Research on CO_2 Emission Abatement Effect of Nuclear and Natural Gas Power Based on LEAP

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Overview

CO_2 emission from fossil fuels is a major cause for the global warming effect. Stabilization and reduction of the atmospheric carbon dioxide (CO_2) concentration will be one of the prime challenges for the energy sector in the upcoming decades. Carbon capture and storage (CCS) is widely seen as a possibility to continue fossil power generation while contributing to CO_2 abatement. The high cost of CCS and the existence of geological storage explosions and leakage have led to controversy in the public's acceptance of CCS technology. And the transition to the large-scale renewable energy power is difficult. In future energy systems with high shares of fluctuating renewable energy generation, nuclear power will become increasingly important for the utilization of surplus electrical energy. However, a key factor of nuclear power project progresses smoothly largely depending on public support. In the face of public opinion war among medias, enterprises and experts, communication disorders between nuclear power enterprises and the public fall into an unprecedented awkward position. The development of natural gas power is considered as a one of effective ways to reduce emissions and socio-economic costs. As a measure to establish a climate-friendly energy system, a power system research on coordinated development of natural gas and nuclear power would be considered. Therefore, future electrical power scenarios aimed at environmental and economic effects for China would considered a full mix of energy options. Here, we addressed this deficiency by comparing different power scenarios. Based on the LEAP tool and China's demand for electricity, this paper establishes a bottom-up model (LEAP-China-Power) to simulate different electric power planning policy scenarios that could be enacted from 2012 to 2050. In addition to a baseline scenario, we design CCS priority scenario and nuclear and Natural Gas Combined Cycle(N&N) priority scenario. Life cycle emission factors are included in the model. The results indicate that nuclear&NGCC priority scenario is superior to CCS priority scenario in terms of total costs. Finally, we propose that China's future power planning recommendations be made according to sensitivity analysis and environmental assessment.

Keywords: LEAP, CCS, Renewable energy, Nuclear, Natural gas

Methods

Developed at the Stockholm Environment Institute (SEI) in Boston, LEAP is a software tool for energy policy analysis and climate change mitigation assessment. In particular, it can be used to assess the effects—physical, economic, and environmental—of alternative energy programs, technologies and other energy initiatives.

First, we set parameters for the model based on national electrical power planning reports, the latest statistics, and a survey of electric power technologies. The learning curve and security cost are then added to the model. Finally, electricity demands from 2012 to 2050, power structure, CO_2 emissions, and total costs of different scenarios are simulated.

(1) Industrial activity level

$GDP_i = GDP * t_i$ where GDP is national gross domestic production. GDP_i is the share of GDP (value-added) originating from industry i. All GDP values are calculated according to the current year's price. t_i is the percentage of the share of GDP originating from industry i.

(2) Electricity demands

$$E = \sum_{i}^{n} e_i * GDP_i + N_u * e_u + N_r * e_r$$

where E is the country's electricity demands (kWh). e_i is electricity consumptions per the share of GDP originated from industry i (kWh/dollar). N_u and N_r are the number of urban and rural separately. e_u and e_r represent urban and rural electricity consumption per capita.

(3) CO_2 emissions calculation

$$CE = \sum_{i=1}^{n} (f_{ic} + f_{ig})P_i$$

where CE is total CO_2 total emission. f_{ic} is the CO_2 emission factor during construction period of technology i. f_{ig} is the CO_2 emission factor during electric power generation period of technology i. P_i is electric power generations of electric power technology i.

(4) Total cost calculation

$$TC = \sum_{i}^{n} fc_i * Ca_i + foc_i * Ca_i + Vc_i * P_i$$

where TC is the total cost (US dollar) of electric industry. fc_i ($/kW) is the capital cost of power technology i. foc_i ($/kW) is the fix O&M cost of power technology i. Ca_i ($/kWh) is the electricity installed capacity of power technology i. Vc_i ($/kWh) is the variable cost of power technology i.

Results

China's demands for electricity will increase gradually from 2012 to 2050. The proportion of demands for electricity by the secondary industry is declining. The rate of demand for electricity by the tertiary industry, in the total demand, shows an upward trend in that industrialization is the dominant force of urbanization. With the rapid pace of urbanization, labour will transfer from the primary industry to the secondary and tertiary industries. The development of tertiary industry can also promote urbanization. Significantly, the predictive value of the demand for electricity does not affect the analysis of CO_2 emissions and total costs of the three scenarios.

The CO_2 emissions in N&N priority scenario are the lowest, followed by those in the CCS priority scenario. The CO_2 emissions in the baseline scenario are the highest. The CO_2 emissions in the CCS priority scenario decrease from 2025 to 2030, which is mainly because SC and USC undertake the base load' when SC and USC electricity generation increases, conventional PC is eliminated. After 2030, SC and USC will be China's major thermal power technologies. Thus, corresponding CO_2 emissions will increase, which results in CO_2 emissions showing an upward trend.

In the N&N priority scenario, the effect of CO_2 emissions abatement is remarkable. From 2015 to 2030, cumulative reduction of CO_2 emissions is obvious that as the major base load, the increase in the generation of nuclear and natural gas power cause decreases in the generation of conventional PC electricity and in CO_2 emissions decrease, which have good effects on the reduction of CO_2 emissions. After 2030, with the expansion of SC, USC and IGCC installed capacity scales, electricity generation increases accordingly, which results in increased CO_2 emissions, but the change is modest. From 2040 to 2050, CO_2 emissions will gradually stabilize. Compared to the CCS priority scenario, the N&N priority scenario has the obvious advantage of reduction in CO_2 emissions.

Conclusions

In this paper, the environmental and economic impacts of nuclear power, natural gas and new thermal power technologies were evaluated from the perspective of the life cycle using the LEA-China-Power model. With the expected increase in demands for electricity and the response to the challenge of climate change, China should actively encourage to develop nuclear power and natural gas power energetically, promote CCS R&D, and construct demonstration stations. Coordinated development of Generation Ⅲ nuclear and natural gas power is excellent choice. Therefore, the effective way to realize safe and clean electrical power supply and emission reduction is to develop the advanced technology to protect the security of nuclear power and reduce the cost of natural gas power, and improve the management levels of nuclear power as well.

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