

# Evolutionary Trajectory of China's Energy Transformation from a Multi-Level Perspective

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**Abstract:** China's energy transition is of great significance. From the multi-level perspective, government intervention has dominated the transition process of energy development since the founding of the people's Republic of China which causes resources are difficult to achieve optimal allocation, meanwhile, other realistic predicament such as market mainstay missing, poor competition coordination mechanism also exists. The booming of Energy Internet is expected to break out the dilemma of energy transition under the pressure of landscape developments.

## Introduction

China is now the world's largest energy consumer. As the world's largest carbon emitter with the largest increment, China in terms of sustainable development is facing multiple constraints which come from ecological damage, resource depletion, environmental degradation caused by fossil energy production and consumption, thus it is imminent to accelerate the energy transformation. Energy transformation is a fundamental change in terms of energy production and consumption structure, it will have a profound impact not only on the economic and social development of a country but also on the global geopolitical pattern. China is now in the accelerated development stage of industrialization and urbanization. Thus, it needs to shorten the fundamental transformation from high-carbon structure to low-carbon one.

To form a sustainable energy supply and demand structure, Energy transformation as a dynamic engineering system, cannot do without multi-level collaborative evolution which come from macroeconomic situation changes, energy system reform and innovation of market niche. Therefore, by introducing social-technical systematic transformation theory from multi-level perspective (Multi-Level Perspective, MLP) to China's energy transformation research, it avoids the isolated analysis of certain elements. The article reviews the transformation of energy development since the founding of the People's Republic of China, and comprehensively analyzes of energy transformation and its evolution trajectory, stage characteristics and realistic predicament, finally the proposal of how to achieve realistic path of China's energy transformation for current and future stage is puts forward. The paper deepens the energy transformation study for certain specific countries, it not only provides insight to policy makers when designing a sustainable energy regulatory framework, but also can be used as a useful reference for visionary enterprises to invest into energy internet based innovation development.

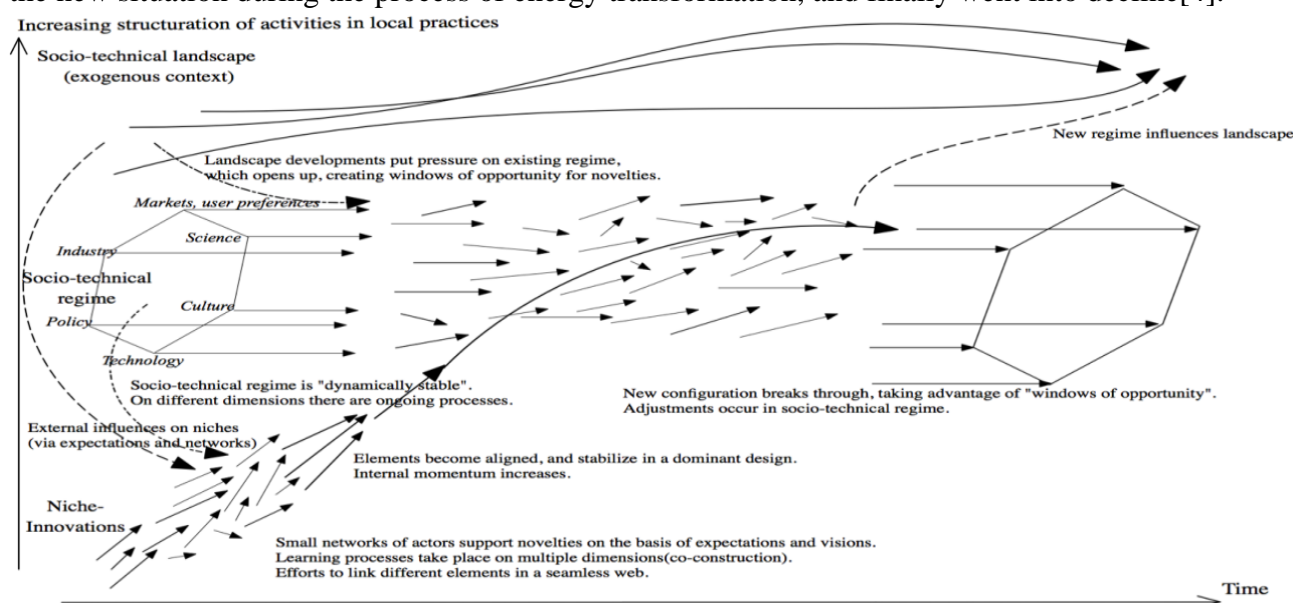
## Multi-level Perspective of Social-technical System Transformation Theory

Energy transformation did not happen as expected: large scale renewable energy technologies and low carbon innovations were confronted with apparent resistance during proliferation[1]. Araújo K. reviewed the energy transformation process, challenges and opportunities, with particular emphasis on the analysis of the importance of region specific[2]. China's energy transformation is

different from any other country or region in the world in terms of resource endowment, historical evolution of social economy and energy system.

Social-technical system transformation theory links all related theories together such as innovation theory, regime theory, evolutionary economics, technology social science, the theory emphasizes the process and mechanism of change from multi-level perspective, it can be used as a global perspective to understand the complex transformation from multi dimensions. The multi-level perspective of social-technical transformation theory is divided into three levels of explorative transformation: niche (referring to where the radical innovation occurred) , social technology system (referring to the rules and regulations formed by many subjects, such as industry, policy, culture ,science and technology, including social cultural system, political system, scientific system, technical system, user and market system) and exogenous social and technological circumstances, they are constantly enhancing in accordance with the stability of the configurations[3].

From multi-level perspective, the key of the transformation is institutional change, and it is believed that the transformation of social-technology system is the result of the dynamic interaction and coevolution among the three different levels (referring to *Fig. 1*). Kungl & Geels using multi-level perspective, analyzed the power enterprises in Germany from 1998 to 2015, observed that the enterprises were no longer stable in the face of multiple pressures, the enterprises did not adapt to the new situation during the process of energy transformation, and finally went into decline[4].



**Figure 1.** Multi-level perspective on transitions[5]

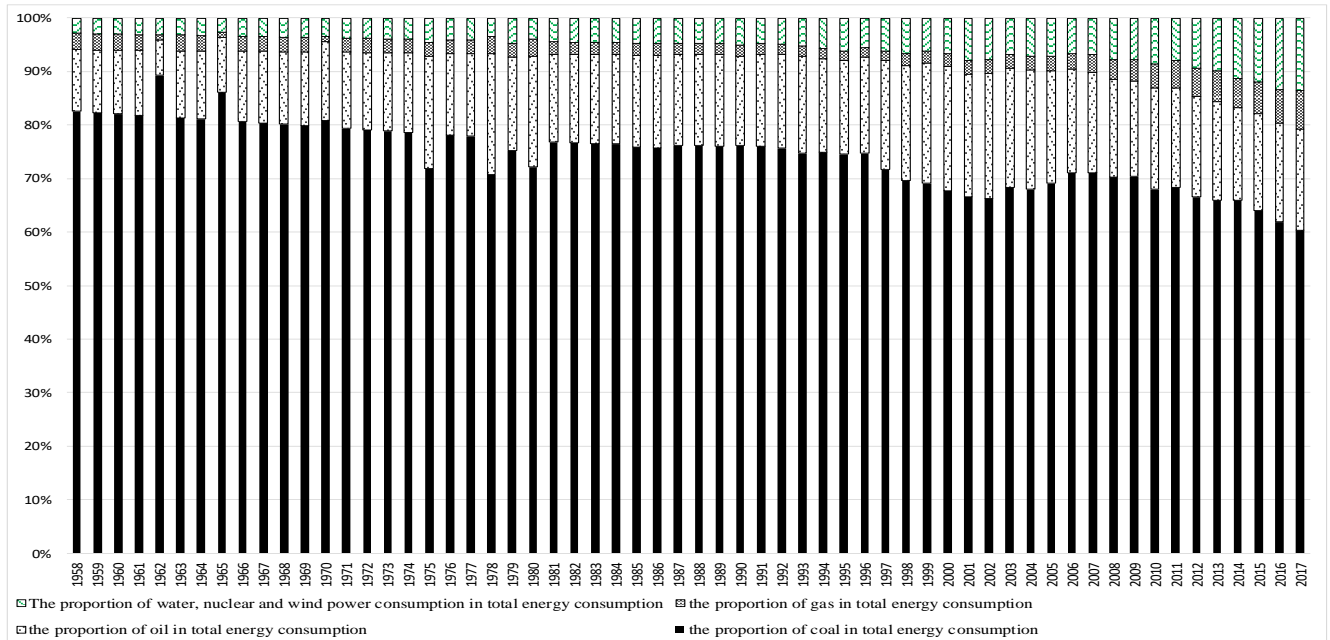
The research on China's energy transformation can deeply analyze the key problems which we are facing, ignoring the important feature of linking energy transition to the stage of economic development, without considering the complicated historical background and social reality, it is difficult to implement the solutions when it encounters current situation difficulties. Based on the multi-level perspective, this paper sorts out the transition course of energy development since the founding of the people's Republic of China, and seeks the realistic path to break through the predicament of energy transformation.

## Evolutionary trajectory and Phase characteristics of China's energy transformation

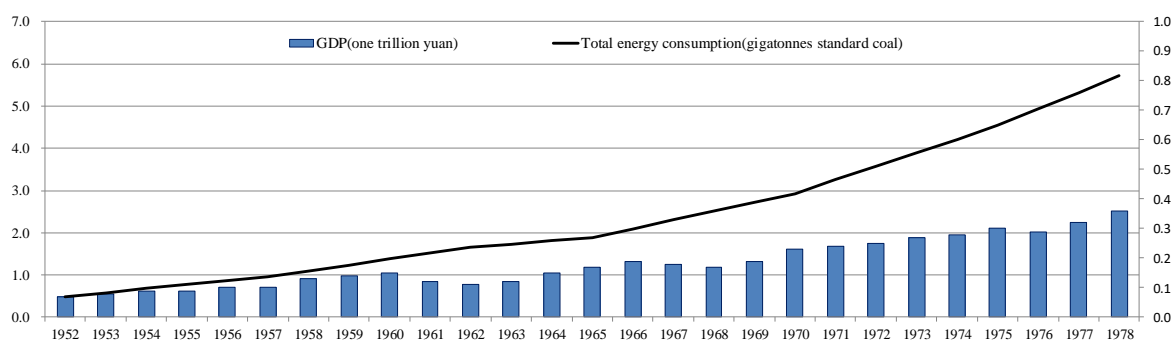
In the past four decades, China has achieved economic modernization with unprecedented speed, breadth and depth which has caused China's energy consumption to grow rapidly. In the meantime, the energy utilization mode is extensive, and China's energy efficiency per GDP has been far higher than the world average, despite the continuous improvement of energy efficiency<sup>[6]</sup>. To probe into China's energy transformation, in order to avoid an antidote against the disease, no overall plan for a fundamental transformation finding the root cause of the problem, it needs to not only investigate

energy production and consumption structure changes (Fig. 2), but also track back to the establishment of the system from the existing energy source.

**Evolutionary trajectory of China's energy transformation.** Due to the transformation here refers to the transformation of social technological system, thus the paper focuses on the energy system, the interaction among the energy system, the external situation and the innovation niche. After the founding of the people's Republic of China in 1949, the national economy has been fully restored and preliminarily developed after three years of hard work. Therefore, this article takes the 1952 data as the starting point for analysis. Since the data from 1952 to 1977 were relatively small, to make the chart more intuitive, with the reform and Opening-up in 1978 as the separation, the data were divided into two periods from 1952 to 2017 (Fig. 3-1 and 3-2). Per the inflection point of energy consumption total curve and major system reform, the following four stages are defined.



**Figure 2.** 1957-2017 The proportion of various types of energy in total energy consumption in China



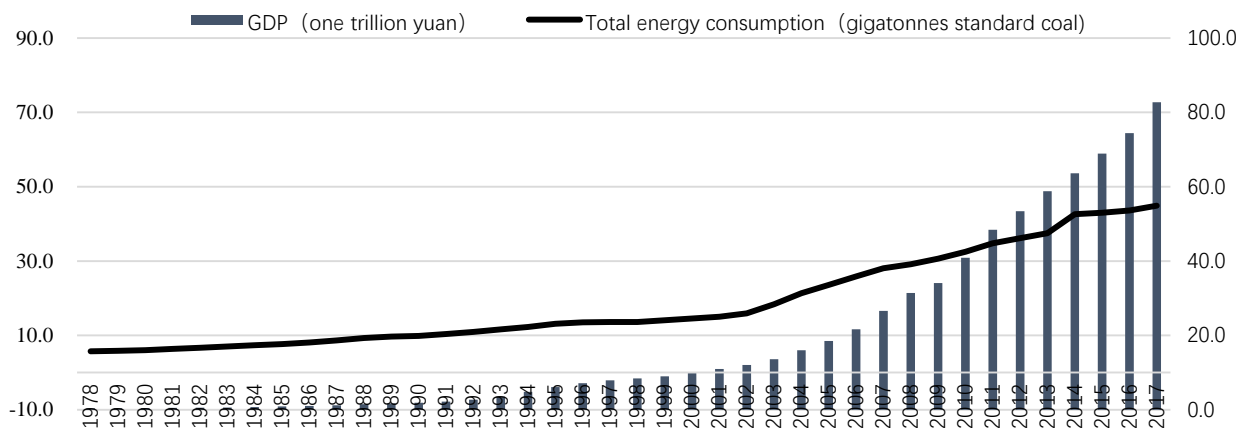
**Figure 3-1.** The evolution of total energy consumption (TEC) and GDP in 1952-1978

**The Stages and Characteristics of China's Energy Transformation.** 1952-1977, The existing system is established and innovation niche is suppressed. The main features of this stage: the establishment of the planned economic system and the extensive utilization of energy.

China has established the strategy of giving priority to the development of heavy industries and conducted highly centralized planned economic management. The planned economy targeting to achieve mandatory planning as the goal, using the mandatory plan as method, makes the country become a large company, From the countryside to the city, all production units are produced and allocated according to the state directive. One-sided emphasis on heavy industry, the pursuit of

economic development speed, resulting in serious industrial structure imbalance, industrial development deformity, and the development of agriculture and business is seriously lagging. The real background of the planned economy is the government with strong resources control capability. The high degree of public ownership results in the failure of individual incentive mechanism.

The management style for capital-intensive energy industry and other industries are exactly same, directly under the energy management department of ministerial level by central government; thus, it brought a lot of problems: low degree of function specialization, ambiguity division of labor, overlapping functions, over integration of government administration with enterprise, low efficiency of management. Along with the industrialization process through price distortions, policy subsidies and mandatory national mobilization, is the extensive economic development mode of high input, high consumption and low output to energy, resources and environmental factors. From 1952 to 1977, an average annual GDP growth rate of 6.48%, while the corresponding total energy consumption increased from 0.49 tons to 6.28 tons of standard coal, an average annual growth rate of 10.09% (Fig. 3-1).



**Figure 3-2.** The evolution of total energy consumption and GDP in 1978-2017

1978-2002, To cultivate innovation niche in a stable regime. The stage main characteristics: promote the reform of the supply side, energy conservation and emissions reduction; Energy marketization reform is not smooth.

Reform and opening-up began from 1978, the planned economy to market economy system transition also began, the market principal status of the enterprise gradually became clear.

At this stage, the focus of energy transformation lies in the supply side reform to promote energy conservation and emission reduction. The Chinese government began to pay attention to environmental protection and strive to adjust the service orientation of heavy industry and the products structure from 20C80s, a large number of policies have been formulated to promote energy conservation and emission reduction, such as the instructions promulgated in 1982 "Directive on the development of coal washing and rational utilization of energy resources".

In the later period of 20C90s, China proposed to change the mode of economic growth and made remarkable progress. it was approaching zero growth in energy consumption while economic growth, economic efficiency improved, and emissions of major pollutants declined.

Take the power industry as an example in the field of energy marketization reform. Due to the shortage of power, many offices were started in 1995. In 1997, Ministry of Electric Power was abolished and State Power Company was established to serve the entire power system in China, and "government and enterprise are separated and the province is an entity". In 2002, "Electric Power System Reform Plan" proposed "the power plant is separated from the power grid, and the main parties bid to enter the power grid" and two-way split State Power Company. However, there was a shortage of electricity because of high-speed economic growth, actually only to break State Power Company exclusive electric, the power plant was separated from the power grid, but "advocate complementary separation, distribution separated, bid online" is still struggling. In fact, the government decides the interests of power generation enterprises by dividing electricity price,

which is actually the government's decision on behalf of enterprises. The power enterprises cannot become the market players. The reform of the government and enterprises needs to be deepened.

Since middle period of 20C80s', although the government was determined to break down the administrative monopoly in energy, but rapid economic development to make timely and effective for energy supply for the first priority. It was a long time before there was any further reform of the energy system quite a long time in-depth reform of the energy system. The planned economy is still in place, the commodity economy is merely a supplement, and the energy market is not yet in place. Despite some efforts to separate government from business, however more due to the energy industry as the monopoly of state-owned enterprises, corporate executives appointed by the government at the same time as the "referee" and the role of the "players".

2003-2014, market niche and the regime expanded simultaneously. The main characteristics: demand side reform, promoting energy marketization; Renewable energy was booming.

This stage further clarified that the transformation of the mode of economic growth needs to give full play to the role of market mechanism. The direction of energy and environmental issues is recognized through market instruments, such as environmental markets represented by carbon trading. Although at present China has established the carbon trading market in Wuhan, and other cities, but there is little to mark parts of a voluntary emissions trading on exchanges energy-intensive industry enterprise's participation, for more environmental protection consciousness is strong buyers of individual behavior. Due to the lack of trading mechanism, exchanges have not been effective.

Since 2005, "improving energy efficiency" has been listed as a national key development strategy. On January 1, 2006 the implementation of The Renewable Energy Act, renewable energy by 2006-2006 accounted for 2% of the global total to 20.5%[6], but the pressure of renewable energy consumption is high, and the conflict between high installation capacity and low utilization capacity is faced[7].

2015-So far, the conflict between niche and the current regime intensifies. The main features: deepening the supply-side reform and saving energy and efficiency. The Energy Internet is emerging.

In view of China's economy into the "New Normal" period and the double pressure of resources and environment, the government introduced a series of policies, tax cuts and the combination of state-owned enterprise reform approach to production capacity and inventory, increase the supply of clean energy. China is to shift from industrial economy to service economy, energy intensive industries such as steel and cement to capacity produced results, and is subject to the influence of the global economic recovery is slow, energy consumption grew by 0.9 percent in 2015 and 1.3 percent in 2016, far less than ten years the average growth rate of 7.2% in 2005-2014 [6].

In 2015, Several Opinions on Further Deepening the Reform of the Power System established the institutional framework of "governing the middle and opening both sides" to support the development of distributed renewable energy. The Guiding Opinions on Promoting the Development of "Internet+" Smart Energy make the top-level design of the development of Energy Internet. In 2016, the consumption of renewable energy increased by 33.4%[6], and the energy structure is shifting to low-carbon fuels. The situation has intensified the pressure on the current energy system and opened a window of opportunity for innovation in Energy Internet market. The situation has intensified the pressure on the current energy system and opened a window of opportunity for innovation in the energy Internet market. The Internet is a renewable energy as the priority, the basis of the electric energy, using modern information technology to achieve a variety of energy cooperation, coordination, centralized and distributed collaborative supply and consumption, the broad participation of the new ecological energy system[8]. Energy Internet will demand agglomeration to network platform, demand agglomeration stimulate the division of labor, division of labor increase knowledge, to reduce the information cost, bring change in thought mode, management mode, and the way of activity, to make fundamental changes in the traditional market and market forces. The conflict between the innovation niche and the current system has intensified.

## Discussion and Conclusion

It is not only the fear of climate change that drives the energy transformation, but also the yearning for a better energy life. The superposition of large population size and territory area makes China more focused on innovation, more frequent exchanges and higher incidence of technological innovation. Due to the large scale of market demand and the level of traditional and innovative consumption as well as different levels of expenditure, new technology products are easy to be accepted step by step in the market, and marketization and industrialization are fast. China's Internet development level, new energy technology, smart grid infrastructure is in the leading level in the whole world, the depth of fusion of disruptive innovation, can the liberation and development of the productivity greatly.

The development trend of Energy Internet and the need of real structural adjustment determine the position and reform path of the government. From the perspective of evolution, the historical transformation relies more on the development of technology, and the future energy transformation will also rely on the adjustment of the "selection environment", i.e., shaping the market through policies, regulations and incentives[9]. Energy Internet greatly expanded space and boundary and redefine energy industry, change energy running environment, strengthen the market main body consciousness of cooperation, make the energy from the production end directly to the consumer end, thoroughly reconstructing value chain pattern of interests' distribution, also has the potential to reverse affect production from the consumer end end, make the production truly on-demand, establish a new supply mode and trade relations.

Energy Internet brings scattered market players to a common platform and brings ideas and the transformation of business model. Energy Internet provides a new market for a wider range of players to enter the sustainable energy sector and brings fundamental changes in the market force, break the existing balance, crack energy transformation dilemma It provides a new market for a wider range of players to enter the field of sustainable energy development, bringing about fundamental changes in market forces, thus breaking the existing equilibrium and solving the dilemma of energy transformation.

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