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Review

Safety and effective developing nuclear power to realize green and low-carbon development

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Abstract

This paper analyzes the role of nuclear power of China's energy structure and industry system. Comparing with other renewable energy the nuclear power chain has very low greenhouse gas emission, so it will play more important role in China's low-carbon economy. The paper also discussed the necessity of nuclear power development to achieve emission reduction, energy structure adjustment, nuclear power safety, environmental protection, enhancement of nuclear power technology, nuclear waste treatment, and disposal, as well as nuclear power plant decommissioning. Based on the safety record and situation of the existing power plants in China, the current status of the development of world nuclear power technology, and the features of the independently designed advanced power plants in China, this paper aims to demonstrate the safety of nuclear power. A nuclear power plant will not cause harm either to the environment and nor to the public according to the real data of radioactivity release, which are obtained from an operational nuclear plant. The development of nuclear power technology can enhance the safety of nuclear power. Further, this paper discusses issues related to the nuclear fuel cycle, the treatment, and disposal strategies of nuclear waste, and the decommissioning of a nuclear power plant, all of which are issues of public concern.

Keywords: Nuclear power and nuclear energy; Role of nuclear power; Scale development; Nuclear safety; Radioactivity release; Nuclear fuel cycle

1. Introduction

To implement the Four-Energy Revolution of General Secretary Xi Jinping and to realize the promise of emission reduction by 2020 and 2030, which China has made to the international community, its energy structure and power structure must undergo profound adjustment and transformation. The development of nuclear power and the construction of infrastructures is an important link of energy production revolution. However, after the Fukushima nuclear accident, some doubts on nuclear power safety and fears of nuclear accidents and radioactive leaks have been raised in the international community, in general, and in China, in particular. To promote nuclear power development and also rebuild confidence on nuclear power safety, this paper focuses on the status and role of nuclear power in the energy structure, nuclear safety, radioactive waste management and control, nuclear waste treatment and disposal, as well as nuclear power plant decommissioning.

2. Benefits of nuclear power development in reducing the CO_2 emission, improving the environment, and realizing green, low-carbon energy development

Within 30 years of development, China has established a complete nuclear industry system through comprehensive nuclear scientific research. As a result, China's nuclear power industry has already begun to take shape: 27 units are

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currently operational with a total capacity of 25.5 GW. At present, 24 units with a total capacity of 26 GW are under construction, comprising 36% of the total world construction capacity and ranking first in the world.

2.1. The current situation of energy and environment in China

China's economic and social development is facing the dual challenge of how to balance its limited domestic and environmental resources while mitigating CO_2 emission to address climate change. At present, China's ecological environment pollution is extremely serious. In recent years, PM2.5 has become a serious threat to people's health and the main killer of the lucky index. For this reason, managing haze and reducing emissions have become the urgent strategic tasks of China's energy structure adjustment.

China is a big consumer of carbon energy, coal, and other traditional fossil fuel-based energy sources. With the huge amounts of CO_2 emissions, China has faced great pressure from the international community to reduce carbon emissions. In 2009, the Chinese government made a commitment to reduce carbon emissions per unit GDP by 40%–45% by the year 2020. In order to achieve this goal, China's energy structure must transform to a low-carbon emission model, such that by 2020, 15% of the total primary energy consumption must come from non-fossil energy sources. In the 2015 Paris Climate Change Conference, the Chinese government also promised to reach CO_2 emission peak by 2030, in which the proportion of non-fossil energy in the total primary energy consumption must already reach 20% of the total electricity consumption (NPB, 2016).

2.2. Expectations regarding China's energy development

China's economy is gradually moving towards a stable growth period; in fact, towards the middle of the 21st century, the per capita GNP will reach the level of moderately developed countries (CEPPEI, 2015). Owing to the industrial structure adjustment and enhancement, the consumption of energy for secondary industries in China will continue to decline along with the elastic coefficient of electricity (Table 1). During the 13th and 14th Five-Year Plans, the elastic coefficient of electricity will be reduced to 0.6–0.9. During the period of 2025–2050, this will be further reduced to below 0.5. By the years 2020, 2025, and 2030, it is expected that the national total social power demand will be 7.5, 9, and 10 PW h, representing average annual growth rates of 5.9%, 3.7%, and 2.2%, respectively. Taking into account the emission reduction commitments, China should strengthen the development and use of non-fossil energy (CNEA, 2013, 2015). Table 1 below lists the expected primary energy consumption structure and scale during the 13th Five-Year Plan and subsequent periods.

Table 1
Expected primary energy consumption structure and scale.

Items		2014 (real)	2020	2030
Total amount of consumption (Gtce)		4.26	5	6
Non-fossil energy		0.47	0.75	1.2
Fossil energy		3.79	4.25	4.80
Coal		2.81	3.20	3.07
Oil		0.73	0.55	0.83
Natural gas		0.25	0.50	0.90
Consumption ratio (%)	Non-fossil energy	11.1	15.0	20.0
	Fossil energy	88.9	85.0	80.0
	Coal	66.0	64.0	51.2
	Oil	17.1	11.0	13.8
	Natural gas	5.8	10.0	15.0

By 2020 and 2030, the scales of non-fossil energy by non-power utilization are expected to be 0.1 and 0.13 tce, respectively, whereas the scales by power generation are expected to be 0.65 and 1.07 tce, respectively. In addition, by 2020 and 2030, the unit coal consumptions will be 290 and 280 gce $(kW\ h)^{-1}$, respectively. This means that in 2020 and 2030 non-fossil energy-generating capacities shall reach 2241.4 and 3821.4 TW h, respectively (Kang, 2014).

2.3. Development of non-fossil power generation excluding nuclear power

2.3.1. Conventional hydropower

China is rich in hydropower resources. With current technologies and facilities, it can generate about 660 GW; however, with the subsequent hydropower developments, plants will gradually move to the west, where development conditions are relatively difficult, plant construction costs continue to rise, and issues such as immigration, environmental protection, and others, continue to become prominent. During the 13th Five-Year Plan new hydropower plants have been constructed in the Dadu River and Lancang River Basin, generating a total of 26.76 GW; in 2020–2030, development will mainly concentrate in the Jinsha River, Nujiang River, and the Yalong River Basin, which is expected to generate a total of 83.67 GW. By 2020, China's hydropower installed capacity is expected to reach 350 GW, generating about 1295 TW h; by 2030, this is expected to reach a maximum of 450 GW, generating about 1665 TW h by 2030.

2.3.2. Wind power

China's wind power resources are very rich; onshore wind resource of about 70 m higher is about 2.57 TW, while offshore resource with depths of 5–25 m is about 0.19 TW, thus comprising a total of about 2.76 TW. Although wind power development is conducive to reducing greenhouse gas (GHG) emissions, it may also have negative impacts on the ecology and the environment. This may also have climatic and seasonal impacts and can lead to a low load factor. Wind power development must consider the combination of centralized and decentralized modes; it must take into account the characteristics of the power grid and power load, so that the problem of long distance transmission can be resolved. By 2020, wind power installed capacity and power generation capacity are expected to reach 0.2 TW and 400 TW h, respectively, while in 2030, wind power installed capacity and