Analysis of Power Planning Deviation Influence on the Non-fossil Energy Development Goal

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Abstract. Due to the international circumstances changes and domestic economic restructuring, the policies and planning of energy development have been adjusting in recent years, especially in energy power industry. Under these influences, the Chinese energy development goal “non-fossil energy accounts for 15% of the primary energy consumption” which planned to be realized in 2020 becomes uncertain. To ensure the goal can be achieved, a new energy power planning scheme is provided. Based on this planning scheme, the sensitivity analysis method and the maximum deviation method are proposed to quantify the influence of planning deviation on the target percentage. At the same time, the energy replacement is provided to fill the deviation. Research results shows that the main influence factors of target percentage is the hydro and nuclear power develop scale and their output channel construction. If the hydro and nuclear power capacity can’t reach their target scale, wind and solar power capacity can fill the vacancy instead. But if the vacancy of hydropower exceeds 58GW, or vacancy of nuclear power exceeds 27GW, the “15% goal” would be very difficult to achieve. Accelerating the construction of the hydropower output transmission lines helps to guarantee the ”15% goal”.

1. Introduction
On the united nations climate change conference (UNCCC2009), China promised to increase the non-fossil energy proportion to 15% of national primary energy consumption by 2020[1] (“15% goal” for short). In order to achieve the goal, many national departments and agencies carried out lots of systematic research. Many effective solution of the 15% goal have been put forward.

Some relevant suggestions are proposed in [1]. The non-fossil energy utilization, technology and policy are analyzed, and the key role of power industry is emphasized. In [2-3], a large number of non-fossil energy planning scheme are analyzed for the sake of feasible path to the 15% goal. In [4], under the scene of nuclear power slowdown, an effective 15% goal planning scheme is provided.

However, under the new situation of economic and energy development, more uncertainty of the 15% goal should be considered. For example, power transmission construction lagged behind; immigration of hydropower reservoir blocked; approval of nuclear power construction becomes tightened; renewable energy price subsidies expand slow; when the energy consumption control, the basic interest of thermal power enterprise should be guaranteed. Any change of these factor might mislead the development deviate from the planning path[5]. If the deviation exceeds the critical value, the 15% goal can’t be realized. So, during the 13th five-year, an effective energy development plan is necessary, and furthermore, the planning scheme implementation progress should be closely focused on during the period.
Firstly, a power planning scheme of the 15% goal is put forward in the paper. Secondly, based on the scheme, the influence of planning implementation deviation is evaluated. After the evaluation and comparison, the energy replacement method is provided for filling the vacancy. Lastly, the relevant measures and suggestions is proposed to ensure the non-fossil energy development goal come true.

2. Analysis of the Development Goal

As China came into the “New Normal” period, the national energy development has entered into a “shift phase”. The annual bulletin of the national bureau of statistics shows that, from 2001 to 2014, China's total energy consumption increased from 1.46 Btce (billion tons of standard coal equivalent) to 4.26 Btce[6], with average annual growth rate 8%. However, influenced by economic situation, the total energy consumption will be limited in 4.4 Btce in 2015, with growth rate 3.4%. Based on such a trend, combined with energy consumption forecast results from many institutions[2-3], 2.6~3.6% would be a reasonable range of the average annual growth rate during the 13th five-year, and the corresponding energy consumption is 5~5.25 Btce in 2020. In the interval, 3.4% is the specific growth rate predicted by the national energy administration. It means national primary energy consumption will be 5.2 Btce in 2020.

In accordance with the proportion of 15% in the 5.2 Btce, the non-fossil energy consumption should reach 780 Mtce at least to achieve the goal. In the 780 Mtce, 130 Mtce can be used directly[2], 650 Mtce has to transform into electricity. If the conversion rate of coal-to-electricity takes \(\eta = 0.305\) kg/kwh by 2020[4], the 650 Mtce energy is equal to about 2100Twh (terawatt-hour) electricity.

In a word, the non-fossil energy consumption in form of electric energy has to reach 650 Mtce (2100Twh) to achieve the 15% goal.

3. Methodology of Energy Power Planning

3.1. Boundary Setting

In order to provide 2100Twh electricity from non-fossil energy for energy consumption by 2020, a feasible energy power planning scheme[7] is indispensable. Boundaries of the scheme include the following constraint.

3.1.1. Power Demand. Planning scheme has to meet the power demand, not only in the whole country but also in every provinces or municipalities. Influence of economy, society and electrification should be considered, and predict result from domestic and foreign institutions should be referred. Forecasting by multiple methods[8], China 2020 power demand is expected to about 7700Twh, with average annual growth rate 5.5% during the 13th five-year. Based on the summary, and combined with the economic development and power load growth, the electricity power demand in each area can be obtained respectively.

3.1.2. Resource Potential. Non-fossil energy has significant regional distribution characteristics, and its development is limited by the resource conditions. Hydropower, wind power, solar power and nuclear power respectively mainly concentrated in the southwest region, “three north” area, west region and east coastal areas. Therefore, the power capacity of non-fossil energy located in a certain area may not exceed its technology development scale.

3.1.3. Utilization Status. Planning scheme is based on the present development and utilization situation of non-fossil energy. The exit of non-fossil energy generators is not considered due to their recycling characteristic. Only the equipment update of non-fossil energy generators is need to be considered.

3.1.4. Policy and Planning. Relevant state agencies have announced many policy or planning, includes all kind of non-fossil energy development planning[9-11]. Combined with these policy and planning,
the non-fossil energy development target range can be determined as: hydropower 300-350GW; nuclear power 50-60GW; wind power 200-250GW; solar power 100-150GW.

3.1.5. Environmental Capacity. Non-fossil energy can’t be enough to afford all the power demand, so fossil energy will afford the rest. Calculating the pollutant discharge of thermal power and the CO₂ emission scale and layout is necessary[12] to ensure that the fossil energy development in all regions must not exceed the environmental capacity. According to the State Council “Air Pollution Prevention and Control Action Plan”, the eastern developed regions such as the Yangtze River Delta is prohibited to approve new coal-fired power generation project.

3.1.6. P≥15%. By 2020, the proportion P of non-fossil energy accounts for primary energy consumption is not less than 15%.

3.2. Benchmark Scheme
Under the constraint of the boundary above, take the lowest cost of total social power supply as the optimize objective, and take the regional distribution of energy power generation as the variables, then switch on the optimization and calculation[13-14] to generate the planning scheme. After scheme adjustment of power balance[15-16] and power waste calculation of wind, solar and hydro energy, an effective scheme can be obtained. The scheme includes scale and layout of each kind of non-fossil energy.

- Total scale of benchmark scheme. Conventional hydropower 350GW; pumped storage power 40GW (peak regulation only); nuclear power 58GW; wind power 200GW; solar power 100GW; and biomass power 30GW.
- Layout of benchmark scheme. Take southwest region (Sichuan, Chongqing & Tibet) for example. As shown in Fig.1, hydropower 126GW; wind power 5GW; solar power 4GW; and biomass power 1.5GW.

![Diagram](Image)

**Figure 1.** Planning layout of non-fossil energy in southwest area

In the scheme, the total amount of the non-fossil energy generation is 2230Twh, the corresponding proportion P is 15.6%, and this is beyond the 15% goal.

4. Method of Deviation Quantitative Evaluation

4.1. Sensitivity Analysis
In order to implement the benchmark scheme, it’s need to ensure that all types of non-fossil energy are completed as expectation or beyond expectation by 2020, otherwise the 15% goal may not be achieve in time. In order to control the risk, influence of deviation $\Delta g$ on $P$ should be designedly evaluated.

**Figure 2.** Change of $P$ due to the planning scheme deviation

On the dimensions of percentage and absolute values, the power capacity deviation of the non-fossil energy $\Delta g$ is expanded step by step, and the corresponding $P$ can be calculated. As shown in Fig.2, to $P$, all kinds of non-fossil energy power capacity deviation move in the opposite direction. The higher $\Delta g$ goes up, the lower $P$ goes down. If calculated by percentage deviation, the most obvious influence on $P$ is the $\Delta g$ of hydropower; if calculated by absolute values, the most obvious influence on $P$ is the $\Delta g$ of nuclear power. This is because hydropower accounts for the most part of gross generation, and the utilization hours of nuclear power is the highest.

Based on the above analysis, the sensitivity relation[17-18] $S$ between $P$ and power capacity scale can be obtained by (1) and (2). The results is shown in the Tab.1.

$$S = \frac{\Delta P}{\Delta g}$$

(1)

$$P = \sum_{i=1}^{N}(h_i \times g_i) \times t + F \times \frac{E}{E} \times 100\%$$

(2)
In the formula, $N$ is the number of non-fossil energy category; $h$ is utilization hours; $F$ represents the total amount of non-fossil energy consumption that is not converted to electricity; $E$ represents the total energy consumption in 2020.

### Table 1. Sensitivity of P due to the non-fossil energy scale

| $\Delta g$ | $S_{\text{hydro}}$ | $S_{\text{nuclear}}$ | $S_{\text{wind}}$ | $S_{\text{solar}}$ | $S_{\text{bio}}$ |
|------------|---------------------|----------------------|-------------------|-------------------|----------------|
| 1%         | 0.068               | 0.025                | 0.024             | 0.008             | 0.007          |
| 1GW        | 0.019               | 0.042                | 0.012             | 0.008             | 0.023          |

In Tab.1, $\Delta g$ is the deviation quantity of different kind of power, and $S$ is the sensitivity of P due to the $\Delta g$. As shown in Tab.1, every 1% reduction of hydropower capacity causes 0.068 percentage decrease of P; every 1GW reduction of nuclear power capacity causes 0.042 percentage decrease of P, etc. Obviously, the capacity of hydropower and nuclear power are the main influence factors to the P.

In addition, to achieve the goal, “development” is just one element, beyond that, “utilization” is another key element to implement the planning scheme. By 2020, even hydropower and nuclear power reach the target capacity, if the construction of output channel lags behind and results in power wasting, the 15% goal may not be realized.

Taking the “West to East power transmission project” for example, if one UHV DC transmission is delayed from putting into operation, the hydropower wasting will increase about 8GW, then P will reduce 0.211 percentage; If one double circuit UHV AC transmission is delayed from putting into operation, the hydropower wasting will increase about 6GW, and the corresponding P will reduce 0.158 percentage. The reduction is very serious to P=15.6% of benchmark scheme.

$$P = \frac{\sum_{i=1}^{N} [(h_i \times g_i) - (h_0 \times g_0)] \times t + F}{E} \times 100\%$$  \hfill (3)

In the formula, $h_0$ and $g_0$ are utilization hour and effective transmission capacity of non-fossil energy generation.

In a word, the development progress of hydro and nuclear power and their output transmission construction are the dominant influence factors to the proportion of non-fossil energy account for primary energy consumption. Therefore, can the 15% goal be achieved largely depends on the hydropower and nuclear power whether be developed and consumed according to the planning scheme.

### 4.2. Maximum Deviation Analysis

If P goes lower than 15% due to the vacancy of some non-fossil energy power capacity, expanding the other non-fossil energy power capacity to fill the vacancy is a feasible method. The adjusted planning scheme can’t across the boundaries proposed in chapter 2.1.

During the 12th five-year, the southwest hydropower construction has been hindered by the national environmental impact assessment, resulted in hydropower develop progress lagging behind the target. Moreover, the hydropower output transmission line also didn’t constructed on schedule. Meanwhile, affected by the Fukushima nuclear accident, there was no new nuclear power project be approved in more than 2 years. These situation and the long construction period of hydro and nuclear power plants (at least 5 years) may make the hydro and nuclear power can’t reach their planning scale by 2020.

The policy of wind and solar power are more incentive in 13th five-year. By electric energy replacement method, the P’s vacancy of hydro and nuclear power capacity can be replace by wind and solar power. In this way, maximum deviation $\Delta g_{\text{max}}$ of each kind of non-fossil energy can be calculated by (4) and (5).

$$\Delta g_{\text{max}, j} = \max \left( -\Delta g_j \right)$$  \hfill (4)
In the formula, $g_j$ represents the planning scale of power capacity of non-fossil energy $j$; $\Delta g_j$ is its capacity deviation; if $\Delta g_j < 0$, target isn’t reached, if $\Delta g_j > 0$, target has been over completed; the utilization hour $h$ of wind and solar power are in the intervals 1800-2000 and 1200-1400 respectively.

Calculating based on $P=15.6\%$ of the benchmark scheme, the result can be obtained.

\[
\Delta g_j = \frac{1}{t \times h_j} \left[ 15\% E - t \sum_{i=1,i\neq j}^N h_i \times (g_i + \Delta g_i) - F \right] - g_j \tag{5}
\]

In Tab.2, $\Delta g_{\text{max}}$ is the maximum deviation quantity; $\Delta g_{\text{wind}}$ and $\Delta g_{\text{solar}}$ represent the increment of wind and solar power to offset the $\Delta g_{\text{max}}$ to keep the $P$ above 15%. As shown in Tab.2, when the capacity of wind and solar power are expanded 50GW (boundary value) respectively, the 100GW capacity can replace 58GW of hydropower or 27GW of nuclear power, and the corresponding $P$ exactly equal to the critical point 15%. If the wind power capacity is not enough, solar power can be made up for it. $P$ won’t suffer a significant impact if the solar or biomass power capacity is not enough, because their generation share in benchmark scheme are seldom.

In addition, the basic scale and increase of the wind and solar power capacity are limited, so it’s hard to over develop 50GW respectively to fill the vacancy by 2020. At the end of 2014, wind and solar power capacity are 98GW and 24GW, and their year increase in 2014 are less than 20GW and 10GW. So the maximum deviation analysis results above are slightly optimistic.

In summary, by 2020, if the power capacity vacancy of hydropower exceeds 58GW, or the power capacity vacancy of nuclear power exceeds 27GW, the 15% goal of non-fossil energy would be very difficult to achieve.

5. Conclusion

Seen from the research results above, the development and utilization of hydro and nuclear power is the key to achieve the 15% goals by 2020. Nuclear power mainly distributed in coastal areas, which is close to the east power load center, and the energy supply is convenient. While hydropower is concentrated in inland areas. Especially during the 13th five-year, most of the new hydropower are located in Sichuan and Tibet, which is far from the load center. Therefore, enough hydropower output channel is important to realize the hydropower development and consumption target.

However, the construction of hydropower output transmission lines has been lagging behind in these year, which resulted in seriously hydropower wasting, especially nearly 20Twh in 2014. With the hydropower development in Sichuan and Tibet, the maximum electric power surplus in the wet season is increasing constantly. By 2020, the output demand is nearly 34GW in the area. If the growing output demand continuously turns into hydropower wasting, the 15% goal can’t be achieved. Therefore, in order to achieve the goal, the construction of hydropower output transmission lines in Sichuan and Tibet should be accelerated.

6. Suggestion for the Energy Development Goal

In order to realize the 15% goal of non-fossil energy, the energy power planning method has been put forward in the paper to formulate the power planning scheme on the constraint of the proportion of

| $j$     | $\Delta g_{\text{max}}$ | $\Delta g_{\text{wind}}$ | $\Delta g_{\text{solar}}$ | $P$    |
|---------|-------------------------|---------------------------|---------------------------|-------|
| hydro   | -58                     | +50                       | +50                       | 15.0% |
| nuclear | -27                     | +50                       | +50                       | 15.0% |
| wind    | -56                     | -56                       | +50                       | 15.0% |
| solar   | -76                     | +30                       | -76                       | 15.0% |
| biomass | -20                     | 0                         | 0                         | 15.1% |
non-fossil energy. The influence of planning implementation deviation on the 15% goal has been quantified, and the methods and suggestions on how to eliminate the deviation have been proposed.

The research results show that, to different kind of non-fossil energy, the planning deviation of hydro and nuclear power performs the most significant influence on the target percentage. If the vacancy of hydropower exceeds 58GW, or vacancy of nuclear power exceeds 27GW, the 15% goal would be very difficult to achieve. During the 13th five-year, accelerating the construction of the hydropower output transmission lines helps to guarantee the 15% goal.

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