Simulation Analysis of Impact of Industrial Structure Transformation and Energy Consumption Change on Carbon Emission in Zhejiang, China

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Abstract

Greenhouse gas (GHG) emissions have cumulatively increased over the last decade despite the implementation of various mitigation policies. Global emissions of CO_2 from fossil fuel combustion and cement production have continued to grow by 2.5% per year on average over the past decade. According to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change in order to stay below a temperature thresold of 2 ℃ CO_2 emissions would need to be kept below 3,670 $GtCO_2$. However, CO_2 emission caused by energy consumption will continuously increase to 360Gt by 2040 even though it will be mitigated from 6.5 to 1.6Gt each year. Many countries have ratified GHG emission targets by 2030 in recent years. UK, Canada, Germany, Japan, Russia and USA promised to reduce by 60%, 30%, 55%, 25%, 25% and 30% respectively. India set to lower the emissions intensity by 33-35%. China once again promised to peak carbon dioxides emission by 2030 at emission intensity by 60-65% below 2005 levels in Paris Agreement in 2016 that means GHG emission will increase to 9.8 billion tons, and increase the share of non-fossil energy of the primary energy to around 20% by that time.

Zhejiang Province, which is located in the Southeast of China, has a population of 47,993,400 as of 2012. Total area of Zhejiang covers 104,414 km^2. It comprises 11 prefecture-level cities. As one of the most developed regions in China, the GDP of Zhejiang has averagely grown 12.3% since 2005, and it accounts for 6.2-7.2% of China's GDP. However, energy consumption of Zhejiang province measured by coal equivalent increased by 63% in the period 2005-2015. Thermal power accounts for 79.8 % of total power supply, which causes enormous amounts of GHG emission along with economy growth.

Promoting extensive use renewable energy to optimize energy structure is regarded as efficient approach to mitigate GHG emission. Renewable energy considered to be zero or neutral regarding GHG emissions, is an efficient substitute for the conventional fossil-fuelled energy. Renewable energy system is able to supply about

70% of the demand, and 69% of the fossil fuel can be saved when using the hybrid configuration instead of the diesel generators. Even so, it is inevitable that improving energy efficiency is still one of core issues in energy utilization. Smart grid offers an answer to the shift to more sustainable technologies such as distributed generation and micro-grids. It allows renewable energy resources to be safely and efficiently plugged into the grid to supplement the power supply. It is also the ultimate solution to challenges that emerge from the increasing power demands.

Both smart grid and renewable energy are collectively introduced in this research in order to analyze their impact on economic growth, energy supply and demand and environmental improvement. A power supply and demand model is constructed to analyze the effect of smart grid introduction on power supply structure, total power supply and demand. A comprehensive model is constructed to evaluate the impact of introducing smart grid and renewable energy on economic growth and environmental improvement under different emission limitation. In this research, Input-Output simulation model is applied to generate a dynamic analysis based on extend regional Input-Output framework. GRP maximization is set as objective to comparatively analyze GRP growth, energy supply and demand and GHG emission in seven scenarios.

In this research, scenario S0 is set as BAU (business as usual) to predict the actual economic growth, energy consumption and GHG emission. Scenario S1t1, in which is introduced into carbon tax and subsidy for renewable energy, is set to analyze under the emission reduction target of 10%. Scenario S1t2 is introduced into carbon tax and subsidy for renewable energy under the emission reduction target of 20%. In scenario S1t3, carbon tax and subsidy for renewable energy is introduced under the emission reduction target of 30%. What’s more, carbon tax and subsidy for smart grid and renewable energy are collectively introduced under the emission reduction target of 20% in scenario S2t1. Scenario S2t2 means carbon tax and subsidy for smart grid and renewable energy are introduced under the emission reduction target of 20%. In scenario S2t3 carbon tax and subsidy for smart grid and renewable energy are introduced under the emission reduction target of 30%. Finally, the optimal scenario is obtained by comparative analysis.

Besides, the whole industrial system is divided into three sectors, conventional industry including eleven industries, conventional energy industry including three industries and electricity industry including smart grid industry and five power generation industries. Specially, electricity stability is divided into three types. Static stability is defined that electricity is absolutely stable without any outage. Dynamic stability I is defined that outrage is acceptable but it recovers in 10-20 seconds. The definition of dynamic stability II is that outrage is not acceptable but voltage is unstable within a range of plus or minus 10%.

In conclusion, introducing smart grid and renewable energy ultimately fulfill energy structure optimization and efficiency improvement. Scenario S1t1 shows thermal power, solar power and wind power is 552, 3.26 and 87.72 billion kWh respectively by 2030. In scenario S1t2 thermal power deceases to 534.34 billion kWh while solar power and wind power increase to 14.38 and 99.31 billion kWh. In scenario S1t3, They are 515.64, 33.17 and 99.31 billion kWh respectively. With introduction of smart grid and renewable energy, scenario S2t1 presents that thermal power further deceases to 456.74 billion kWh while solar power and wind power increase to 45.92 and 115.46 billion kWh. They are 426.99, 65.02 and 141.5 billion kWh respectively in scenario S2t2. Scenario S2t3 concludes that thermal power, solar power and wind power is 383.63, 81.7 and 173.02 billion kWh respectively.

Moreover, the substitution effect of solar power and wind power on thermal power relies on distribution of smart grid under electricity stability in different scenarios. Renewable energy accounts for 25.7% under static stability, 13.3% under dynamic stability I and 35.9% under dynamic stability II in scenario S2t1. It accounts for 24.6% under static stability, 23.8% under dynamic stability I and 30.7% under dynamic stability II in scenario S2t2. And renewable energy supply 52.5% of power under static stability, 16.6% under dynamic stability I and 79% under dynamic stability II in scenario S2t3, which is optimal supply structure in all the scenarios.

Emission mitigation target can be achieved by implementing a combination of policies. In scenario S1t1, carbon tax is 19 CNY/ton while total subsidy for solar power and wind power is 10.8 and 264.25 billion CNY so that GHG emission reduce by 10%. Carbon tax is 22 CNY/ton and total subsidy for solar power and wind power is 38.48 and 292.7 billion CNY in scenario S1t2 under the emission reduction target of 20%. Scenario S1t3 explains that carbon tax is 25.2 CNY/ton and total subsidy for solar power and wind power is 80.54 and is 292.73 billion CNY under the emission reduction target of 30%. Furthermore, scenario S2t1 presents that carbon tax is 44.7 CNY/ton, and total subsidy for smart grid, solar power and wind power is 519.11, 152.33 and 319.4 billion CNY respectively under the emission reduction target of 10%. In scenario S2t2, carbon tax is 51.7 CNY/ton and total subsidy for smart grid, solar power and wind power is 531.9, 219.42 and 322.36 billion CNY under the emission reduction target of 20%. Scenario S2t3 concludes that carbon tax is 78.1 CNY/ton and total subsidy for smart grid, solar power and wind power is 598.06, 295.5 and 325.73 billion CNY under the emission reduction target of 30%. Especially, GHG emits to peak since 2029 in scenario S2t1, since 2027 in scenario S2t2, and since 2025 in scenario S2t3.

Trade-off between economic growth and environmental improvement can be realized. Industrial growth changes in order to achieve target of emission mitigation. Smart grid develop stably in scenario S1t1, S1t2 and S1t3 due to economic growth incentive in the study area. Total output of smart grid is 1105.7 billion CNY at average annual growth rate (AAGR) of 7.129% in scenario S2t1, 1211.8 billion CNY at AAGR of 8.015% in scenario S2t2, and 1355.8 billion CNY at AAGR of 9.087% in scenario S2t3. Total output of solar power is 263.9 billion CNY at AAGR of 53.7% in S2t1, 360.9 billion CNY at AAGR of 56.7% in S2t2 and 443.6 billion CNY at AAGR of 59.0% in S2t3. And total output of wind power is 659.1, 781.1 and 925.2 billion CNY at AAGR of 32.0%, 33.5% and 35.0% in scenario S2t1, S2t2 and S2t3 respectively. Accordingly, total GRP grows to 74.38, 74.25 and 73.72 trillion CNY at AAGR of 6.00%, 5.98% and 5.95% respectively when renewable energy is introduced in S1t1, S1t2 and S1t3. It grows to 74.19, 73.52 and 71.82 trillion CNY at AAGR of 5.69%, 5.32% and 4.54% respectively when renewable energy and smart grid are collectively introduced in scenario S2t1, S2t2 and S2t3. Although economic growth slows down

along with GHG emission mitigation, it still realizes maximum by reason of expanded reproduction and development of smart grid and renewable energy.

Therefore, the optimal policy can be selected by comparative analysis. Evidently, GHG emission is cut down most by virtue of policy implementation even though GRP growth is minimum in scenario S2t3. Beside, structure of electricity industry is improved, and most importantly, power structure, power demand and supply is optimized. Power structure, power demand and supply under different electricity stability is also optimized in this scenario. Hence, it can be regarded as optimal option to realize trade-off among economic growth, environmental improvement, energy demand and supply. Obviously, mitigating GHG emission has to be at the cost of economic slowdown. It is strongly necessary for planner or decision maker to thoroughly consider policy targets and effects.

Keywords: Simulation analysis; Smart grid; Renewable energy; GHG emission; Input-output