

Comparative study of energy consumption structure between the U.S. and China

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Abstract. At the early stage of development, China has a monotonous energy consumption structure dominated by coal, which damages the environment and has adverse impacts on the economy and sustainable development of the country. It is urgent to change the existing energy structure to reach the goal of sustainable development and improve people's living standard. The U.S., as the world's strongest power, has been where China is now, so it is feasible to draw lessons from the U.S in its energy consumption structure. In this study, massive data about the changes in the energy consumption structure are collected and processed, and the types of energy in China and the U.S. are compared. In 2030, China will become the largest consumer of petroleum, and the problems in China's energy consumption such as supply-demand imbalance, low utilization of energy, and overdependence on imports, will rear their ugly heads. Thus, through theoretical analysis and data analysis, we analyze China's current structure of energy consumption, its similarity with and difference from that in the U.S., and propose suggestions to improve China's energy consumption structure.

1 Background

Energy is the basis of national development, and the capacity to control energy manifests a country's comprehensive national strength. An important indicator of a country's technical strength and standard of life is its development of energy, its effective utilization of energy and the energy consumption per capita. Due to the limits in natural reserves, coal takes up over 60% of all energy consumption in China. In general, coal plays a dominating role in China's energy consumption structure, and since 1993, China has been a net exporter of oil, and since 2009, China has shifted from a net exporter of coal to a net importer of coal. Thanks to industrialization, China has enjoyed a more diversified energy structure, grown from a "self-sufficient energy supplier" to a big energy importer, and the stable supply pattern has shifted to a pattern subject to prices and the climate.

2 Literature review

To probe into the correlation between GDP and energy consumption, Zheng (2011) processed the energy consumption data and GDP data of Henan Province from 1980 to 2008, and selected indicators of good correlations (coal consumption, oil consumption, and natural gas consumption), established an econometric model to explore the correlation between energy consumption and GDP growth.

Zeng and Li (2014) measured the influencing factors of the energy consumption structure by the grey time series technique, and selected 11 factors that affect the energy consumption structure in four dimensions — economy, structure, technology and politics, to assess the weights of these factors.

Zhou et al. (2017) analyzed the consumption proportion, the temporal and spatial distribution, evolution and influencing factors of four types of energies in provinces in China by using the K-means clustering method and the Stirpat model. Based on the data collected from provinces in China, they concluded that factors that were positively correlated to the coal-dominated energy consumption structure are energy consumption intensity, the weight of the second industry, the energy production structure and capital investment.

3 Current situations of energy consumption structure in China and the U.S.

3.1. Evolution of the energy consumption structure in China and the U.S.

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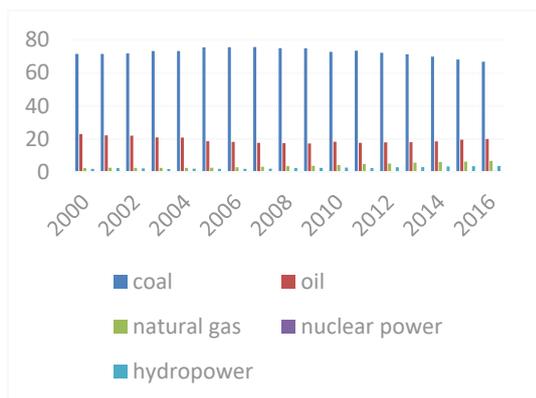


Fig. 1. Proportion of energies in total energy consumption in China from 2000 to 2016

Since 2010, the proportion of coal consumption drops, but it remains the first place in the list of energy consumption, reaching 65%. The oil consumption rises quickly and is expected to become the most important energy in the energy consumption structure. With China's West-East Natural Gas Transfer Plan, the proportion of natural gas in the energy consumption structure rises; the hydropower and nuclear power, as two forms of new energies, have been taking up an increasing proportion in energy consumption. Thus, China relies heavily on coal in energy consumption. Though the proportion of oil consumption rises, China's energy consumption structure differs much from those in developed countries.

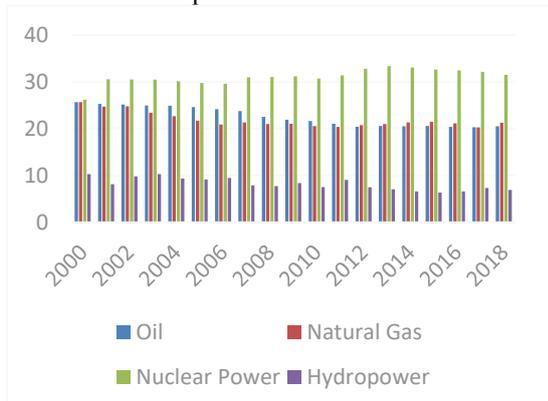


Fig. 2. Proportion of different energies in the energy consumption structure in the U.S. from 2000 to 2018

Since 2010, the nuclear power consumption has increased in the U.S., while the consumption of fossil energies like oil and natural gas has dropped year by year. In 2013, amid the overall energy consumption in the U.S., oil takes up 20.55%, natural gas occupies 20.98%, nuclear power takes up 33.33%, and hydropower takes up 7.03%. As predicted, the top three traditional energies in the U.S. will be reduced by 77%. Due to the energy consumptions released by the U.S. government and the progress of energy technologies, the American energy consumption structure has seen tremendous changes, which promoted large-scale development of shale gas and new energies.

3.2. Comparison of the energy consumption structure between the U.S. and China

3.2.1. Comparison in coal consumption between the U.S. and China

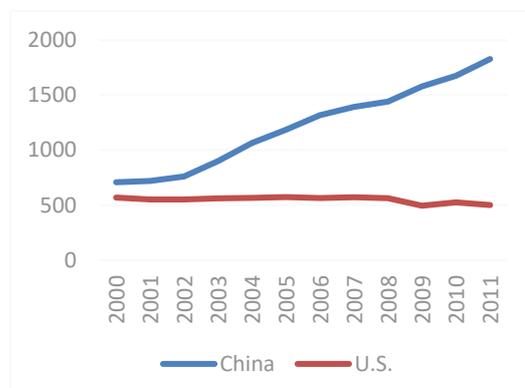


Fig. 3. Coal consumption in the U.S. and China in 2000-2011

As Figure 3 shows, since 2000, coal consumption in China has been rising. In particular, from 2008 to 2011, China has shifted from an exporter of coal to an importer of coal. The coal consumption in China has reflected the defects in China's coal consumption structure.

From 2000 to 2007, the coal consumption in the U.S. has been rising, but it has dropped in these years, and the U.S. has invested more to development of new energies.

3.2.2. Comparison in oil consumption between the U.S. and China

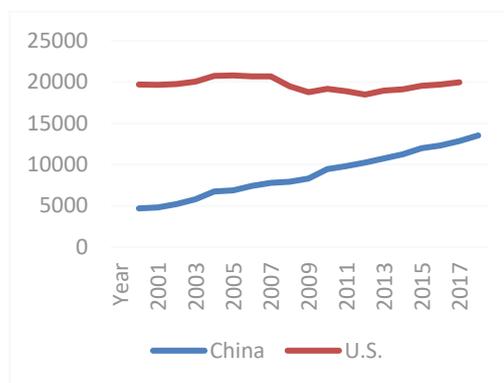


Fig. 4. Oil consumption in the U.S. and China in 2000 – 2018

The oil reserve in China is 25.6 barrels, taking up 2% of the world's total reserve, and the reserve per capita is rather smaller. Despite the small oil reserve, China has a high oil consumption volume and relies heavily on import. In 1993, China became a net importer of crude oil. In the twenty some years that followed, China's import of oil increased year by year, and the oil consumption rises as well.

The oil reserve in the U.S. is about 39.23 billion barrels, and the U.S. has the largest reserve of oil in the world.

Since the financial crisis in 2008, the oil consumption has decreased by 877.49 million tons in the U.S., taking up 21.79% in the world's total oil consumption. Since 2010, the oil consumption in the U.S. has been rising

slowly despite small fluctuations, and in 2018, the overall oil consumption in the U.S. reached 892.84 billion tons.

3.2.3. Comparison in natural gas consumption between China and the U.S.

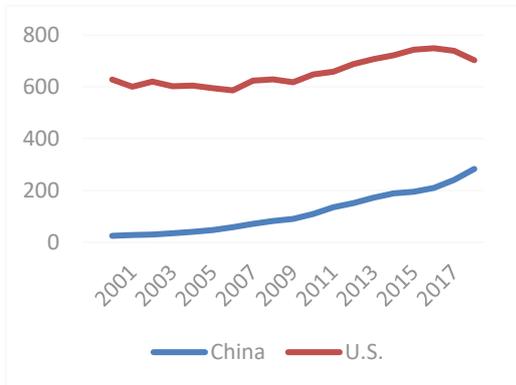


Fig. 5. Natural gas consumption in the U.S. and China in 2000 – 2018

In 2000, China consumed 24.7 billion m³ natural gas, taking up 1% of the world’s total consumption of natural gas. In the following decades, China has made great progress in development of natural gas. In 2018, the natural gas consumption in China reached 280.3 billion m³. As the consumption of natural gas increases, the consumption of natural gas is expected to reach the same level as coal and oil in the consumption of primary energy in China.

The U.S. has led the world in natural gas development. To boost natural gas development, the U.S. initiated reforms in the natural gas market in the 1970s. In 1965, the U.S. consumes 66% of natural gas consumed across the world, and in 2018, the oil consumption in the U.S. reached about 817.11 billion m³, taking up 21.23% of the overall energy consumption in the world. This may be attributable to the U.S. government’s initiative to develop shale gas. The rich reserve of shale gas leads to a drop in the price of natural gas, a decrease in the profit of distributors, and some distributors begin to withdraw from the market.

3.3. Comparison in new energy consumption between the U.S. and China

3.3.1. Comparison in nuclear power consumption between the U.S. and China

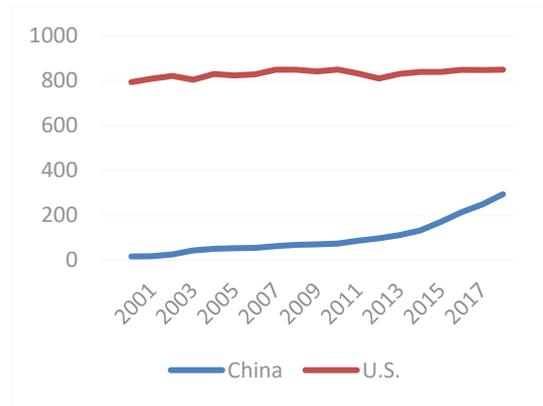


Fig. 6. Nuclear power consumption in the U.S. and China in 2000 – 2018

China started to develop nuclear power late in the 1980s. In this decade, China made considerable progress in nuclear power development. In 2010, the nuclear power consumption in China reached 73.88 TKWH, which grew to 294.36 TKWH in 2018, taking up 10.9% of all consumed nuclear power in the world. Given the quick growth in nuclear power consumption in China, China is expected to exceed major developed countries in nuclear consumption in the near future.

The U.S. boasts the world’s strongest nuclear power generation facilities and capacity. The U.S. has 104 nuclear reactors, making up 24% of all nuclear reactors. Since 2011, the proportion of nuclear power consumption in the U.S. takes up 30% of the world’s total nuclear power consumption. In 2018, the total nuclear power consumption in the U.S. reached 849.56 TKWH, taking up 31.45% of the world’s total nuclear power consumption. In the full-dimensional energy consumption strategy in the U.S., it encourages clean energy to meet the needs of energy consumption.

3.3.2. Comparison in biomass energy consumption between the U.S. and China

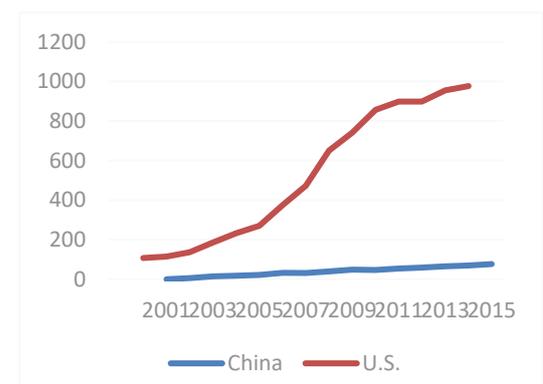


Fig. 7. Biomass consumption in the U.S. and China in 2000-2015

In the past four decades, biomass has been used in China for power generation. In 1998, about 185 million farmers used energy-saving stoves, with a thermal efficiency rate at 25%. The rural areas in China have natural advantages in utilization of biomass energy, and biomass energy-based power generation has been widely adopted in rural

China. In 2015, the power generated by biomass in China reached 52.7 KWH. The number has been rising and is expected to increase in the future.

Since 1979, the U.S. has been using biomass fuels to generate power. The biomass energy consumption has been increasing since the 2000, and in the context of low-carbon development around the world, the biomass energy enjoys a great prospect in the U.S. The installed gross capacity of biomass power generation in the U.S. is above 10,000 MW, and the unit capacity is between 10 MW and 25 MW.

4 Problems in China's energy consumption structure

4.1. Coal is the dominating energy and other energies take up small proportions

In China's energy consumption structure, coal still plays a dominating role and ranks the first place in the consumption of the primary energy. There is still a long way to go in development and use of coal. We should not only avoid high consumption and waste due to rapid growth, but formulate industry policies, accelerate industrial restructuring, reduce unnecessary energy needs, adjust economic development modes and ensure sustainable development.

It is expected that in 2020, the overall energy consumption in China will reach 2 billion tons of standard coal. China should develop clean energy, reduce coal consumption, change the coal-dominated energy consumption structure, adjust the energy consumption structure, and make the energy structure more diversified.

4.2. Low energy utilization rate

Compared with developed countries, China has a unit consumption rate of high energy-consumption products. The energy intensity of the mining industry, the manufacturing industry, the power generation industry, the natural gas and water production and supply industry, and the architecture industry has reduced, while the energy intensity in transportation, warehousing and postal services, and information transmission has increased. The coal consumption for thermal power generation in China is 370 g/kWh, the electricity consumption rate of the power station is 5.87%, which is 35 g and 1.87% higher than the international level, respectively. However, the energy structure in China is monotonous, quality energies are in short supply, and domestic supply cannot meet the needs of economic growth; the allocation of energies is yet to be improved and the utilization rate of new energies is low; the energy consumption structure is unbalanced. China needs to introduce advanced energy technology from abroad, increase the energy utilization rate, and reduce energy consumption. The per capita energy consumption volume of major energies is higher than key energy consuming countries.

4.3. Clean energy takes up a small proportion in the total energy consumption

Clean energy has gained momentum across the globe, making it a trend to shift from an energy consumption structure based on high intensity fossil fuel emission to renewable energies. The current situation reveals that this year is the best timing to develop clean energy. In the U.S., clean energy plays played an unmatched role in improving the energy utilization rate. Due to the low energy utilization rate, the power generated in the world has not been fully utilized. In the past decade, developed countries have had advanced experience and technology in utilization of renewable energy, which provide lessons for the developing countries. Energy is the prerequisite of human activities, and the discovery and development of quality and advanced energy has boosted development of the human society. Against the backdrop of globalization, energy and environment have become hot topics to build a human community of a shared future. These are problems that require attention in China's initiatives towards sustainable economic development.

5 Measures to address problems in China's energy consumption structure

5.1. Optimizing industry structure and developing renewable energies

Given the current national situation, China must stick to the market of socialist characteristics and establish necessary regulation policies. As per the previous drafts of regulations, the basis of the industrial structure has changed from percentage to functions, and the key is to strengthen the industrial clusters. With research and development, design, marketing, branding, technological service, and supply chain management as the focuses, the major distribution as the key, China should adopt the "break chain" strategy to improve international labor division, and the impact of the society and the environment. It undermines the modernization of the industrial structure and production services, advances novel industrialization, and promotes modernization of the industrial structure and a shift in the economic growth mode.

5.2. Developing technologies to improve energy utilization

Development of technologies is of great significance for protection and improvement of the environment. China has rich natural resources, and the oil and gas industry report provided by the economy and technology research institute of China National Petroleum Corporation reveals the unbalanced energy consumption structure in China. As the report shows, the import of petroleum and overdependence on imports have reached an unprecedented level, with an import of 396,000 tons, and an overdependence degree of 67.4%. Developing scientific technologies can effectively reduce our dependence on import of crude oil, maximize the

utilization of existing resources, and lead the country towards the goal of a thousand year's development.

5.3. Strengthening international cooperation

Since 1993, China has shifted from an exporter of petroleum to an importer of petroleum, with the volume of import increasing year by year. Meanwhile, the dependence degree on imports of oil has increased year by year, reaching above 50%. Thus, to alleviate the energy crisis, China needs to develop new energies. As per the industry development prospect in China, the new energy development plan should be implemented in three steps. In the first step, China needs to introduce some new energies to the market and test the adaptability; the second step is to introduce more new energies to the market; the third step is to allow the market to select among the new energies to replace the fossil fuels. These three steps should be implemented one after another, rather than fulfilled in one stroke. China's initiative to grow stronger will lay a technical and industrial foundation for large-scale development of new energies.

6 Conclusions

With economic progress and population growth, the current reserve of resources in China can no longer meet the massive demand for resources. There is large shortage in the energy supply, and the dependence degree on imports is above 60%. It is of great urgency to improve energy utilization, reduce energy waste and balance the supply and demand of energy. Therefore, to develop new energies becomes the inevitable path towards sustainable development. However, development of new energies cannot be fulfilled in one stroke, but requires labor, material and financial power. The government should design plans, effective strategies and legal rules. China can draw on the lessons in energy structure optimization from the U.S.

Acknowledgements

This study is a result of the education reform research program of Northwestern Polytechnical University Ming De College in 2019, and a phased research achievement of the "Research on teaching reforms of the business negotiation course based on the practice-oriented mode" (No.85, 2019).

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