China Clean Energy Development

In the 21st century, China energy consumptions are very massive, especially to produce the electricity. The cost and availability of energy not only impacts significantly to the people quality of life, but also the national economies, relationship between nations and their environment stability. With lower cost and easy to find, the fossil fuels such as coal, crude oil and gas have become the choice of major power source for the industry. On the other hand, many experts consider whether the fossil fuels are not the reliable sources. One is, the amount of fossil fuels is finite (not renewable), which means these sources will soon run out in the future (Ritchie and Roser, 2020)[1]. Other is, burning fossil fuels actually release huge amount of CO_2e gas to the atmosphere, these gases also known as the greenhouse gases. Statista (2021) recorded the share of CO_2e emission for China energy sector in 2019.

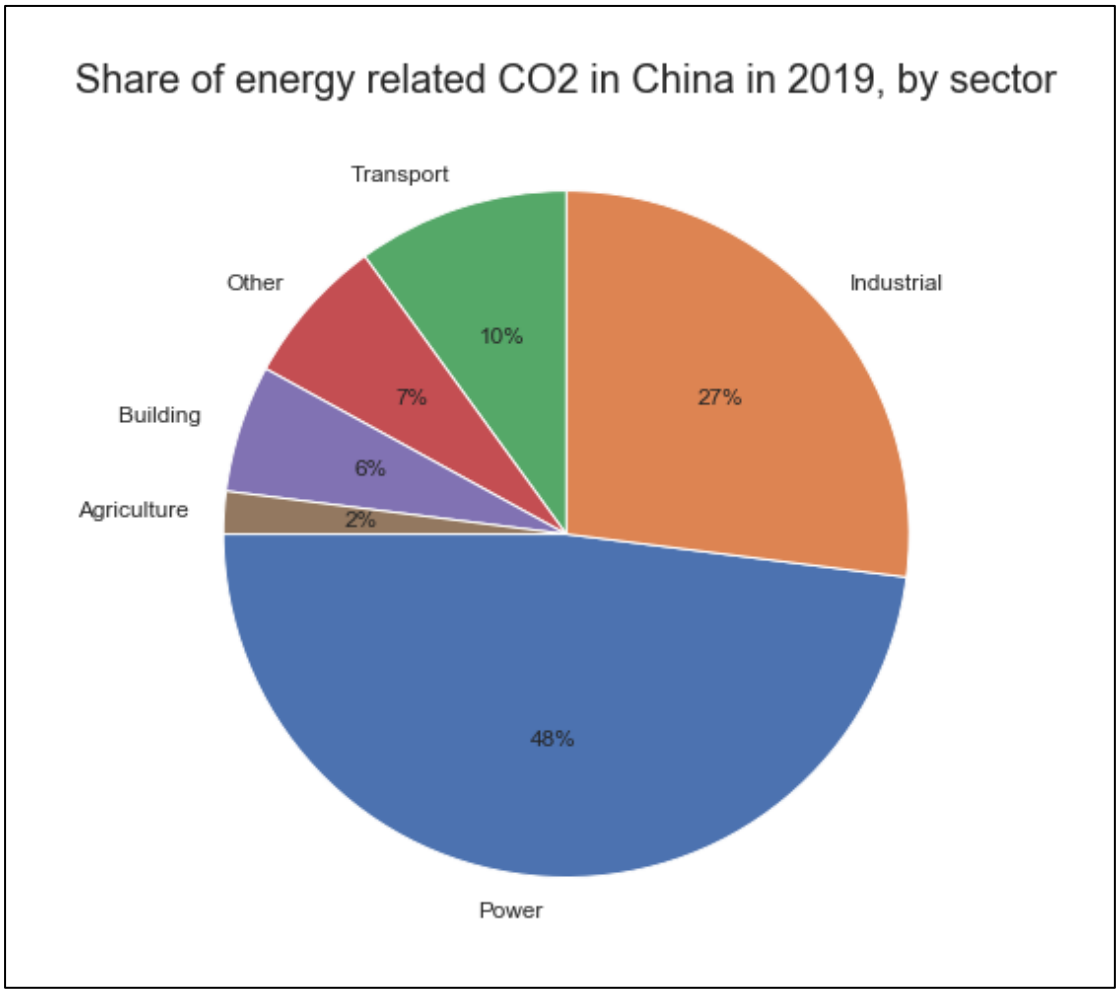

Figure 1. Share of energy related carbon dioxide emissions in China in 2019, by sector. (Source: Statista Research Department, 2021)[2]

Half of China energy sector emission came from the power generation sector, which is famous for electricity power generation with around 48% of CO_2e. Followed by the emission of industrial and manufacturing sector, either to consume or produce energy, with 27% of CO_2e. The transportation industry is another sector which consume fossil fuel to produce CO_2

emission which accounted for 10%. The rest of industries like agriculture, building and other, also contribute to small portion of the energy sector emissions.

These emissions are hardly visible but it actually exists on our atmosphere. The huge amount of these gases being trapped on the atmosphere has resulted in warming phenomenon which is known as global warming. Until now, the global warming has brought many adverse effects to the humanity. For example, increase in global sea level due to the ice melting, increase in ocean surface temperature which harm the biodiversity as well as increase storm occurrence, also the earth's average temperature rises every year resulted in drought, until the random climate occurrence and sudden disaster appears.

Lately, the direct effect that humanity felt is through the disaster like natural burning forest, heatwave, extreme weather and flood. EM-DAT (2020)[3] found that both the extreme weather and flood are two most frequent disaster faced by humanity every year. This is proved from the recent Zhengzhou flood in China, which happened in mid-2021 due to sudden storm rainfall that last for 72 hours (Feng, 2021)[4]. The increase in sea level might also harm the China coastal cities like Shanghai as well as Hainan island. The morning in 13rd October, exactly at Yundong landmark (云洞) in Haikou city was flooded by the seawater (Sina, 2021)[5]. The unexpected flood has raised many awareness especially habitants of the China coastal cities.

To tackle further warming and more disaster events, the Chinese government officials require to cut the main source of the issue, which is the emission. Such challenges actually have been addressed just before the 21st century, through the Tokyo protocol (1997) joined by 192 parties/countries includes China. These countries commit to reduce average emission by 5% compared to 1990 levels over the five-year period of 2008–2012 (UNFCC)[6]. Similarly, in November 2015, UNFCCC established conference called 'Paris Agreement'. The conference aims to limit global temperature rise to no more than 2°C but preferably to 1.5°C by 2100, through common but differentiated responsibilities of the Parties/Countries (UNFCCC)[7]. Soon after China agreed to joined this movement, China published the 13th Five Year Plan in March 2016. The plan consists of 2016-2020 pledges for emission reduction, includes the strategies on new energy transition (Chinese Government, 2016)[8].

Coal Shares

As a current developing country (发展中国家), China is still in the industrialization stage, massive industrial production by burning fossil fuels, have created another new problem such as climate and environmental issues. Therefore, the carbon emission reduction is a must, where currently China is strived for, by cutting the fossil fuel use. By the record, in very early days, China coal's consumption reached 90% of the country's total energy (Toutiao, 2021)[31].

Since the 13th Five Year Plan, China manages to restrict the production and use of coal as energy source in the last 5 years. This is given by the data on the decline of coal consumption since 2015 published on the "China Statistical Yearbook 2020" (National Bureau Statistic of China, 2020)[9].

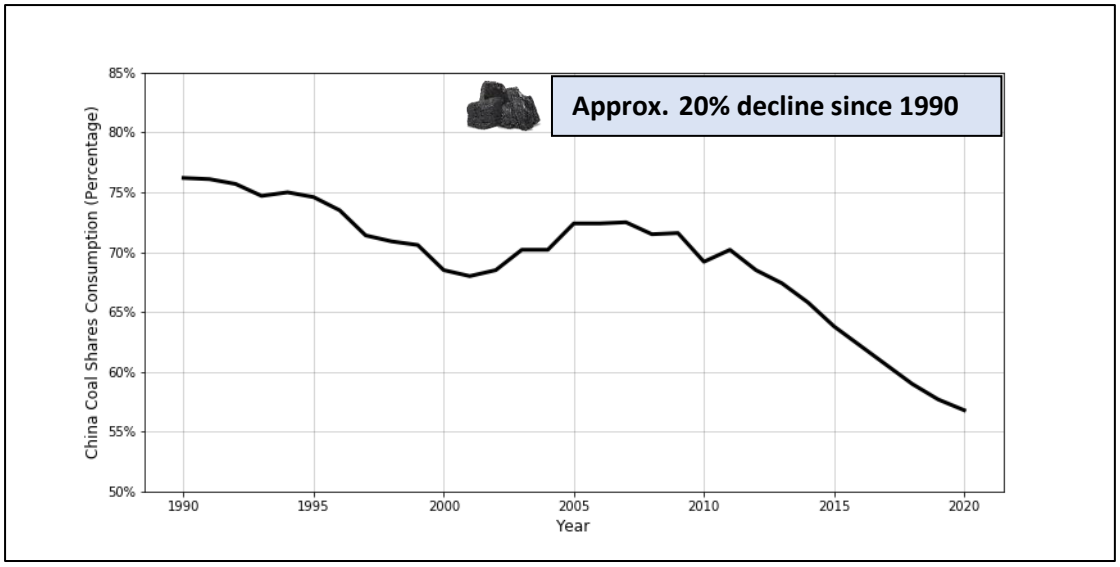

Figure 2. China's coal shares of energy consumption from 1990 to 2020. (Source: National Bureau Statistic of China, 2020)[10]

In China, coals are regularly use to power up the electricity and industrial work, which are 2 largest emitters in China energy sectors (**Figure 1**). Overall, the Figure 2 shows the decline in coal consumption for China since 1990 with 76.2% to 56.8% in 2020. As we can see, the huge drop is occurred since 2011, the constant downhill explains whether Chinese government officials are seriously taken account of the global warming issue. Precisely after the Paris agreement and 13th Five Year Plan. On the same time, National Bureau Statistic of China (2020)[9] also recorded if China renewables energy shares have increased around 10% between 1990 and 2019, where 5% increase since 2013.

Later in March 2021, the Chinese Government (2021)[11] issued the 14th Five Year Plan, it includes the plan for China in order to reach carbon peak by 2030 and carbon neutrality by 2060. They also emphasize one section in clean energy-coal transition to achieve these goals:

> **Chapter 11, Section 3:** Pledge to accelerate the development and increase the proportion of non-fossil energy shares in total energy consumption by 20%. Promote the replacement of coal powered electricity, as well as reasonable control on the development and scaling of coal-powered industry.

Xu and Singh (2021)[12] also reported in April, that China aims to cut the coal use to below 56% of total energy consumption by end of 2021. Alternatively, replacing coal with bio-energy source might help to reach the carbon peak by 2030 as well. This also mentioned in **Chapter 9; Section 1:** where China will focus on the improvement of biotechnology, specifically utilization of bio-energy (Chinese Government, 2021)[11].

Bio-energy

Bio-energy is a clean and renewable energy produced from organic matter (biomass) such as plants, crops and organic waste. In the industry, bioenergy sources are likely to be burnt to produce electricity and machinery power generation. The incineration process will produce

GHG emissions, however since using organic source matter, these emissions are actually mitigated. This is due to plants carbon storage function by absorbing the carbon dioxide. As the result, the bio-energy technology is carbon neutral.

In China, the biomass energy accounts for a growing proportion in total renewable energy. In the first quarter of 2019, installed biomass capacity accounts for 2.54% of renewables. In 2018, China's biomass power generation experienced 14% increase year-on-year, generating 90.6 billion KW of power. In the first quarter of 2019, biomass power generation increased by 16.7% year-on-year, reaching 24.5 billion KW (Jiang, 2020)[13]. They also expected that by the end of 2020, the biomass capacity installed reach 15 GW. The increase in biomass power generation has positive dependence with the total power capacity.

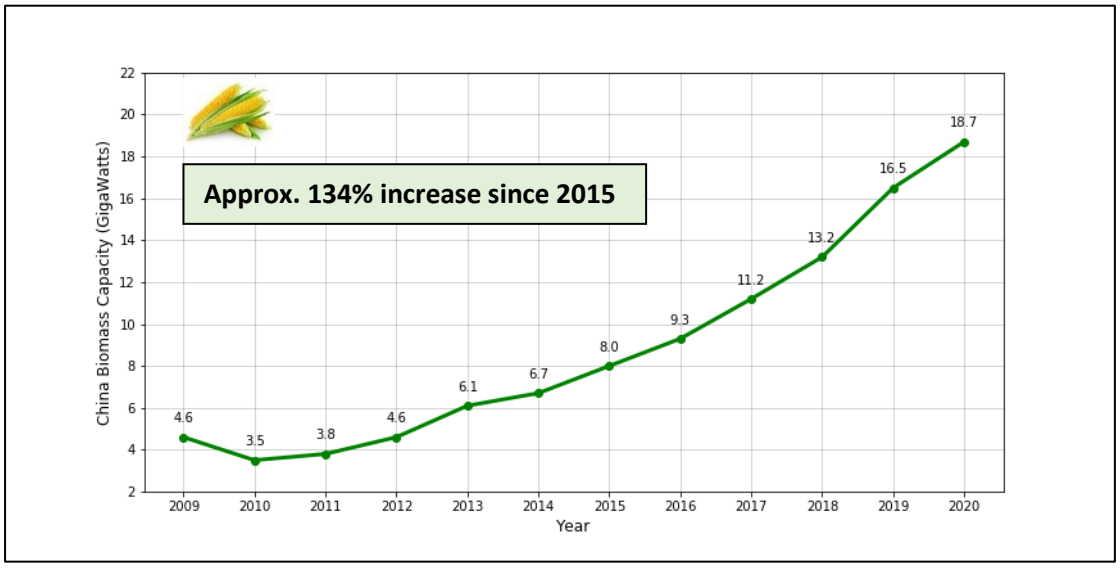

Figure 3. Capacity of bioenergy in China from 2009 to 2020. (Source: Jaganmohan, 2021)[14]

The annual biomass installed capacity after 2010 is pretty solid. Since 2010, the total capacity has risen by more than 4 times. Estimation of 10.7 GW installation since 2015, which resulting in 18.7 GW of total biomass capacity (Jaganmohan, 2021)[14]. In the last 3 years, there are approximately 5.5 GW newly installed capacity, which contributed by topped biomass power generation provinces such as Shandong, Zhejiang, Anhui and Jiangsu province, with increase installation of 0.46 GW, 0.26 GW, 0.33 GW and 0.45 GW respectively (Liu, 2020)[15].

Compare to other renewables, apparently bio-energy still lack of local officials' attention and incentives, which makes this market hard to scale widely. However, with cutting-edge technologies and innovation, researchers are able to combine the Bio-Energy with Carbon Capture & Storage technology (BECCS), which yield in negative carbon emission. Yang et al. (2021)[16] recognized that BECCS may still take years to mature and readily to implement in China. They project, with 73% of national crop residues used between 2020 and 2030, it could reduce 8620 Mt CO2-eq of total GHG emission by 2050, contributing 13–31% of the global GHG emission reduction goal for BECCS, and more than 4555 Mt reduction from China alone.

Beside biomass, others clean energy such as wind, solar, hydro and nuclear power also takes role contributing to achieve China dual carbon targets as well.

Solar Power

Using the technology called solar panel (solar PV) to convert sun power to electricity and power generation source. It is considered as clean and renewable energy, which is vital towards our carbon neutrality roadmap.

In China, the market of solar PV is huge. However, since the technology 100% rely on natural sun source, the consistency of solar power production might be an issue sometimes. With the total of 6,990 Billion Kilowatt (kWh) electricity generation in China in 2018, the solar power only contributed for 2.5% (Mirae Asset, 2020)[17]. In fact, in 2018, the total capacity of solar PV reached 175GW (9.2% of total power capacities), which is considered huge.

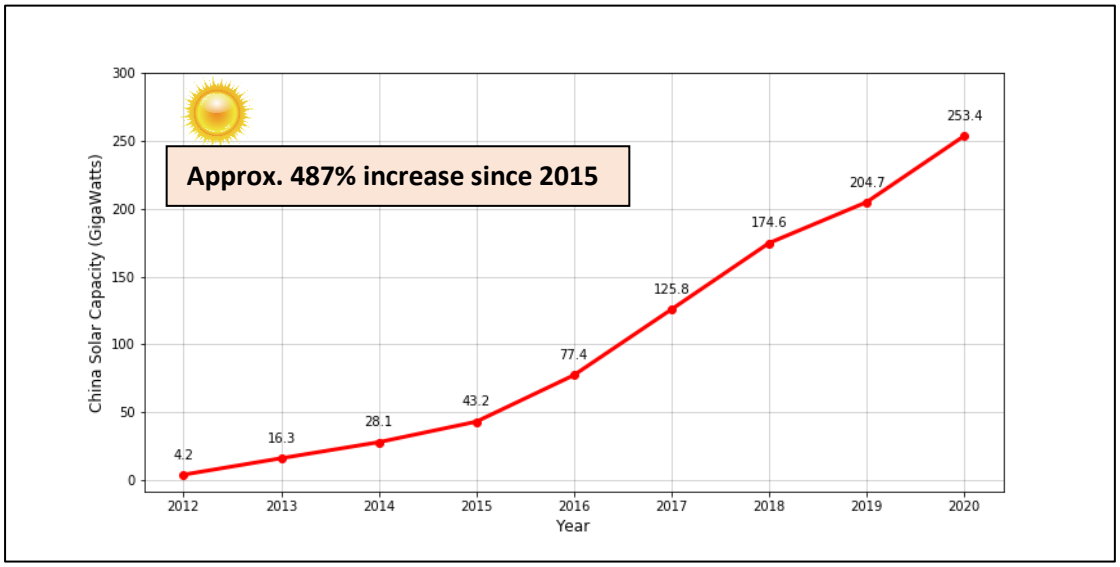

Figure 4. Accumulated of solar power capacity in China from 2012 to 2020. (Source: Statista Research Department, 2021)[10]

Overall, it shows positive trends for China's solar power market, especially on the last 5 years which yield almost 500% increase in new capacity, topped by 253.43 GW capacity in 2020. Several reason towards the surges:

One is because increase in the electricity grid storage connection. Lu et al. (2021)[18] found the cost-competitiveness of solar power allows for pairing with storage capacity to supply grid electricity. Therefore, with more storage system, there will be less power waste from solar PV and the surplus will be stored instead.

Second, the FiT tariffs policy which issued by the NDRC, Ministry of Finance and NEA (2019)[19], the Chinese government and officials provide subsidies and cut certain the tariff of newly installed PV before the end of 2021.

Another reason is, new innovations of PV application on different industries, such as sustainable buildings, agrophotovoltaics, and many other industries. China also expected to add up to 65 GW of solar power capacity in 2021, taking total solar installations beyond 300 GW by the end of the year.

Wind power

Similar to solar power, the wind power in China were gaining momentum for these last 2 years, due to FiT tariff policies as well. By utilizing the strong wind power, the installation of wind turbines is mostly on higher grounds like hilltops and on the seashore. Despite, similar seasonality drawbacks like photovoltaic, the wind power actually has better electricity production shares compare photovoltaic in China, due to better strategic area.

Mirae Asset (2020)[17] recorded out of 32.9% of total non-fossil fuel electricity generation, 5.2% is generated from wind power in 2018. Moreover, China owned the total of 184GW (9.7%) wind power capacity by 2018.

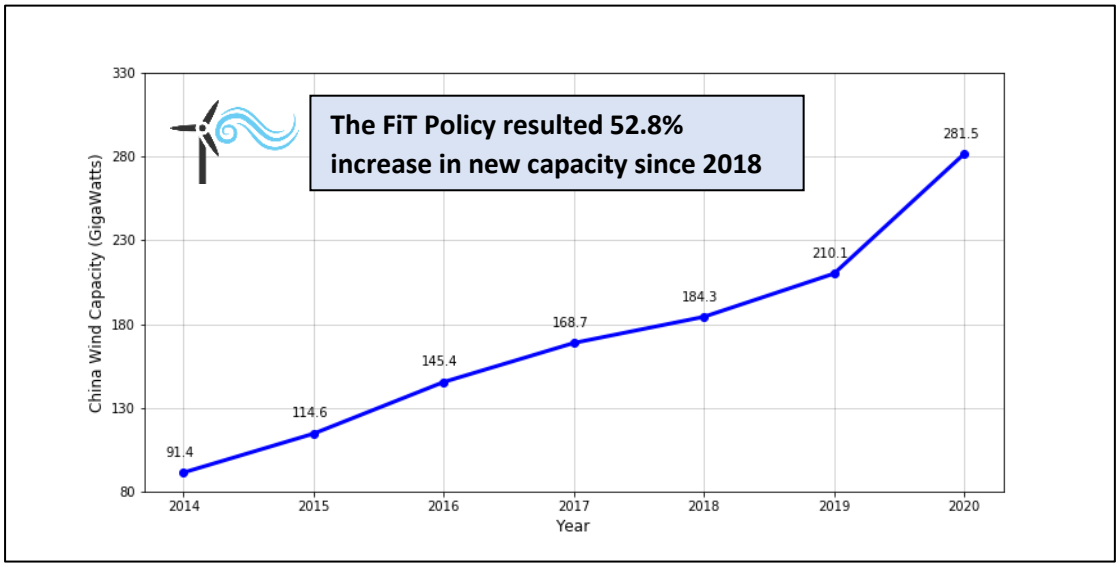

Figure 5. Accumulated Installed Wind Power Capacity in China 2014-2020. (Source: Statista Research Department, 2021)[20]

Similar to photovoltaic solar energy, since 2014 the China wind energy market is on the positive trend as well, especially for last 2 years. This is due to the new 2019 wind power FiT subsidies which is subjected for both onshore and offshore wind power.

The projects that are approved in 2019 & 2020, will enjoy the 2019 FiT and 2020 FiT respectively, only if they are connected to grid by the end of 2021. Thus, this led to massive 2020 installations rush in China, especially the onshore wind power (GWEC, 2021)[21]. This explains the rapid growth of 2020 China's new wind power capacity.

In 2020, IRENA (2021)[22] recorded with total of China's accumulated wind power capacity, where 273 GW was built onshore and only 8.99 GW was built offshore. Since the offshore wind FiT subsidies still going on until the end of 2021, there is still huge investment and opportunity for the offshore wind power to grow this year.

Hydro-power

Compare to solar and wind power, China's hydro power market is very promising. Among all the renewables, China hydropower energy is the largest, which accounted for 18.4% of total power capacity or around 350GW in 2018 (Mirae Asset, 2020)[17]. Not only that, in 2018, they also produce 17.9% shares of China's electricity. Apparently, hydropower has been a mature industry in China's renewables energy market.

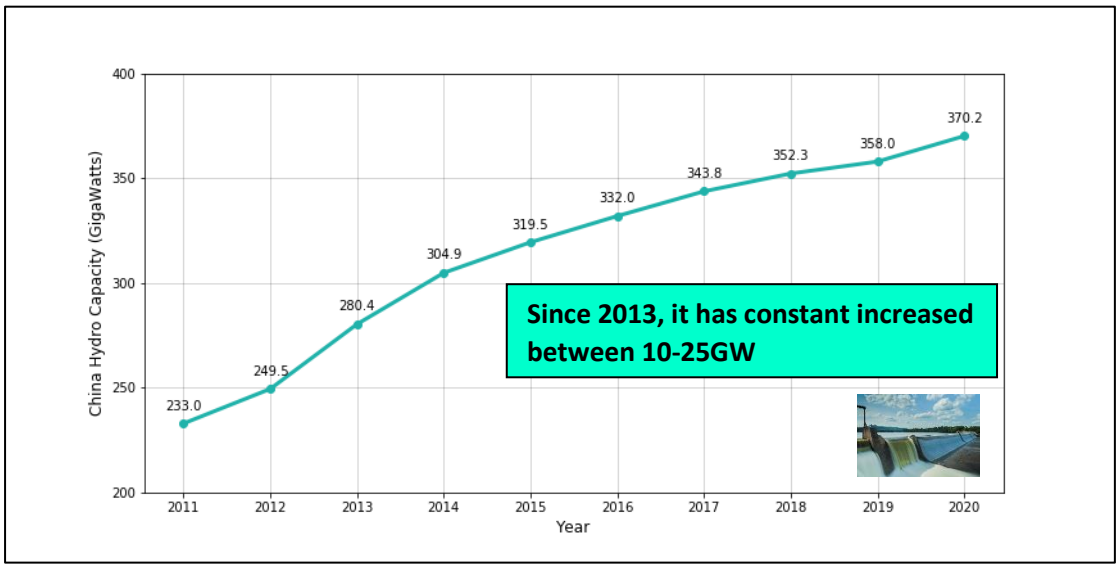

Figure 6. Accumulated Installed Hydro Power Capacity in China 2011-2020. (Source: IRENA, 2021)[22]

Different from solar and wind energy, the hydropower is relatively having steady rise by each year, with approximately 10-25GW of new capacity. This is because, the construction and technology took long time to build. In addition, unlike solar and wind power, hydropower did not have significant subsidies or incentive given by the government officials (Mirae Asset, 2020)[17]. However, they still contribute largest clean electricity shares by 2020.

Nuclear power

Unlike previous 3 clean energies, the nuclear power is not renewables, yet it is considered as the most reliable clean energy. This is because the nuclear power plants run 24 hours a day, 7 days a week and is designed to operate longer stretch. According to Energy-Gov (2021)[23], in 2019, nuclear plants operated at full power more than 92% of the time, making it the most reliable clean energy source on the grid today. In China, out of total 1900GW power capacity, the nuclear power capacity only accounted for 2.3% or 41.6GW in 2018 (Stringer and Koh, 2021)[24]. Despite that, it actually generated the amount of 4.2% of total electricity generation shares in 2018, which surpass the solar power (Mirae Asset, 2020)[17].

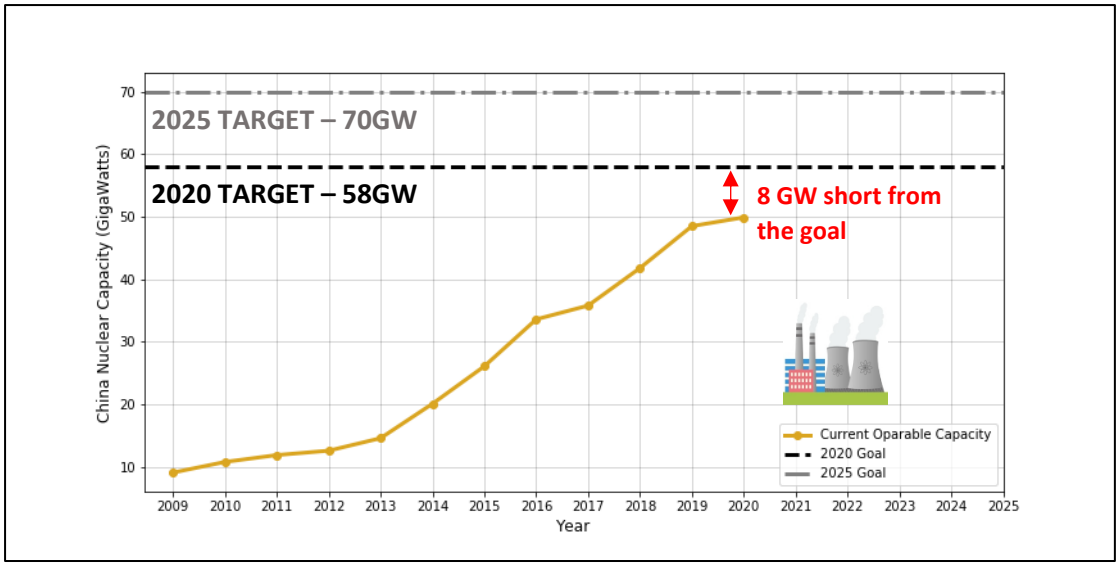

Figure 7. China operable nuclear capacity from 2009 to 2020, with their corresponding 2020 & 2025 goals. (Source: National Energy Administration - Stringer and Koh, 2021)[24]

Number of operable nuclear power capacity in 2009 only about 10GW. However, since 2013, the installation of new nuclear power plant capacity has steady increased until today, which topped with almost 50GW active nuclear capacity in China. From 2015, the total of capacity has doubled, which shows significant impact of Paris Agreement towards nuclear power plant market in China. Despite missing the first total capacity installation goal for 2020 (short by 8GW), yet China is very confident to reach 70GW by 2025 (with 20 new reactors). The COVID-19 pandemic is the reason for lack of power plant installation since 2019. As the result, they unable to scale significantly like previous years and reach NEA target in 2020.

Currently, China is estimated total of 344.7 TWh electricity generated from nuclear power or accounted for 4.9% of total China's electricity shares (World Nuclear Association, 2021)[25]. Furthermore, on October 2021, there is finalize record of 18 nuclear reactors are actually still under construction, 37 nuclear reactors are planned, and 168 nuclear reactors are proposed. In total they might potentially provide approximately 257.3 GWe of electricity source (World Nuclear Association, 2021)[25].

China's Future Energy Demand

With the announcement of President Xi Jinping for China pledge to peak the emissions before 2030 and carbon neutrality by 2060 (SOLARBE, 2021)[26], and the 14th Five Year Plan which released in March 2021, the objective on reducing fossil fuel source, as well as promoting the clean energy is very vivid. Especially, for the upcoming 5 years, where the transition and process occur. On 12 October, China officially established a carbon peak and neutral "1+N" policy. The "1" is considered as the carbon peak and carbon neutral instruction and roadmap, and the "N" is considered as policy measures and actions in key areas and industries, including carbon peak action plan by 2030 (界面新闻, 2021)[32].

One of the reputable Chinese institution namely "Tsinghua University's Institute of Energy, Environment and Technology" create the 2025 and 2060 energy-mix shares roadmap in order to reach future carbon neutrality and 1.5-degree or 2-degree goal (Meidan, 2021)[27].

Energy Source	2025		2060	
Coal	52%	Fossil Fuels: **80%**	3%	Fossil Fuels: **14%**
Oil	18%		8%	
Natural Gas	10%		3%	
Wind	4%	Clean Energy: **20%**	24%	Clean Energy: **86%**
Nuclear	3%		19%	
Biomass	2%		5%	
Solar	3%		23%	
Hydro	8%		15%	

Figure 8. Forecasts of China's energy mix, 2025 and 2060 (Source: Tsinghua University's Institute of Energy, Environment and Technology - Meidan, 2021)[27]

This projection shows whether by 2025, China's residents will still rely on the fossil fuel share to produce energy, yet the coal shares will reduce to 52%. On the other hand, at 2060 there is almost no fossil fuels source, as China already 86% transition towards clean and renewable energy with wind, solar and nuclear energy being the top 3 clean energy industry.

Another projection from NDRC and CNREC (2019)[28], they foresee the local non-fossil energy shares will account for 42% in 2035 and 65% in 2050. This is closely similar to the Tsinghua University roadmap. Given the projection of 18% decrease of CO_2 proportion by 2025 as well.

Moreover, Tsinghua University's Professor He Jiakun added with higher ambition to reach 1.5-degree, more than 85% of all energy and more than 90% of electricity in China should come from non-fossil energy (renewables and nuclear) by 2050 (Myllyvirta, 2020)[29].

Thoughts and Conclusion

With China ambitious plan and declaration for future carbon neutrality, the future of clean energy is very promising. However, to achieve such transition especially over next 40 years, China requires changing the entire economy system into "carbon neutral economy system". For instance, the carbon trading system which has been launched lately in China by 2021, increase investments in carbon-free technologies, renewables energy and CCUS. On top of that, application of clean cost-efficiency energy system in every industry might help the residents to accept the transition faster.

As China is the world's largest consumer of electricity (World population review, 2021)[30], energy sector has become the crucial movers for China's economy. Especially, after recent announcement from the chairman of the State Grid Corporation of China, Xin Baoan in 2021 Energy and Power Transformation International Forum, that with about 27% of the final energy consumption in 2020, it is expected it will increase to 39% and 70% in 2030 and 2060, respectively (Toutiao, 2021)[31]. Therefore, the full transition of reaching 86% clean energy by 2060, should be fairly adjusted along with their economy as well, considering China will still rely the fossil fuel energy by 2025.

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