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# The role of China in 2 degree world: the needs for change in energy system planning

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**Abstract**

China is taking the crucial role to fulfill the global 2-degree target, which is claimed that the global temperature should be kept below 2 degrees by 2100. China is now the top CO2 emitter in the world and has much potential in carbon mitigation, and is now on the stage of its 12th five years plan and facing the problem of energy system optimization.
This paper presents an assessment of possible changes in energy system planning in China within a 2 degree world. Our study is based on China-ESPT, a bottom-up and technological based optimization model with rich technical details at sectorial levels, including industry, power generation, and transportation, residential and commercial sectors. Three scenarios are designed referring to three kinds of mitigation pathways to fulfill the global 2-degree target: Equal per capita cumulative principle (EPC), grandfather principle (GF), and contraction and convergence (CC). The results show us the effect of carbon mitigation pathway, and relevant changes for energy system infrastructure, it is possible to evaluate both mitigation policies and technology innovation. Besides, we also considered the total cost for the adjustment of energy system. This analysis offers good reference and strong support for China's policy design and optimization both in short term by year 2020 and long term by year 2050. Under the 2-degree global target scheme, China should find its own way to both meet the global target as a main role and make optimal and cost-effective adjustment for energy system via a sustainable development way.


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*Keywords:* 2-degree target, emission mitigation, China-ESPT model, energy system adjustment, mitigation pathway

## 1. Introduction—The global 2 degree target

It has been claimed that the global temperature should be kept below 2 degrees by 2100. In the long run, greenhouse gas concentration levels of 400 to 450 ppm CO2eq, or less, are needed to keep a

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reasonable chance of staying below the 2 °C target. The 2 °C target corresponds to a reduction in global emissions of around 50% by 2050, compared with 1990 levels.

China is now the top carbon emitter in the world and thus takes the critical role in carbon mitigation and fulfill of the global 2 degree target. We are now standing at the end of the 11th five-year, energy conservation and carbon mitigation are the two important issues, together with economy development. The need for adjustment of China's energy system structure is under serious consideration during the next five-year plan.

In order to carry out the study on how to utilize China's energy system in future, we made the quantitative analysis based on China-ESPT model. For section 1, we explain the global background and China's critical role for the 2 degree target. In section 2, the China-TEESP model is introduced both for its design for different sector and the three scenarios. The model is developed by our group. Section 3 shows the main results based on scenario analysis, mainly focusing on the change of energy system.

## 2. Methodology—China-ESPT model

The study is based on our independent developed model—China-ESPT model (China Energy System Planning and Technology evaluation Model). It is a bottom-up optimization model with rich technical details for full-economy sectors, and solves linear programming problem to describe the reality of the energy system. The model is based on the reference energy systems, and here it can describe the energy systems can be a variety of energy extraction, processing, conversion and distribution sectors and end-use sectors in detail, also can describe the main characteristics of the energy system, the complex internal linkages and more external constraints. We have five sectors in the model: energy resource supply, electricity generation sector, transportation sector, residential and commercial building sector, industry sector (include cement, iron and steel, Chemical industry, Non-ferrous metals, Nonmetallic industry, Spinning and Papermaking industry). Start year is 2010, and we take every 5-year as a step. Scenario considering the 2 degree target.

Table 1. Model structure

| Energy Resource Supply | Power Generation | Transportation | Building | Industry |
|---|---|---|---|---|
| 55 technologies | 68 technologies | 110 technologies | 40 technologies | 108 technologies |
| Primary Energy | With CCS | Passenger | Residential | Chemical industry, Nonferrous metals, Steel; |
| Refinery Energy | Without CCS | Freight | Commercial | Nonmetallic industry, Spinning, Paper-making |

Three scenarios are designed referring to three kinds of mitigation pathways to fulfil the global 2-degree target: Equal per capita cumulative principle (EPC), grandfather principle (GF), and contraction and convergence (CC). The equal per capita annual emission (EPC) scheme provides each citizen in the world an equal emission right in each year straightway. And the well-known variant, namely, contraction and convergence (CC) is proposed by the Global Commons Institute. In this scheme, the annual emission per capita in developed countries gradually descends, whereas that in developing countries ascends yearly. As a scheme based on the status quo, grandfathering rule (GF) refers to an essential economic idea of public goods distribution. In this scheme, the global space would be allocated top-down among countries proportional to their actual emissions in the reference year. Among these schemes, CC allots China the least total allowances during the whole period, with only 200 GtCO2 and 145 GtCO2, respectively. In fact, in our study, we find that for most developing countries, EPC appears to provide the earliest peak years, whereas CC constantly provides the least peak allowances. See figure 2.

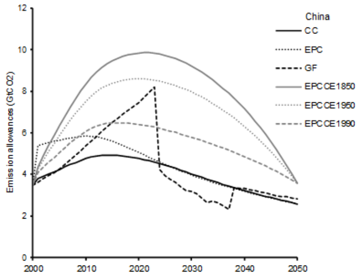


Fig. 2. China's allowance trajectories under different scenarios

## 3. Results

In order to fulfil the emission mitigation trajectories, we consider the results mainly from energy system adjustment, renewable energy, energy efficiency in different sectors and electricity generation mix. In the CC scenario, the CO2 emission has to peak in 2030, then start to decrease. The primary energy demand for CC Scenario can be seen in table 2, and the electricity generation installation mix in table 3.

Table 2. Primary energy demand (CC Scenario) Unit: Mtce

| Year | Coal | % | Oil | % | Gas | % | Hydro | % | Nuclear | % | Wind | % | Solar | % | Biomass | % | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2010 | 2083 | 72% | 538 | 19% | 110 | 4% | 45 | 2% | 42 | 1% | 18 | 1% | 0 | 0% | 7 | 0% | 2899 |
| 2020 | 2145 | 74% | 854 | 29% | 320 | 11% | 140 | 5% | 140 | 5% | 65 | 2% | 1 | 0% | 30 | 1% | 3910 |
| 2030 | 1900 | 66% | 956 | 33% | 490 | 17% | 300 | 10% | 300 | 10% | 150 | 5% | 4 | 0% | 50 | 2% | 4300 |
| 2040 | 1820 | 63% | 989 | 34% | 590 | 20% | 490 | 17% | 490 | 17% | 200 | 7% | 15 | 1% | 60 | 2% | 4600 |
| 2050 | 1718 | 72% | 1050 | 19% | 700 | 4% | 750 | 2% | 760 | 1% | 220 | 1% | 35 | 0% | 65 | 0% | 5060 |

Table 3. Power generation installation (CC Scenario) Unit: GW

| Year | Year | Coal | % | Oil | % | Gas | % | Hydro | % | Nuclear | % | Wind | % | Solar | % | Biomass | % | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2010 | 2010 | 574 | 68% | 12 | 1% | 16 | 2% | 190 | 22% | 17 | 2% | 26 | 3% | 0.4 | 0% | 5 | 1% | 845 |
| 2020 | 2020 | 630 | 48% | 12 | 1% | 65 | 5% | 360 | 27% | 68 | 5% | 105 | 8% | 16 | 1% | 9 | 1% | 1311 |
| 2030 | 2030 | 625 | 38% | 12 | 1% | 110 | 7% | 445 | 27% | 153 | 9% | 266 | 16% | 67 | 4% | 11 | 1% | 1657 |
| 2040 | 2040 | 615 | 31% | 11 | 1% | 154 | 8% | 487 | 25% | 254 | 13% | 365 | 19% | 77 | 4% | 21 | 1% | 1968 |
| 2050 | 2050 | 603 | 27% | 10 | 0% | 205 | 9% | 478 | 21% | 388 | 17% | 408 | 18% | 99 | 4% | 25 | 1% | 2234 |

In the EPC scenario, the CO2 emission is not that strict than CC scenario, due to the model calculating, the carbon mitigation can be enhanced if the cost for carbon emission raised after year 2030. We can observe the primary energy demand and electricity generation installation mix in table 4 and table 5.

Table 4. Primary energy demand (EPC Scenario) Unit: Mtce

| Year | Year | Coal | % | Oil | % | Gas | % | Hydro | % | Nuclear | % | Wind | % | Solar | % | Biomass | % | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2010 | 2020 | 2300 | 55% | 840 | 20% | 330 | 8% | 270 | 6% | 180 | 4% | 88 | 2% | 39 | 1% | 62 | 1% | 4200 |

| | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2020 | 2030 | 2100 | 45% | 940 | 20% | 500 | 11% | 400 | 9% | 460 | 10% | 170 | 4% | 69 | 1% | 114 | 2% | 4650 |
| 2030 | 2040 | 1950 | 37% | 955 | 18% | 570 | 11% | 420 | 8% | 750 | 14% | 223 | 4% | 126 | 2% | 123 | 2% | 5230 |
| 2040 | 2050 | 1860 | 33% | 945 | 17% | 610 | 11% | 430 | 8% | 950 | 17% | 242 | 4% | 213 | 4% | 135 | 2% | 5670 |

Table 5. Electricity generation installation (EPC Scenario) Unit: GW

| Year | Year | Coal | % | Oil | % | Gas | % | Hydro | % | Nuclear | % | Wind | % | Solar | % | Biomass | % | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2010 | 2020 | 723 | 51% | 13 | 1% | 55 | 4% | 83 | 6% | 85 | 6% | 148 | 10% | 24 | 2% | 18 | 1% | 1411 |
| 2020 | 2030 | 635 | 35% | 11 | 1% | 115 | 6% | 213 | 12% | 213 | 12% | 298 | 17% | 78 | 4% | 21 | 1% | 1798 |
| 2030 | 2040 | 611 | 28% | 10 | 0% | 160 | 7% | 335 | 15% | 332 | 15% | 375 | 17% | 219 | 10% | 22 | 1% | 2196 |
| 2040 | 2050 | 602 | 23% | 9 | 0% | 177 | 7% | 431 | 17% | 429 | 17% | 411 | 16% | 431 | 17% | 20 | 1% | 2575 |

In the CC Scenario, the CO2 emission mitigation trajectory is stricter than the EPC scenario, thus overall the primary energy demand and power generation installation is lower than the EPC scenario results. Especially after year 2030, when the peak of CO2 emission reached in CC scenario, the renewable energy demand shows more obvious increasing trend than the EPC scenario. While the EPC scenario is not only focusing on carbon mitigation but also cares about energy conservation and energy efficiency improvement. The energy system structure adjustment in the EPC scenario seems more close to the development reality.

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