃ scenario, Guizhou, Jiangxi, Shaanxi, Shanxi, Hunan is among the regions with most benefits from reduced adverse health damage.
- In 2015, the national per capita work time loss from $PM_{2.5}$ and ozone-related health impacts 6.3 hours. It will increase to 6.5 hours in 2030 and decrease to 4.7 hours in 2050 in Stated Policies scenario. In 2050, per capita work time loss is 2.6 hours in Below 2℃ scenario.

Cost-benefit analysis

Developing renewable energy needs additional installation investments and operational costs. Savings will come from reduced CO2 emissions, reduced morbidity, reduced mortality, saved fuels expenditure and saved OM in thermal power plants and GDP gain due to more labor supply.

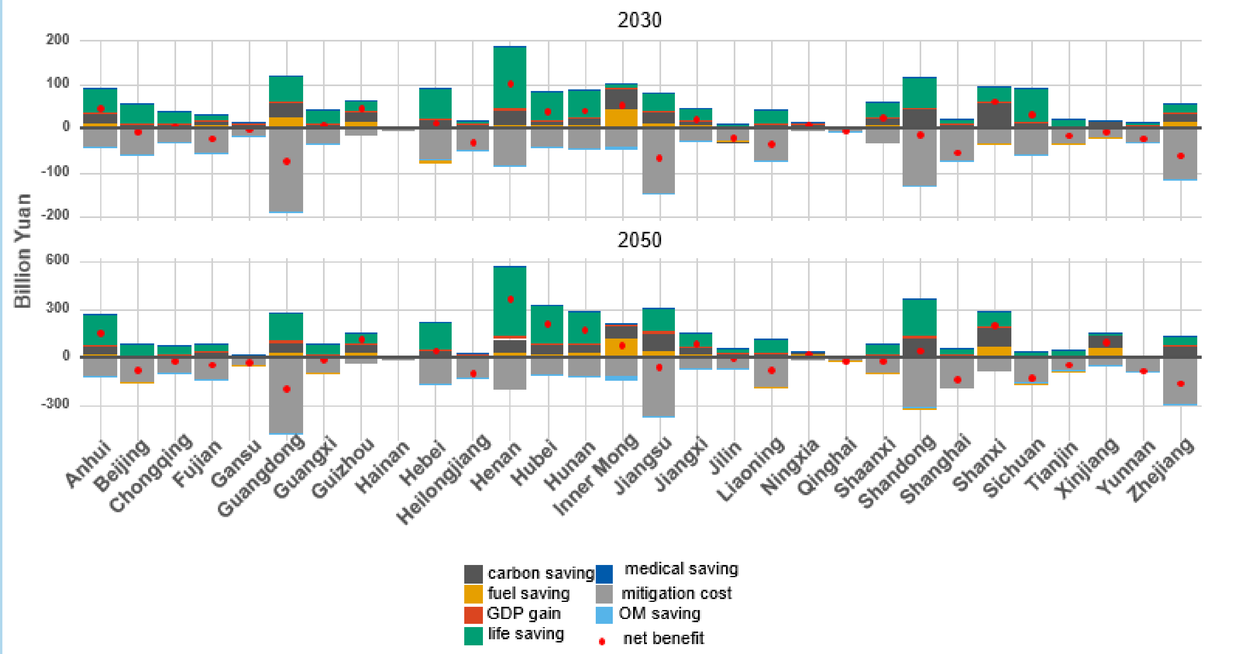

Figure 6: Cost and benefit analysis of developing renewable energy in 2030 (top) and 2050 (bottom).

Compared with Stated Policies scenario, renewable energy could reduce up to 20 ug/m^3 $PM_{2.5}$ and 5 ug/m^3 ozone in 2030 and 40 ug/m^3 $PM_{2.5}$ and 15 ug/m^3 ozone in 2050. The avoided premature death is 0.3 million in 2030 and 0.5 million in 2050. VSL saving is 997 billion CNY in 2030 and 2620 billion CNY in 2050. Renewable energy could also save 9.3 billion CNY health expenditure in 2030 and 44 billion CNY in 2050. The net benefit is about 170 billion CNY in 2030 and 970 billion CNY in 2050. Most of the benefit is from VSL. The net benefit is higher in 2050 in China. For some provinces, the net benefit is negative in 2030, but it will be positive in 2050.

Discussion and Conclusion

Cost and benefit of developing renewable energy

- Air pollution is an essential issue recently in China and will continue to be a problem due to large demand of energy for the development. Developing clean energy is a considerable option to reduce air pollutants emissions and mitigate climate change in the long period.
- China has large potential on renewable energy, which could substitute fossil fuel and reduce air pollutants and GHGs emissions. Large-scale renewable energy development would bring substantial environmental co-benefits in China.
- Our study demonstrates that more ambitious deployment of renewable energy will contribute massively to reducing air pollution and improving air quality, improving human health, saving health expenditure, avoiding premature deaths and increasing economic growth. The net benefits will not outweigh the costs in the medium run such as 2030, but in the long such as 2050, the net benefits are quite significant.

National level

- In the short-term before 2030, the net benefit of development renewable energy is positive, but not significant in China. In the long-term until 2050, the net benefit of renewable energy is increasing and becomes very significant in China.

Provincial lelve

- Most of provinces in China have significant benefit from development of renewable energy, especially Henan, Hubei, Jiangsu, Anhui, Hunan, Guangdong, Shanxi. Some of provinces have negative net benefit, such as Inner Mongolia, Fujian, Yunnan, Shaanxi, Sichuan and Qinghai have negative net benefit.

Cnsidering the air quality and health benefit, climate mitigation and investment and employment in renewable energy-related sectors, developing renewable energy in China ambitiously is optimal energy policy from long-term green growth way.