Renewable Energy and Energy Efficiency Partnership (REEEP) Funded project

可再生能源和能源效率伙伴关系(REEEP)支持课题

Renewable Energy Roadmap for China in 2030

Executive Summary of the Final Report

ENERGY RESEARCH INSTITUTE

Energy Research Institute National Development and Reform Commission

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1. Energy and climate change challenges

Energy demands have increased together with the fast economy and social development. As the largest developing countries in the world, China's fossil fuel - based energy structure has faced strong challenges from resource shortage and environment protection.

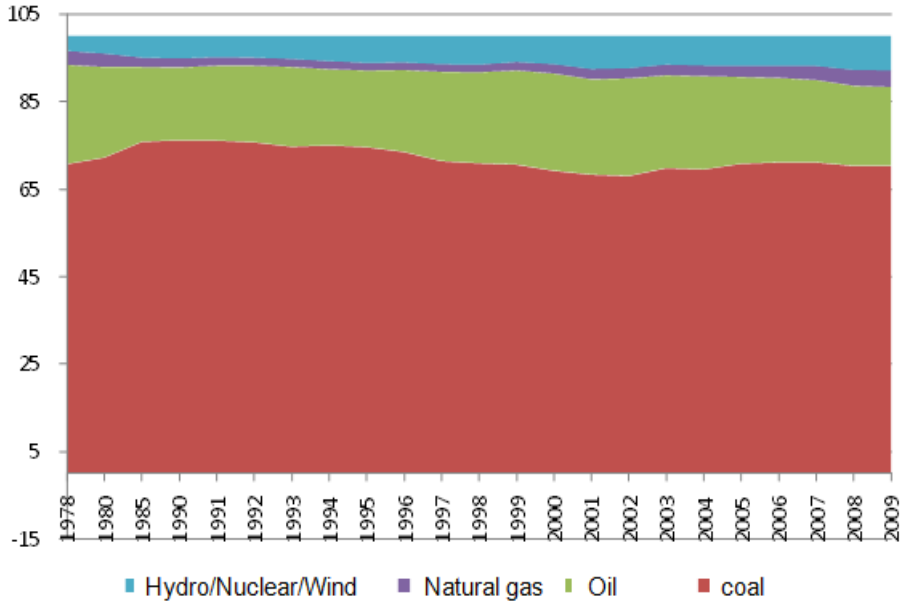
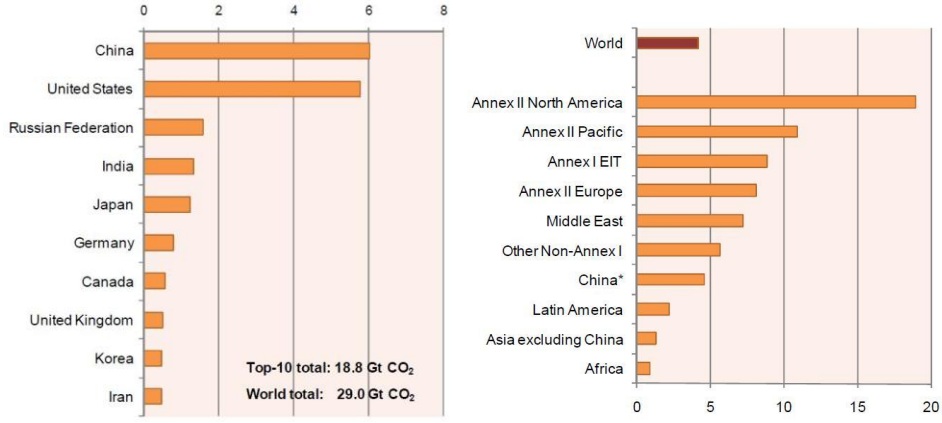


Figure 1. China's energy structure 1978~2009（%）

Considering climate change, China has not much space in both total emission and per capita emission. The further increase of energy demand and carbon emission will face more and more external pressure.



Total CO_2 emission （Billion tons） Per capita emission（Tons/person）

Figure 2. IEA statistics of total global CO2 emission and per capita emission in 2007

Source： Carbon emission from fuel combustions (IEA, 2009)

With the purpose to maintain a sustainable and stable energy supply, to resolve the current resource and environment limitation and to respond to the climate change, the development and utilization of domestic renewable energy resources is not only the important method to resolve the current contradictions of energy supply and demands but also the strategic choice to realize the future energy and environment sustainable development.

2. Resource for China's renewable energy development

China has rich renewable energy resources with the potential of billions tce, which can play a stable supportive role in China's energy system.

Table1. China's renewable energy potential

Type	Theoretical potential (hundred million kW)	Economic potential (hundred million kW)	Annual energy production (hundred million tce/year)
Wind	43	7~12	5~8
Solar	1700 billion tce	22	11~14
Biomass	-	-	8.9
Hydro	6	5	8.6
Geothermal	462.65 billion tce	0.2	0.5
Ocean	6100	9.9	5.5
Total	-	59	40-46

Source: Renewable energy development strategy, China Academy of Engineering, 2008

3. Optimal renewable energy development and utilization

Renewable energy products include different forms such as electrical power, thermal power, gaseous fuel, solid fuel and liquid fuel etc. All kinds of renewable energies have different resource hosting conditions, technological characters, developing levels, and commercialization degrees. To take all factors of renewable energy into consideration, such as technology maturity, economical characters, and the contribution to carbon emission reduction, the direction of renewable energy optimal utilization will be as followed in the next 20 years:

- Focus on the development of power generation technology;
- Actively and steadily development of liquid fuel technology;
- Developing technologies related to renewable energy for gas and heating supply according to different local conditions.

Hydropower

Hydropower has good industrial basis and specific resource. Hydropower is the leading player and representative of clean energy in China. Currently, the biggest obstacle of hydropower is non-technical challenges which come from the environmental and social constraints. Such non-technical challenges can be guided by building effective costs or revenues transfer system. Development of large scale

hydropower will be the inevitable choice after an overall consideration of issues like social costs and energy security.

Wind Power

Wind power has pretty clear predictions from technology, cost and market development perspectives. Following hydropower, wind power is one of the renewable energies with the biggest developing scale and the most competitive economic characters. Besides this, the process of wind power production will not occupy and consume other natural resources (such as soil, water). It has not much negative impact on environment neither. Wind power should be given more priority in the future energy development plan. Grid integration technology for wind power has been taken as a bottleneck at present. The potential of policy improvement and institutional reconstruction has not been put forward yet. But this problem will be resolved through technology innovation and policy changes. The grid integration will not be the bottleneck problem in the future.

Biomass power generation

Comparing with main stream electrical power generations such as coal power and hydropower, biomass power does not have cost advantage. Comparing with the future renewable energy such as wind power and solar power generation, biomass power does not have the resource advantage and marginal cost decrease potential. So biomass power generally has weak economic competitiveness. Considering utilization methods, second generation biomass fuels should be promoted. As a conclusion, it is very important to balance among issues of biomass resource availability, cost and competition of other utilization methods. Biomass power generation facilities should develop limitedly and conditionally. But there is still a big potential for developing biomass power generation in the major rice-producing areas, large scale ranches, forestry and rural areas, where biomass power and its advantages cannot be replaced by other energies.

Solar power generation

The sun radiant is large in scale and will be the primary resource of renewable energy in the future. There are two different approaches to generate electricity from the sun: photovoltaic (PV) and solar-thermal technologies. The process of PV generation does not consume water, and does not require spinning turbines and high temperature components. The maintenance costs are low and suitable for the application in large open areas like desert and also suitable for the application in city in the form of building integration projects. This shows the advantage of PV as a distributed power generation technology. The major problem for the further development of PV is the cost. The cost for PV is still very high globally. Costs of PV generation are about 3-4 times of thermal power and twice of wind power. With the modification of new materials, manufacturing process, the improvement of system convert efficiency, and the increase of application market percentage, the cost of PV generation trends to decrease rapidly. Considering that the industry basis of large scale PV application has already been built, PV industry has the capability to further lower the cost. It was predicted that the cost of consumer side PV (the price of end users) will be close to

the traditional power price by 2015. It is also predicted that around 2020, the cost of large scale on-grid PV (on-grid price) will be close to the traditional power price. PV will be competitive in economy at that time and can be applied in large scale.

Solar-thermal power generation

Through heat storage technologies, solar-thermal power generation technology can supply steady power and has the advantage that can be easily adjusted comparing to traditional power. On the other hands, solar thermal has disadvantages like high water consuming in desert area, difficulty for maintenance of high temperature parts and the lack of industry technology basis, and these make solar-thermal power generation still has a long way to go before being scaled up. Overall, solar-thermal technology has the potential to commercialize in some fields, but comparing to PV, it is still not obvious whether solar thermal can play a crucial role for power supply.

Geothermal & ocean energy

There are many kinds of geothermal electricity generation technologies. They are not replaceable by other energy technologies in some special areas. But considering the economic characters of the technology, resources, industrial developing basis, it is still a long way to go before both of them can play the role as major and strategic energy resources.

The 1.5 generation biofuel

At present, China has started to grow cassava, sweet sorghum and other energy plants in the marginal land to produce the so called 1.5 generation bio-ethanol. But China has large population and relatively small land resource, the usable lands are relatively limited. There's no concrete investigation on the usable margin lands in the country, nor clear figures about the distribution of usable margin lands area. So it is not clear if 1.5 generation biofuel can be the major substitution of oil. Large scale biofuel production also requires large amount of resistance and large scale of energy plants to fulfill the feedstock shortage. Management of these forestry plants requires technology breakthrough and practical tests for a long time.

The second generation biofuel

Considering the industry development, the 1.5 generation biofuel technology is worth to be promoted currently. But from the long-term perspective, biofuels generated from agriculture and forestry residues which are mainly composed of lignocelluloses or the second generation biofuels produced by algae represent the future of biofuels. These products, including cellulose ethanol, biomass gas synthetic fischer-tropsch synthesis diesel, and biomass catalytic diesel, are possible to substitute oil in a large scale. At present, the second generation biofuel technology is not mature yet and it is currently a global cutting-edge energy technology. There are no specific research conclusions about when the second biofuel can be commercialized and the economic characters of this technology at that time. The R&D and investment situations in China are far behind the current international advanced levels. Overall, the future of biofuel technology in China has great uncertainty.

Biomass gasification and solid biomass products

The biomass gasification can generate biogas for heating, cooking and power generation. This kind of technology is pretty mature. The current major problem is that the application scale is still small and with lower economic competitiveness. The solid fuel has the advantage of substitute the coal in city heating system. It has the potential to develop market in the areas rich in resources.

Solar water heater and commercial solar heating

Solar water heater and commercial solar heating technologies are capable of supplying hot water, and provide industrial heating and cooling service. It can substitute boilers in industry. But nowadays only solar water heater technology has gained good market development. Commercial solar heating technology is expected to get further development with the technology progress, improvement of policies, and the modification of heating price. The application of solar heating technology will be expanded to industrial heating and cooling system.

4. Long term renewable energy development outlook

This study provides three, i.e. low, middle and high development scenarios according to different characters of renewable energies. The main difference between low and high development scenario is the prediction of the development in the 2020 to 2030 period.

--High scenario: Under the motivation by the environment and climate change, more investment will be provided and strong policy will be applied in the renewable energy sector for the application and commercialization of new technologies. Through enhancing grid capability and constructing flexible power system, the potential of renewable energy consumption will release its greatest possibility. At the same time, positive market promotion measures will be applied, on-grid price will be reasonable, technology research will go much further, the intellectual property rights protection system will be approved and the distributed renewable energy power generation technologies will be fully promoted. Under all these conditions, the percentage of renewable energy in the energy consumption system will increase rapidly and the policy will drive the industry effectively.

--Low scenario: China’s energy strategy is focusing on energy efficiency improvement and renewable energy will develop at a regular speed. For renewable energy policy, though China gets experiences from developed countries and avoids many mistakes, total investment on renewable energy sector will be less than enough. The cost of renewable energy application is still high. Due to the lack of financial support, the development potential of renewable energy will not be released completely. Besides, the grid construction will be far behind the renewable energy development, and will have a big negative impact on the scale up of wind and solar power market. In this case, the development of wind power will be slowed down around 2020 but will have a rapid development trend around 2030. This is a conservative scenario.

--**Middle scenario**: The scenario is in between the high and low scenario, which have a detailed consideration of different kinds of factors like resource potential, environment limitation, social costs etc. Regular scenario is the development plan with balance and stability.

When considering the role of renewable energy in future, there are two main uncertainties. One is the total contribution of renewable energy and the other one is the total energy consumption. Since there are many other factors affecting the total energy consumption in future, this study focuses on the contribution of renewable energy itself.

The total amount of renewable energy utilization in China in year 2030 will be 8.3 billion tce, 10.5 billion tce, and 13.3 billion tce in the low, middle and high scenarios respectively. But there is still big uncertainty there. (Figure 3)

From the practical view, although the low scenario has more possibility to be the real situation, our study believe that it is important to have a much more positive view on the high scenario which is suitable for the needs of reality and future progress in China. Especially when considering China's economic reform, energy structure adjustment, resource and environment problems and reaction to climate change, China's renewable energy sector has a great possibility to achieve a much more ambitious target in the next 20 years.

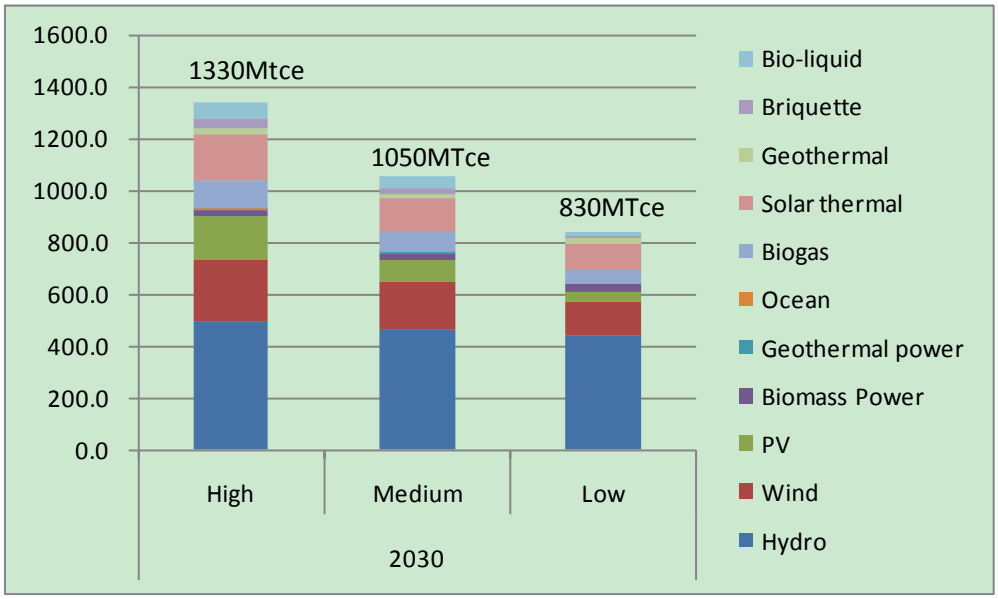


Figure 3 Scenarios for China's renewable energy development in 2030

With the positive plan, the total renewable energy supply will be 800 Mtce in 2020, and will be 1300 Mtce in 2030 (Figure 4). There could be a increase of 500 Mtce every 10 years in the future 20 years. Renewable energy would be an important component of China's energy structure, play a significant role in increasing China's energy security level and make a great contribution to dealing with climate changes.

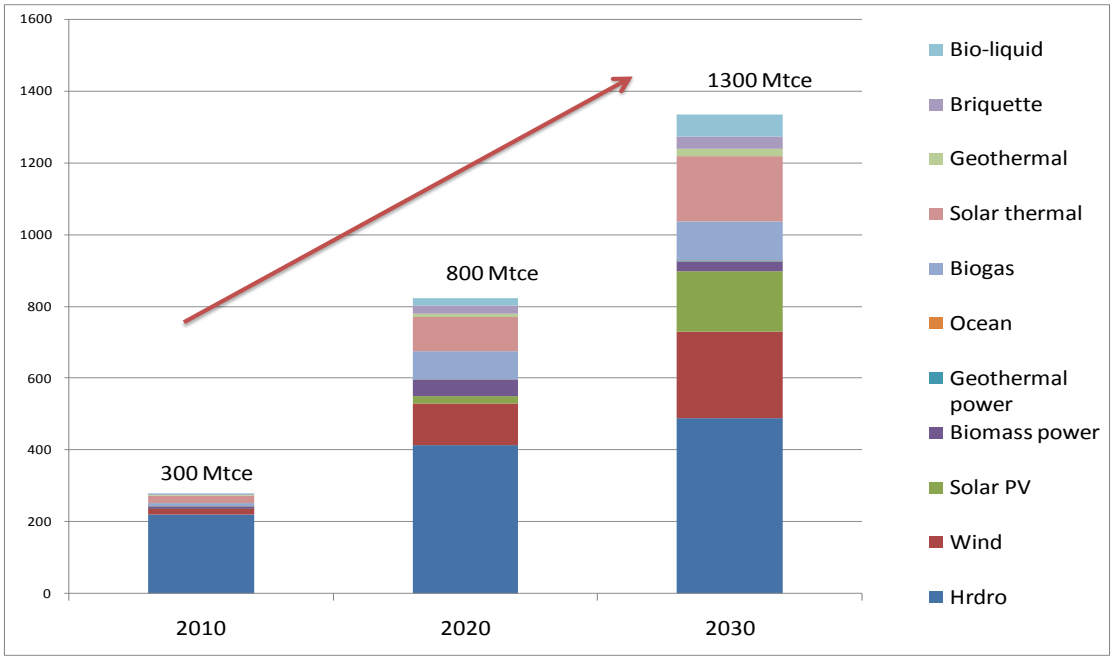


Figure 4 Renewable energy developments under the high scenario

Considering the contribution of renewable energy, if the total energy consumption can be limited to less than 4.5 billion tce in 2030, renewable energy would then have the possibility to reach up to 30% of total energy consumption. However, based on the trend of China's energy consumption from 2003 to 2009 (Figure 5), the possibility of less than 4.5 billion tce in 2030 is very small. It is most probably that total energy consumption will go beyond 5.0 billion tce, or will be even higher than 5.5 billion tce.

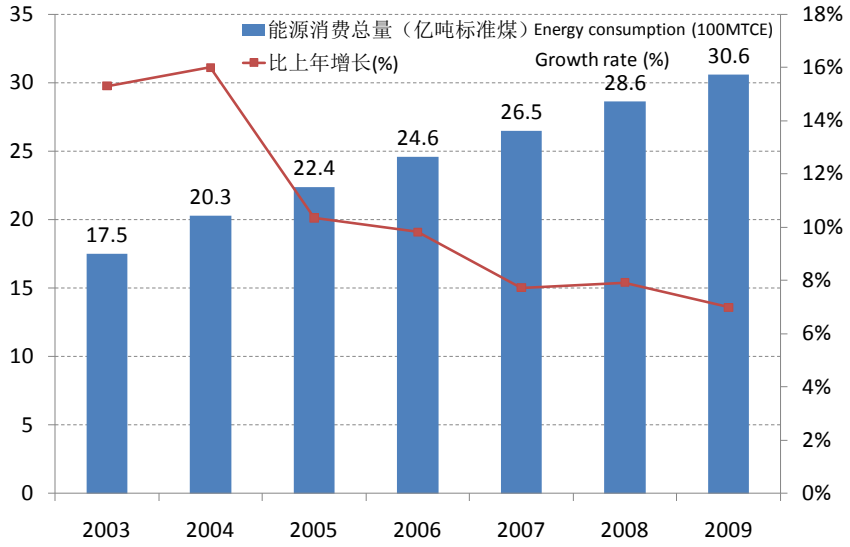


Figure 5 China's total energy consumption（2003~2009）

If the total energy consumption is limited to be below 5.0 billion tce, the contribution of renewable energy could be between 16.8% and 26.7%. If the total energy consumption is 5.5 billion tce, the lowest contribution of renewable energy would be 15%, which is on the same share with China's middle and long term developing target in 2020. Under the case of total consumption being 5.5 billion tce, the contribution of renewable energy would be up to 25% under the high scenario. If the total energy

consumption would reach over 6.0 billion tce, renewable energy contribution will be between 14% and 22%. In conclusion, the contribution of renewable energy to total energy consumption will be volatile in large range, from the highest 26% to the lowest of 15%. Most probably, the contribution of renewable energy to total energy consumption would be between 20% and 22% (Figure 6).

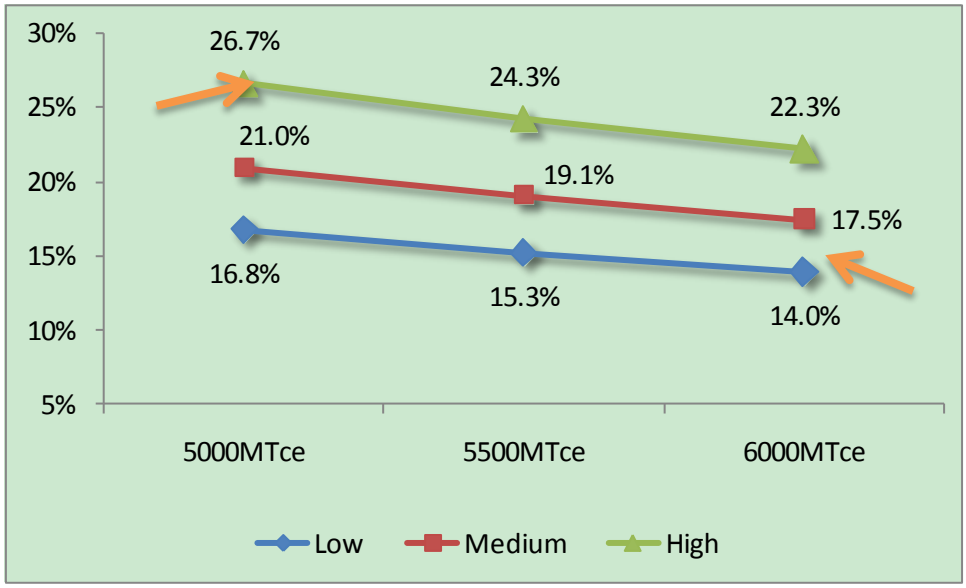


Figure 6 Contributions of renewable energy to total energy consumption in 2030 under different scenarios

If the total energy consumption in 2020 and 2030 were as high as 4.5 billion tce and 5.5 billion tce respectively, there would be an increased energy demand by 1.3 billion tce and 2.3 billion tce in 2020 and 2030 respectively. According to the calculation, from now to 2020, renewable energy could contribute to 40% of the increased energy demand in 2020 and 45% in 2030 (Figure 7).

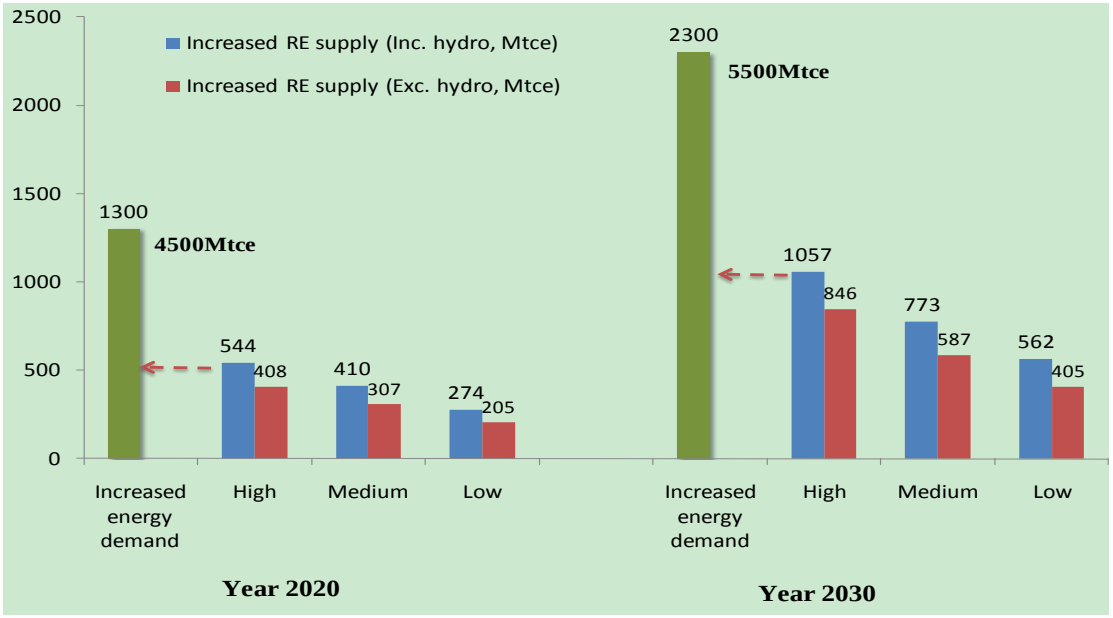


Figure 7 Renewable energy contributions to the new energy demand under the scenario with high total energy consumption

With development of renewable energy technologies, the competitiveness of renewable energy will be stronger. Renewable energy will be scaled up and play a more important role in China's energy structure. Specially, as a new energy form, although the contribution of renewable energy in total energy consumption is still limited, it will make a considerable contribution to the new energy demand, which will become a strategic energy resource in future.

The strategy status of China's renewable energy development

Prior to 2010: about 300 Mtce, accounting for 9.7% of the energy demand

China's energy demands mainly rely on fossil fuels, the contribution of renewable energy is less than 10%. In rural areas, renewable energy plays the supportive role. Wind power generation, solar power for low and medium temperature heating application, biogas, geothermal heating technologies are completely commercialized and being scale development.

Medium term-2020: about 550~820 Mtce, accounting for 13.8%~20.6% of the total energy demands; non-hydro renewable energy contribution will be 200~400 Mtce, accounting for 5~10% of total energy demands.

Fossil resource energy is still the dominate energy resource, but the contribution of renewable energy is growing bigger and bigger. Renewable energy will play an important role to meet the new energy demands. Renewable energy technologies are tending to be matured and have all required conditions to be promoted in large scale.

Long term-2030: about 840~133 Mtce, accounting for 16%~26% of total energy demand; non-hydro renewable energy contributes 400~850 Mtce, accounting for 8~17% of total energy demands.

Renewable energy has significant advantage in cost and has obvious competitiveness. Renewable energy will develop in large scale especially in the newly increased energy system, and will become one of the mainstream energies.

Roadmap for wind power

On-shore wind power will be the major technology in the short and medium term. Meanwhile, more efforts will be made to promote the distributed wind power system and on-grid offshore wind power technology. The development of wind power in China should follow the roadmap as below:

1) By 2020, the whole industry should develop steadily. In this period, more efforts should be made to support R&D and resolve three key obstacles that constraint the development of China's wind power: detailed wind power resource research and evaluation; grid update to be suitable for large-scale wind power development;

industry innovation system with independent technology property rights and suitable for the China's condition and international competition .

2) Year 2020 ~2030, mature wind power industry chain with independent intellectual property rights has been built. The wind power industry will participate into international market while keep expanding the domestic market. Wind power will play a much more important role for economy and social development. Offshore wind will be one important developing direction.

3) After 2030, the wind power will have greater competitive advantage in the market. The wind power industry grows into the mature development track. The distributed power combined with off-grid wind power and large-scale energy storage equipments will be the new developing direction.

Roadmap for solar energy

For solar PV, the main technology will be crystalline silicon cell in the short to medium term, and thin film will get a significant progress; high efficiency, high stability and low cost will be principles for the development of PV. According to international experiences and analysis above, China's PV roadmap is as followed:

1) Investments for R&D should be increased, with a special focus on advanced technologies which can lower the costs. The large-scale production will help to achieve the significant decrease in cost. The price of large-scale PV will drop to or under 1 RMB per kWh by year 2015.

2) Promotion of PV application, especially roof PV system, desert PV power station, and related supporting technologies like grid integration and large-scale storage technology etc.. The price for large-scale PV power generation will drop to or under 0.6 RMB per kWh, which will reach to the demand side price level.

3) From year 2020 to 2030, the price of power generation from crystalline silicon cells technology will be 0.4~0.5 RMB per kWh, large-scale PV will have competitive advantage in the market with the coming out of new materials and PV cell structure. PV power will be a major energy resource with the economic advantages and environmental friendly characters.

Roadmap for solar-thermal

1) By 2015, the major problem to be settled is the integration of solar-thermal application and building construction.

2) By 2020, R&D of middle and high temperature solar-thermal application technology will have significant progress, the solar energy for air conditioner will be commercialized, and the commercial and industrial solar-thermal hot water system will be applied in large scale.

3) By 2030, the technologies of solar thermal hot water supplying systems, heating systems and cooling systems will be matured. It will play an important role in the hot water supplying, heating and cooling applications.

Roadmap for biomass

-- Biomass power generation

Biomass power generation technology should be promoted with diversified development strategy, different technology plans should be applied according to local conditions. For the scale, small, medium and large scale biomass power generation should be considered according to raw material resource. Small scale projects will dominate the market. All different technical plans should be encouraged to adapt China's complicated national conditions.

-- **Biofuel**

The development of biofuel can be classified into three stages, short term (before 2015), medium term (2015~2020) and long term (after 2030). According to raw material availability, land resource limitation and technology development in different stages, the roadmap is described as below:

- Short term (before 2015): Biofuel coming from non-grain crops (for example, cassava, sweet potato etc.) will be paid more attention. Investment for cellulose fuel R&D will be increased to achieve the breakthrough. Demonstration plants will be started in this period.
- Medium term (2015~2020): Biofuel coming from sugar crops such as sweet sorghum will be commercialized with large scale production. The cellulose ethanol will also be commercially applied. Selected energy crops will be planted in saline and sandy area in large scale. By 2020, the application of the second generation biofuel technology in large scale will be a major task, and biofuel will become main substitution of fossil fuel.
- Long term (after 2030), second generation biofuel technology with resource from non-grain crops such as sweet sorghum, cassava and sweet potato will be matured. The production technology of cellulose fuel ethanol will be commercialized. The key task will swift to the effective development of marginal land.

-- **Biodiesel**

- By 2015, traditional technology will be applied to produce biodiesel from waste oil and cottonseed oil. The advanced etherification technology, like the technology of planting high productivity colza in winter free land, will be launched as demonstration. The research of woody oil plants with high productivity, FT biodiesel and biomass liquid diesel will also be promoted; The R&D of microalgae oil technology and microalgae hydrogen will also be encouraged to overcome technique and equipment obstacles.
- By 2020, a number of demonstration projects will be completed such as oil crops breeding base, 200,000 Ha oil-yielding jatropha plants, large scale shrub and grass plants with high productivity, wind resistance and draught resistance characters. FT diesel will be in demonstration stage. Technology of biomass liquefaction for diesel will achieve also achieve breakthrough. Through technology improvement and scale up, total biodiesel production will be 8 million tons.

- By 2030, different biodiesel technologies like FT diesel and pyrolysis diesel will be commercialized while traditional biodiesel from animal and vegetable fats have already been well developed and applied. Due to more raw material choices, the scale up of oil-yielding energy forests and alga, the total output capacity of biodiesel will achieve up to 20 million tons per year.

Major challenges and policy recommendations

Remarkable achievements have been made in China's renewable energy sector. But when considering the strategic role of renewable energy in the future energy structure, China's renewable energy industry still faces big challenges:

- The policy and market environment still need to be improved;
- It is still lack detailed and refined research for resource evaluation;
- Technology innovation and creativity capacity is still weak.

In order to set up a solid basis for China to achieve its renewable energy target, more investment should be provided on technology innovation, policy and institutional capacity:

- Improve and promote renewable energy development plan;
- Introduce renewable energy quota system;
- Increase financial support, such as renewable energy fund, tax reduction etc.
- Improve renewable energy market system;
- Further research on resource evaluation;
- Promote industry's technology R&D capacity.