Forecast of China’s Future Nuclear Energy Development and Nuclear Safety Management Talents Development

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Abstract, Firstly analyzes the global energy development, analyzes the impact of carbon emission reduction on the global energy structure, and forecasts the future energy demand and nuclear energy development prospects in the future (by 2040). The growth rate will be higher than the average growth rate of energy; China is one of the countries with the strongest growth in nuclear energy. Then analyzes China primary energy production and consumption, the conclusion is that the absolute production and consumption of non-fossil energy is steadily increasing year by year. According to China’s “Two centenary goals” development goals and future global energy demand and structure (up to 2050) to measure the future installed capacity of nuclear powers, conclusion is that China “Two centenary goals” goals on nuclear power generation capacity is 3.08 million kWh, 10.15 million kWh; Based on the structure of global energy demand and China development policy, it is estimated that China nuclear power generation will be 0.4 million kWh by 2020 and 1.81 million kWh by 2050. Finally, according to the estimated nuclear power installed capacity under different scenarios, calculate the corresponding number of nuclear safety management talents in the future. The conclusion is that China should give full support to nuclear safety management talents development.

1 Global energy development status and prospect forecast
Energy can provide energy and power for human life and production, and is a significant material foundation of the national economy. Energy is a worldwide proposition. Controlling energy means controlling the future destiny of a country, and nuclear energy is one of the important keys.

1.1 Current status of global energy use
BP released the “Statistical Review of World Energy” every year, which briefly reviewed and summarized the world energy structure, prices, consumption and development of various energy sources in the previous year [1]. Generally speaking, global primary energy consumption has maintained a low growth rate; the energy structure has shifted from coal-based to lower-carbon energy. Growth in energy markets slowed in 2019 because of the globe weaker economic. All fuels except for nuclear grew at a slower rate than the 10-year averages. Renewables still grew and made records, provided the maximum contribution (41%) to growth in primary energy. Since 2016, all net growth has come from the Asia-Pacific region, dominated by China’s growth (+28.9%). China has surpassed South Korea to become the fourth largest nuclear power generation country.
1.2 The impact of carbon emission reduction on the global energy structure

At the Copenhagen Climate Change Conference in 2009, an economic model based on low energy consumption, low pollution and low emissions, that is called a “low carbon economy”. The essence of the low carbon economy is the issue of energy efficiency and clean energy structure. The core of developing a low-carbon economy is developing of low-carbon energy. In this context, ExxonMobil’s “The Outlook for Energy: A View to 2040” has relatively optimistic predictions on future energy and emission reduction trends: global carbon emissions are expected to reach their peak around 2030, and remain basically unchanged from 2030 to 2040 [2]. Low-carbon energy sources and nuclear energy will boost the strong growth in renewable fuels and to promote coal consumption fell.

The “Energy Technology Outlook 2010” issued by the International Energy Agency (IEA) has a different attitude towards the prospects for carbon emissions reduction; climate change is happening at a much faster rate than previously expected, and even the goal of “a 50% reduction by 2050” may not be enough to stop climate deterioration. 65% of all greenhouse gas emissions should be attributed to energy supply and use, of which the power industry accounts for 41% of energy-related carbon dioxide emissions. It is necessary to make more research and development efforts to explore more advanced renewable energy and other low-carbon power generation technologies, and to increase the application of nuclear energy and other renewable energy sources is the fundamental solution to curb global warming.

1.3 Future global energy demand and prospects for nuclear energy development

On December 8, 2011, the world-renowned energy company ExxonMobil released the “The Outlook for Energy: A View to 2040”. The report believes that the global population will grow from the 7 billion to nearly 9 billion in the next 30 years, economic output will double, and population and economic growth will further push up energy demand [2]. At the same time, the use of energy will be more efficient, and the power generation industry will become the world’s largest energy demand and fastest growing field. By 2040, global electricity demand will increase by about 80% compared to 2010, and global power generation in 2040 will be approximately 38 millions of kWh.

For different fuel types, “The Outlook for Energy: A View to 2040” pointed out, oil will remain the world’s largest energy, oil demand in non-OECD countries will increase by 70 percent; oil, natural gas and coal in the next 30 years accounted for 80% of the fuel mix in 2025 will reach a peak and then begin to decline. The growth rate of demand for fuels with lower carbon emissions such as natural gas, nuclear power and renewable energy will be higher than the average growth rate of energy demand. Nuclear power will average about 2.2% growth rate [2].

BP released the “BP Energy Outlook” in London in January 2017, which mentioned that between 2015 and 2035, the global nuclear power will grow at an average annual rate of 10.6%. In the future, the growth of global nuclear energy will be promoted by the non-OECD represented by China (an average of 5.9% per year), and China’s new nuclear energy will reach the growth level of the United States and the European Union in the 1970s and 1980s. By 2035, the global nuclear power generation capacity reached about 3.8 trillion kWh [3].

Figure 1. Nuclear power generation in specific regions of the world
Figure 1 is the nuclear power generation in specific regions of the world from 1965 to 2035 year, orange part presents china, yellow part presents other countries in Asia, dark green presents US, light green presents EU, gray part presents other area in the world, the unit of ordinate is Billions of kWh. According to the biennial report of the International Atomic Energy Agency and The Organization for Economic Co-operation and Development (OECD), the global nuclear energy growth rate by 2035 is expected to be between 44% and 99%. The fastest growing region of the nuclear energy industry is East Asia, and the strongest growth countries are expected to be China, India, South Korea and Russia.

2 Energy development status and prospect forecast of china

2.1 Current situation of energy development in China

China is the largest developing country in the world, with a population of about one-fifth of the world’s total, but the energy structure is still in the primary coal stage. This kind of coal-based energy structure has problems such as low energy utilization rate and serious environmental pollution, which is not favorable to the country’s sustainable development. Therefore, China has been committed to adjusting the energy structure in recent years. The “Energy Development Strategic Action Plan (2014-2020)” issued by the State Council in 2014 mentioned: “Develop gas, nuclear power, renewable energy and other clean energy, reduce the proportion of coal consumption, and promote the continuous optimization of energy structure”[4]. Since 2004, total energy production has grown steadily, and the proportion of clean energy production has continued to rise. clean energy such as nuclear power, hydropower, wind power and other non-fossil energy sources increased their share of total energy production from 8.4% (2004) to 14.5% (2015); their share of total energy consumption increased from 7.6% (2004) to 12.0% (2015). In addition, the absolute amount of production and consumption of non-fossil energy is also steadily increasing year by year, and the proportion of coal consumption is decreasing year by year. Table 1 and Table 2 are the total amount and composition of primary energy production/consumption in china from 2004-2015:

**Table 1.** Total amount and composition of primary energy production in China from 2004 to 2015 [5]

| Year | Total energy production (100 million tons of standard coal) | Proportion in total energy production (%) | Nuclear power | Hydropower | Wind power |
|------|-----------------------------------------------------------|-------------------------------------------|---------------|------------|------------|
|      |                                                           | Coal | Oil | Gas       |             |             |
| 2004 | 20.6                                                      | 76.7 | 12.2| 2.7       | 8.4         |
| 2006 | 24.5                                                      | 77.5 | 10.8| 3.2       | 8.5         |
| 2008 | 27.7                                                      | 76.8 | 9.3 | 4.0       | 9.5         |
| 2010 | 31.2                                                      | 76.2 | 8.5 | 4.1       | 10.4        |
| 2012 | 35.1                                                      | 76.2 | 8.5 | 4.7       | 11.2        |
| 2014 | 36.2                                                      | 72.1 | 8.5 | 4.9       | 13.3        |
| 2015 | 36.2                                                      | 72.1 | 8.5 | 4.9       | 14.5        |

**Table 2.** Total amount and composition of primary energy consumption in China from 2004 to 2015 [5]

| Year | Total energy production | Proportion in total energy consumption (%) |
|------|--------------------------|-------------------------------------------|
|      |                          | Coal | Oil | Gas       | Nuclear power | Hydropower | Wind power |
| 2004 | 20.6                     | 76.7 | 12.2| 2.7       | 8.4         |
| 2006 | 24.5                     | 77.5 | 10.8| 3.2       | 8.5         |
| 2008 | 27.7                     | 76.8 | 9.3 | 4.0       | 9.5         |
| 2010 | 31.2                     | 76.2 | 8.5 | 4.1       | 10.4        |
| 2012 | 35.1                     | 76.2 | 8.5 | 4.7       | 11.2        |
| 2014 | 36.2                     | 72.1 | 8.5 | 4.9       | 13.3        |
| 2015 | 36.2                     | 72.1 | 8.5 | 4.9       | 14.5        |
Prospect of China’s nuclear energy demand in the future

2.2.1 According to China economic development level in the future forecast. In the 18th National Congress of the Communist Party of China, the first the concept of “Two centenary goals” was proposed. That is to build a moderately prosperous society when the CPC is 100 years old (2021), and to build a prosperous, strong, democratic, civilized and harmonious socialist modern country when the China is 100 years old (2049). “Two centenary goals” is the core goal of General Secretary Xi Jinping’s “China dream”, it is the call of China to advance with “China dream”.

The fundamental criterion for building a moderately prosperous society is that the per capita GDP exceeds US$3,000; the sign of building a modern socialist country is that the per capita GDP has reached the level of moderately developed countries (the per capita GDP exceeds US$10,000). Throughout the development process of countries in the world economy, per capita GDP from $1,000 to $10,000 is the fastest growing energy needs of the stage. Assuming that the world’s current per capita GDP has reached a well-off level of countries, the per capita energy consumption will reach at least 4 tons of standard coal, and the population will reach 1.42 billion in 2020 [6]. It is speculated that China total energy consumption should reach 5.68 billion tons of standard coal by 2020. By 2050, the per capita energy consumption of a moderately developed country will be around 5 tons of standard coal, and China’s population will remain at around 1.38 billion [6]. It is speculated that China total energy consumption should reach 6.9 billion tons of standard coal by 2050. According to the power consumption conversion factor of 0.1229 (10,000 kWh is equal to 1.229 tons of standard coal) stipulated by the National Bureau of Statistics in 2006, the energy consumption is converted into the number of power generation, and the conclusion is that China power generation will be 4.62 billion kWh in 2020, will be 5.61 billion kWh in 2050. According to Figure 2, nuclear power generation will account for approximately 6.67% and 18.1% of total power generation in 2020 and 2050. Therefore, according to the calculation of China future economic development level, China nuclear power generation should reach 3.08 millions kWh in 2020, and reach 10.15 millions of kWh in 2050. The specific calculation data is shown in Table 3:

| Year | Per capita GDP | Energy consumption | China total energy consumption | Power generation | Proportion of nuclear power generation | Nuclear power generation | Nuclear power installed capacity | Annual capacity factor |
|------|---------------|--------------------|-------------------------------|-----------------|--------------------------------------|------------------------|-------------------------------|-----------------------|
| 2020 | 3000          | 4                  | 5.68                          | 4.62            | 6.67                                 | 3.08                   | 390.66                        | 0.9                   |
| 2050 | 10000         | 5                  | 69                            | 5.61            | 18.1                                 | 10.15                  | 1287.41                       | 0.9                   |

Table 3. China economic development level and energy consumption forecast in the future
2.2.2 According to global energy demand and energy structure forecast. With the development of China economy, the people’s standard of living is ever-increasing, the level of social industrialization and urbanization continues to increase, and the demand for energy, especially electricity, is also rapidly increasing, and the task of ensuring energy supply is more difficult. At the same time, China’s economy has entered a “new normal”, energy consumption has maintained a medium-to-low growth rate, and the energy structure has accelerated to improve. The strategic significance of energy structure adjustment has become increasingly prominent. According to the particularity of the energy sector, certain policies and major changes require a long time period to appear, so it is necessary to look at the longer-term 25-30 years. For different fuel types, the proportion of coal production and consumption in China may continue to decline in the next 30 years, and the development of natural gas and non-fossil energy will continue to accelerate. Nuclear energy, as an important measure to stabilize energy growth and improve energy safety capabilities, as an effective way to adjusting the energy structure and changing the development mode, once again ushered in a new development opportunity. In particular, the current environmental pollution problems in various parts of China have aroused widespread concern from all walks of life. Nuclear power, as a clean energy source, is a fundamental measure to solve environmental issues such as haze and carbon emission reduction. Actively developing nuclear power is not only the need of China energy demand growth, but also the need of environmental protection and sustainable development. According to “the description in the energy technology revolution and innovation action plan”, in the field of nuclear energy, it is necessary to focus on the development of third-and fourth-generation nuclear power, advanced nuclear fuel components, and small-scale reactor technology, strengthen the construction of large-scale commercial water reprocessing plants, and develop underground laboratories for high-level radioactive waste disposal [7]. It can be seen that in the future, nuclear energy will be a critical part in the field of energy technology revolution, and technological innovation will also become an important boost to the development of nuclear energy.

In July 2016, CNPC Economics & Technology Research Institute released the “Energy Outlook for the World and China in 2050” in Beijing, which predicted the energy development trend before 2050 and made certain judgments on the future of the world and China’s energy. The report believes that under the current benchmark scenario, energy efficiency will be a critical part in energy development in the next 35 years, and China’s energy consumption peak will appear in 2035 [8].

![Figure 2. China's power demand forecast from baseline scenario to 2050](image)

Figure 2 shows the amount of energy generated by various fuels at several important time points under the benchmark scenario of China from “Energy Outlook for the World and China in 2050” (The unit of ordinate is Billions of kWh, the blue part represents coal, dark blue represents hydropower, red represents nuclear power, green represents other renewable energy, purple represents gas) [8]. Forecast baseline scenario is made based on the existing policy scenarios, including economic and structural, energy efficiency, energy policy, renewable energy technology and cost. China nuclear energy development forecast in 2020 and 2050 under the baseline scenario: By 2020, China total power
generation will be around 600 million kWh, and nuclear power will account for 6.67%. It is estimated that China's nuclear power generation capacity is about 40 million kWh, and the installed capacity is about 45.66 million kW. By 2050, China's total power generation will be about 1 billion kWh, and nuclear power will account for 18.1%. It is estimated that China's nuclear power generation capacity will be about 181 million kWh and installed capacity will be about 200 million kW.

There will be many uncertain factors in the judgment of energy trends, such as the global economic crisis, the outbreak of wars, major breakthroughs in key energy technologies, and the transformation of energy utilization methods will all cause major changes in the energy field. Therefore, in addition to the baseline scenario in “Energy Outlook for the World and China in 2050”, there are other three scenarios: an extensive scenario, a low-carbon scenario, and a strong constraint scenario. The following is a comparison of the four scenarios in Table 4 [8]:

| The baseline scenario | An extensive scenario | A low-carbon scenario | A strong constraint scenario |
|-----------------------|-----------------------|-----------------------|-----------------------------|
| Lightweight economic model | Extensive economic development model | Low carbon economy model | Carbon emission reduction to achieve 2 °C temperature control target |
| After 2030, energy efficiency will be continuous growth, but the growth rate will slow down | The technical efficiency of energy utilization in industry remained stable | The technical efficiency of energy utilization in industry has been vastly improved | Major breakthroughs have been made in energy saving technology |
| The cost of renewable energy generation has been continuously reduced, and great breakthroughs have been made in the application of energy storage and smart grid technology | The cost of power generation has been reduced and energy storage technology has stagnated | Energy storage and smart grid technology promote the development of wind and solar energy at a faster speed | Major breakthroughs have been made in renewable energy generation technology and intelligent technology, and the cost of renewable energy power generation has been greatly reduced, which has been widely used |
| Countries continue to implement clean energy incentive policies, and the application of carbon dioxide capture and storage (CCS) technology has not been promoted | There is no substantial progress in the global climate negotiations, and the energy structure is still dependent on fossil energy | Clean energy policy is more stringent than the current trend of development, CCS technology began to apply | Significant progress has been made in global carbon emission reduction negotiations. Countries have adopted more stringent control policies on fossil energy, and CCS technology has been widely used |

It can be seen that in the view point of economic development, China demand for energy, especially electricity demand, will be continuous growth for a considerable period of time in the future. In response to China's economic policy of “maintaining growth and adjusting structure”, the importance of nuclear energy has become increasingly prominent.
3 Forecast of nuclear safety management talents development

In order to protect nuclear energy and nuclear technology utilization healthy and sustainable development, nuclear safety management is essential. With the rapid development of nuclear energy, the importance of nuclear safety has become more and more prominent, and nuclear safety guarantee should also be given equal attention. Nuclear safety management talents are one of the important parts. The level and professional quality of the talent team play a vital role in ensuring nuclear safety and promoting the healthy development of the nuclear industry. We should focus on the needs of the expansion and development of china nuclear energy industry, and the needs of china nuclear and radiation safety increasing requirements and standards, scientifically estimate the number of nuclear safety management talents of china in the future, ensure nuclear safety management talents with scientific forecasting.

3.1 According to the calculation of China’s future economic development level

By 2020, china nuclear power generation capacity will be 3.08 million kWh, with an installed capacity of 390.66 million kW. Assuming that the power of new generator sets are all with million kW, the number of nuclear power units should increase by about 333 units by 2020, and the total number should reach nearly 390 nuclear power units. Comparing the average number of supervisors per unit in advanced countries with nuclear power, which is 35.5 persons per unit, the number of china nuclear safety management talents should reach 13,000; by 2050, china nuclear power generation capacity will be 10.15 million kWh and installed capacity 1,287.41 million kW, the number of nuclear power units should increase by about 1231 units, and the total number of units should reach nearly 1,288 units. The number of china nuclear safety management talents should reach 45,000.

3.2 According to global energy demand and energy structure forecast

In fact, as of June 30, 2018, China’s total installed nuclear power capacity has reached 56.72 million kW, exceeding the estimated value under the benchmark scenario. Therefore, it can be explained that the development of nuclear power in china has accelerated, the development of clean energy has exceeded the benchmark scenario, and it has been developed in accordance with the low-carbon scenario. By 2050, china nuclear power generation capacity will be approximately 1.81 million kWh, with an installed capacity of approximately 200 million kW, the number of nuclear power units should increase by approximately 143, and the total number of units should reach nearly 200. Comparing the average number of nuclear safety management talents per unit in advanced countries with nuclear power, which is 35.5 persons per unit, number of china nuclear safety management talents should reach 7,100. The specific data are shown in Table 5:

| Time (unit: year) | Nuclear power generation (unit: million kWh) | Nuclear power installed capacity (unit: million kW) | total number of units (unit: set) | average number of nuclear safety management talents per unit in advanced countries with nuclear power (unit: person/set) | number of china nuclear safety management talents (unit: person) |
|-------------------|--------------------------------------------|---------------------------------------------------|---------------------------------|-----------------------------------------------------------------|-------------------------------------------------|
| Two centenary goals | By 2020 3.08                              | 390.66                                            | 390                             | 35.5                                                            | 13000                                           |
|                    | By 2050 10.15                              | 1287.41                                           | 1288                            |                                                                  | 45000                                           |
| Energy demand Under the baseline scenario | By 2020 lower than now                      | lower than now                                    | lower than now                  |                                                                  | 35.5                                                            |
|                    | By 2050 1.81                               | 200                                               | 200                             |                                                                  | 1621                                            |

Note: the present value is that as of June 30, 2018, China has 56 nuclear power units with a total installed capacity of 56.724 million kW.
4 Conclusion
China nuclear safety management talents are mainly composed of government agencies and technical support organizations (TSO). At present, there are more than 1,000 nuclear safety management talents at the central level and over 10,000 local nuclear safety management talents. Compared with the forecast in two modes, there is still a huge gap in the number of number of china nuclear safety management talents by 2050. Compared with the booming nuclear industry, the nuclear safety management talents are seriously lacking, which is not in line with the development of nuclear industry.

Therefore, for a long time in the future, the relevant government departments should strengthen efforts to increase the number of nuclear safety management talents and make up for the huge gap. We will give full support to the cause of nuclear safety, resolutely implement the “outline of the 13th five year plan for national economic and social development”, and promote the sustainable development of China nuclear energy industry.

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