CHAPTER 12

INNOVATION AS THE DRIVING FORCE FOR CHINA'S RENEWABLE ENERGY POWERHOUSE

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There is a consensus among the international community that energy transition is the key to addressing climate change and simultaneously maintaining an approach to economic growth and social development that aims at efficiency, harmony, and sustainability. Progress in renewable energy (RE) technology, in turn, is both the key driving force and a core element of further energy transition. Almost all major economies of the world have put forward their objectives, supportive policies, and measures to keep RE development moving ahead. European Union leading members Denmark and Germany; authorities of some states of the United States of America (U.S.) such as California, as well as Australia, India, Japan; and even Saudi Arabia and the United Arab Emirates, the primary oil and gas producers in the Middle East, are all proactive in the innovative development of RE sources. Most countries in the world have officially joined the Paris Agreement with its commitment to sustainability through the de-carbonization of the energy system. Forty-seven countries most vulnerable to climate change have proposed a target of realizing 100% RE sources by 2030–50.

As a top consumer and producer of energy, China is experiencing a transition from the traditional approach of coal dominance with its high environmental cost to a low-carbon, environment-friendly system. The Chinese government has developed a comprehensive package of strategic policies and measures to promote an overall transition of the energy system towards sustainability and low carbonization, with the goal of raising the share of non-fossil energy to 15% of primary energy consumption by 2020, and to 20% by 2030.[1]

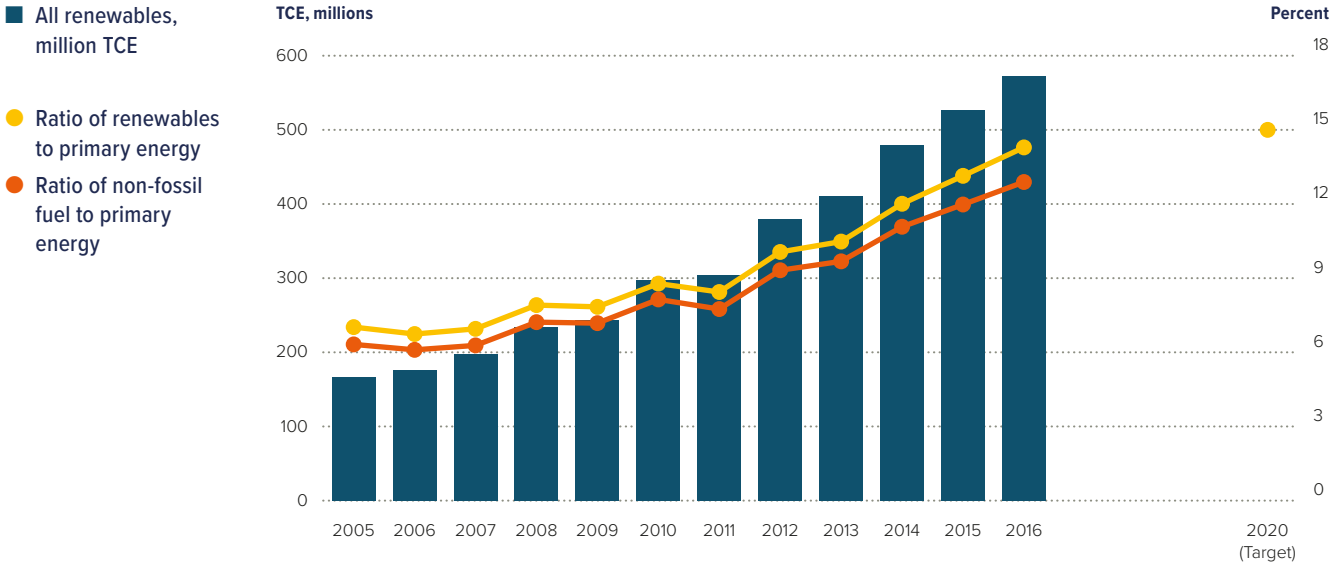
Closely linked to the national energy transition, RE relies on innovative development to efficiently reduce the consumption of coal. Long-lasting policies and measures can safeguard the development of RE technology and industrial innovation, whereas diversified and locally suitable business models along with innovative financial tools will undoubtedly facilitate cost reduction, commercialization, and expansion of its technology.

Innovative development in China's RE sector

In recent years China has enjoyed rapid growth in the RE sector, setting new records in both installed capacity and electric power generation and bringing about a continuous

Figure 1.

China's renewable energy usage, 2005–16



Source: CNREC, 2017b.

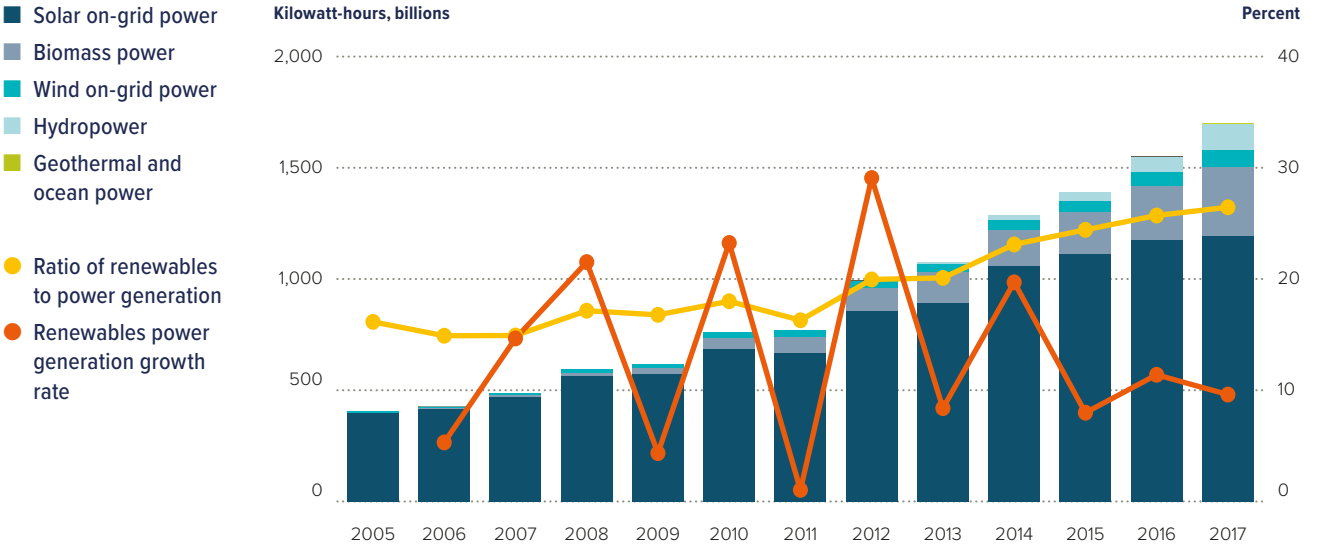
Note: 'Primary energy' is energy that is used directly in its natural form, without any modification. Examples are raw coal, crude oil, natural gas, hydropower, and wind and solar energy, among others. Primary energy is divided into renewable (such as wind and solar) and non-renewable (such as fossil and nuclear) sources. TCE = metric tonnes of coal equivalent.

evolution of its energy structure, resulting in a constantly increasing proportion of non-fossil energy. The total installed capacity of RE power generation grew to 570 million kilowatts (kW) from the 254 million kW of 2010; the proportion of RE electric power generation in total electric power generation rose from 26% in 2010 to 34.6% in 2016. Total renewable electric energy generated in 2016 was over 1.5 trillion kilowatt-hours (kWh), 25% of the national total, compared with 18% of that in 2010. In 2016, China's total energy consumption amounted to 4.36 billion metric tonnes of standard coal equivalent (TCE), with a distribution of 62% coal, 21% oil, 6% natural gas, and 13% non-fossil, of which RE took up 11% of the total.[2] That year, the total RE for commercial use (including all types of electric power and bioliquid fuels) equalled 480 million TCE, approximately 10.8% of the country's total energy consumption.[3] Wind and solar power together provide more than 10% of the total electric power supply in the provinces of Inner Mongolia, Qinghai, and Gansu, providing the greatest share of newly added sources of electric power. Figures 1 and 2 show the history and current status of China's RE source usage and electric generation.

Over the past decade, China has played a significant role in global renewable energy development. In 2008, China ranked 5th worldwide in the amount of wind-generated electric power. In 2011, the country moved up to 2nd place, next only to the U.S., and in 2016, it overtook the U.S. to reach 1st place.[4] Solar photovoltaic (PV) generation also increased quickly from 2014 through 2016, when China replaced the U.S. at the top in this metric. By the end of 2016, China boasted the highest installed capacity of RE sources in the world: it came in 1st globally in the hydropower installed capacity for many years in a row; it was on top in total wind power installations and total solar thermal heat usage for five consecutive years, and it has been number 1 in PV since 2011 with the exception of 2014, when it fell behind.[5]

Figure 2.

China's renewable energy electricity generation, 2005–16



Source: CNREC, 2017b.

Note: There are no available data for the growth rate of renewable power generation for 2005.

As the key force for energy transition, RE is also one of the major instruments used to address climate change. With its commitment to the Paris Agreement, the Chinese government set the goal, with 2005 as the baseline, of reducing its carbon intensity by 45% by 2020 and 60% by 2030. This means that China must make tremendous efforts to reduce carbon emissions. Boosting RE sources would certainly be a critical factor contributing to this goal. Additional goals include investing 41 trillion RMB (US$6.7 trillion) from 2005 to 2030. Of that amount, 10.4 trillion RMB had already been invested from 2005 to 2015. An additional 30 trillion RMB is projected to be invested between 2016 and 2030.[6] All these efforts have established a sound political environment and broad market space to address issues of climate change and sustainable development. To effectively implement its commitment to addressing climate change, China believes that replacing the fossil-fuel dominated energy system with a clean, low-carbon, RE system is a necessity.

For this purpose, China has announced the *Development Plan on Renewable Energy* and set a target of non-fossil energy providing up to 15% of the primary energy demand by 2020, including hydropower (with 340 million kW), wind power (with 210 million kW), solar PV (with 105 million kW), solar thermal power (with 5 million kW), and biomass (with 15 million kW)—together totalling 675 million kW.[7] By 2030, 20% of total primary energy consumption will be from non-fossil energy sources.

Innovation: China's key driver of RE development

Innovation in policy setting stands as the cornerstone of RE and safeguards its development.

Policy innovations

In 2005, based on a thorough investigation of the existing situation and a review of experiences at home and abroad, China promulgated the Renewable Energy Law, which established the legal basis for the country's RE development. The law has put forward a series of innovative provisions, especially the terms of the 'full purchase' and 'feed-in tariff' provisions.[8] With this legal framework, in the RE resource-rich and generation-intensive regions (such as Northeast, Northwest, and North China), high-power direct current transmission networks were erected to realize the West Electricity Supplying East programme, thus providing the necessary infrastructure for the full purchase of renewable energy electricity. The most important determining factor for scaling up the development of RE is its cost. By bidding and other means, China finalized the feed-in tariff for the main RE power generation technologies, such as wind power and solar PV power, so that their costs reflect the characteristic costs of these resources in China. The feed-in tariff has effectively reduced the cost of wind power and solar PV power, driving onshore wind and solar PV power technology to become the first non-hydro RE technologies commercialized in China, and thus contributing to the global effort of cost optimization of wind power and PV power.

The most important determining factor for scaling up the development of RE is its cost.

For many years, China has supported innovative technology in RE development, establishing special funds for it, giving tax exemptions to businesses that use their own funding to invest in innovative technologies, and offering favoured tax status to high-tech and mini and micro businesses.

State-level innovation programmes and pilot projects drive RE technology into scaled-up development and industrialization. The Ministry of Science and Technology has long prioritized RE technology as one of the areas to receive national innovation funding.[9] Notably, programmes that aim to promote the industrialization of these technologies, such as the Solar Leading Runner and the Solar PV Alleviating Poverty programmes, are organized by national energy authorities and local governments. These select and apply advanced technical and market-competitive products through bidding and guide the application of innovative technology, boosting PV industry as a whole.

The scale of the RE industry is expanding, the cost of the technology is decreasing, and policies and measures are being adjusted and modified at appropriate times in the course of RE development. Tariff support for RE electricity has decreased each year since 2015, leaving relevant businesses to face more pressure to make a profit. Under the policy guidance, RE industries have become more motivated to continue technical innovations, develop new products and new technology, and lower costs. These industries have also enhanced their technical capabilities and business management skills. As the governing body for China's RE industry, in 2017 the National Energy Administration proposed establishing a voluntary purchase system for acquiring RE green power certificates and planned to commence power-quota assessment and qualification procedures to mandate the regulation of transactions at the proper time, thus further reducing demand for RE funding support. In the meantime, the policy and regulations also guided enterprises that performed well to obtain a greater market share and helped to secure RE as a stable space for growth.

Technical innovations

Technical innovations are a direct boost to the advancement of China's RE industry. RE technologies, integrated with cross-boundary technologies, preliminarily require technical innovations and adaptive fusions. The field of global RE technology was first explored in Denmark, Germany, and the U.S.; China's RE development began in technology exchanges with Europe and the U.S. As early as the 1980s, China engaged in exchanges with Denmark and Germany over wind turbine technology and human capacity building. With RE industry development, China's innovative capacity for these technologies has consistently improved.

China has carefully prioritized the development of RE technologies with a promising market and rapidly advancing and significant industrial scale-up expansion. For example, the country's wind turbine design technology went through a long process that began with engaging in direct imports, then purchasing licenses, innovating in components, and finally engaging

in internal R&D by local producers. Now China has established a complete production chain with the largest production capacity in the world. A set of high-capacity units, such as those with 1.5 to 3 megawatt (MW) unit capacity, is technically a mature batch product. A larger unit with a capacity of 3.6 to 5 MW can also be produced in quantity. Production capacity of most wind turbine components is up to an internationally advanced level and could meet all the requirements of mainstream models. Technology concerned with bearings, inverters, and control systems also has greatly improved.[10]

In 2016, China exported 319 wind turbines, with a total capacity of 550,000 kW. By end of 2016, 28 countries—including Australia, Pakistan, and the U.S.—had imported 1,404 wind turbines from China, with a total capacity of 2,580,000 kW.

China values intellectual property rights protection to encourage RE innovation. The yaw system wind turbine provides an example.[11] Statistics show that, from 2000 to 2007, patent applications for yaw systems in China and Japan witnessed the fastest increase in the world.[12] From 2007 to 2012, there were 1,203 patent applications worldwide related to the yaw system. China had the biggest share, with 318 applications. The rapid growth of patent applications occurred in the fastest-growing period for wind turbines in China.

Innovation suitable to China's national conditions and practical needs is the essential element in its development of RE technology. For example, when China carried out R&D in wind turbines, special attention was paid to meeting the needs created by the country's diverse wind resources, geographic terrains, and market demands. As a result, China has successfully developed turbines that can accommodate various wind-status conditions and terrains in China, including those characterized by low wind speed, high altitude, tidal zones, and coastal areas.

Business and financial model innovations

Innovations in commercial and financial models are instrumental in the RE scale-up, which calls for constant innovation in business models and the participation of both public and private capital. Total investment in China's RE for 2016 amounted to US$78.3 billion. Not counting large hydropower, the Chinese market share was 32% of total RE investment worldwide. In terms of type of investment, the majority—US$72.9 billion—made in 2016 was still asset financing; financing for small and distributed PV projects reached US$3.5 billion,[13] an increase of 32% over 2015. This success demonstrates that China has adopted a two-pronged approach: one prong is securing quick growth by building major PV stations, and the other prong is supporting the development of distributed PV stations with innovative financing models.

Challenges and countermeasures to the development of RE innovation in China

China has made remarkable progress in the development of RE, but it still faces many challenges. The following issues require the attention of policy makers as well as businesses.

First issue: RE development may grow too quickly, leading to an imbalance between supply and demand. In this case, renewable power generated could not be consumed locally, and could not be integrated into power grids to be transmitted to fulfil long-distance demand, giving rise to problems of curtailed wind or PV electric power. The problem of generating so much renewable power that it exceeds local demand and cannot be integrated into power grids has occurred especially in regions of Western China with abundant RE sources, where more than 20% of the wind or PV power is curtailed. To resolve this problem, the government needs to speed up building infrastructure such as extensive power-transmitting lines. At the same time, enterprises with large power consumption needs should be incentivized to set up production bases in the Western region, where they could benefit from cheaper, more favourable power rates. China should also accelerate the establishment of the power trading market and eliminate institutional obstacles to the development of RE, thus providing a fundamental market guarantee for the development of RE.

Technologically optimal integration of the whole energy system should be consolidated. Thanks to the Internet and other new technologies, RE will become a vital component of the distributed energy system. Power storage technology can play an active role for its flexibility in modulating the supply-demand of power, reducing wind/PV/electric abandonment.

Second issue: There are too many RE enterprises that are too big, especially

manufacturers of PV power products such as batteries, panels, and so on, that produce more than can be consumed. These enterprises lead to surplus production and multiple pressures. The government should, on one hand, address this situation by guiding these enterprises to develop new products tailored towards an expansion to different domestic markets; on the other hand, it should encourage these enterprises to take their surplus to the overseas market and bid on international projects.

Third issue: Previous standards and regulations can hardly meet the demands of the fast-growing RE industry; failures have occurred in guaranteeing the quality and expected outcome of certain engineering projects. The government has come up with a solution by issuing the Measures on Encouraging Industrial Associations & Societies to Establish Standards & Regulations. These Measures should be implemented faithfully, thus facilitating the establishment and improvement of RE industry evaluation rules and standards and promoting the healthy and orderly development of the industry.

Fourth issue: There is a global consensus on the need for sustainable development. RE is an important means to achieving this. Because the RE sector has emanated from cooperation and depends on diversified innovation, China should continue to strengthen international cooperation in this sector with a view to achieving a win-win outcome, carrying out exchanges in technology, policy, and management; sharing best practices; and promoting innovation through cooperation and promoting cooperation through innovation.

Conclusions

China's practice demonstrates that innovation is the original driver of energy transformation and sustainable development. Innovation is also a core element of economic growth. China has become the first middle-income country to join the ranks of the world's 25 most innovative economies in 2016, according to the Global Innovation Index. This demonstrates that China has developed quite a robust innovation capacity and exhibits strong performances in many sectors. As one of China's national strategic decisions, the development of RE is an important path leading to eco-environmental improvement, a necessary choice for addressing climate change and an important step towards realizing energy transition and optimizing energy structure. In the future, China is predicted to continue its innovation in the RE sector with better performance, higher efficiency, and larger contributions, thus further promoting the sustainable development of humankind.

Notes

1 'Primary energy' refers to energy that is directly used without change or transformation, such as raw coal, crude oil, natural gas, hydropower, wind energy, solar energy, ocean energy, tidal energy, geothermal energy, natural uranium, and so on. Primary energy is divided into renewable energy and non-renewable energy. The former refers to natural energy that can be generated repeatedly, and includes solar energy, wind energy, tidal energy, and geothermal energy. The latter is mainly composed of fossil fuels and nuclear fuel.

2 CNREC, 2017a, b.

3 CNREC, 2017a, b.

4 REN21, 2017.

5 REN21, 2017.

6 Jiang, 2016.

7 NDRC, 2016.

8 According to the Renewable Energy Law, the 'full purchase system' refers to the power grid companies (including electric power dispatching agencies), which shall fully purchase renewable electric power generated by planned and approved renewable energy projects based on the benchmark price of on-grid electricity and guaranteed utilization hours, combined with market competition mechanisms, through the implementation of priority power generation systems, without disturbance of secure power supply. See the management regulations on the guaranteed full purchase of renewable energy power issued by the NDRC, available at http://www.ndrc.gov.cn/zcfb/zcfbtz/201603/t20160328_796404.html (in Chinese).

According to the same Renewable Energy Law, the 'fee-in tariff system' is regulated by the NDRC and defined by bidding or other means.

9 The two national programmes on innovation, established by the Government of China and implemented by the Ministry of Science and Technology, targeted the basic R&D of strategic and foresighted technologies, especially the high-priority issues faced by the country's economic and social development concerns.

10 CNREC, 2017a, b.

11 The yaw system is responsible for keeping the blades of the turbine oriented toward the wind.

12 Rentian Zhang and Hong Wei, 2017.

13 UNEP and BNEF, 2017.

References

CNREC (China National Renewable Energy Centre). 2017a. *China Renewable Energy Industry Development Report 2017.* Beijing: China Economic Publishing House. (In Chinese.)

——. 2017b. Handbook 2017 of Renewable Energy Data'. Internal document. China National Renewable Energy Centre.

Jiang, T., editor. 2016. 'Xie Zhenhua on China Will Invest 30 trillion RMB to Address Climate Change in the Next 15 years'. *Xinhuanet*. (In Chinese.) Available at http://www.xinhuanet.com/world/2016-04/23/c_128923516.htm.

NDRC (National Development and Reform Commission). 2016. The Notice on Issuing the 13th Five Year Planning for Renewable Energy Development. Beijing: China National Development and Reform Commission. (In Chinese.) Available at http://www.ndrc.gov.cn/zcfb/zcfbtz/201612/t20161216_830264.html.

REN21 (Renewable Energy Policy Network for the 21st Century). 2017. *Renewables 2017 Global Status Report*. Paris: REN21 Secretariat. Available at http://www.ren21.net/wp-content/uploads/2017/06/17-8399_GSR_2017_Full_Report_0621_Opt.pdf.

UNEP and BNEF (UN Environment and Bloomberg New Energy Finance). 2017. *Global Trends in Renewable Energy Investment 2017*. Frankfurt am Main: Frankfurt School of Finance and Management. Available at http://fs-unep-centre.org/sites/default/files/publications/globaltrendsinrenewableenergyinvestment2017.pdf.

Zhang, R. and H. Wei. 2017. 'Analysis for Yaw System of Wind Turbines'. *Wind Energy* 92: 32.