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# HOW RAPID DEVELOPMENT AND POLICY CHANGES INFLUENCE ENERGY CONSUMPTION IN CHINA: A STUDY OF SICHUAN PROVINCE

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**ABSTRACT**

This study uses a coupled analysis framework to analyze energy consumption, socioeconomic drivers, and energy policies in Sichuan – the most populous province of China's rapidly growing western region. The consumption of total energy and three key energy sources over 2002-2016 is decomposed using the logarithmic mean Divisia index method to identify underlying socioeconomic drivers, which are then coupled with a systematic energy policy review to analyze energy-policy interactions. Based on this analysis we suggest the means to optimize low-carbon development in the provincial five-year plan and to integrate the various policies published by different departments. Given the ineffectiveness in provincial economic restructuring for energy reduction, an energy trading system may be more effective and efficient. Over the coming decade, Sichuan also needs to accelerate its adoption of clean energy resources, in addition to further improvements in industrial production efficiency. The trends and policy implications that have been found for Sichuan are instructive for low-carbon development in China overall, and in its expansive western region especially.

**Keywords:** Energy consumption; energy policy; Logarithmic Mean Divisia Index; coupled analysis; Sichuan; low-carbon development

## 1. INTRODUCTION

The "World Energy Outlook 2018" highlighted the fact that the current geographical position of global energy consumption is being progressively, and perhaps inexorably, transferred to Asia. Over last four decades, China has grown from an impoverished rural country to a major industrial power and the world's second largest economy. Concomitantly, it has also become the world's largest energy consumer and emitter of greenhouse gases. Since urbanization remains the most significant secular driver of China's socioeconomic development, as well as a policy priority, the country will face tremendous pressure in ensuring the security of its energy supply while reducing environmental impacts. This is not only a challenge for China's transition to sustainable development; as the world's most populous country and primary engine of economic growth, meeting this challenge is also a critical issue for global development.

Most studies of China's energy consumption have been at the national level or focused on traditionally important economic and political centers in coastal regions. China's western region, however, has often been scanted, despite the fact that it covers over 71% of China's land area and represents the frontier of future economic growth in the country. In 2000, the central government decided to implement the "Western Development Strategy" to support socioeconomic development in western China. Sichuan is the most populous and economically-developed province in western China, and with 486,000 square kilometers of land area, it has been the leading focus of economic development internationalization in western China's over the past decade. In 2016, Sichuan's GDP reached 3297.37 billion RMB, ranking 6$^{th}$ among mainland China's 31 provinces [1].

Accompanying fast economic growth has been

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soaring energy consumption, which increased from 31.85 megaton coal equivalent (mtce) in 2002 to 139.12 mtce in 2016, ranking Sichuan 7th among China's provinces. However, the energy consumption efficiency of Sichuan was still lower than the national average [2]. Moreover, although Sichuan has one of the largest provincial endowments in clean energy endowments—its hydropower, shale gas and natural gas resources are respectively ranked 1st, 1st and 2nd across China's provinces—the energy consumption structure of Sichuan province has long been dominated by fossil energy, which only accounts for less than 25% of Sichuan's energy endowment. The structural imbalance and large-scale inefficiencies in the energy use not only undermined the efficiency of economic production but also created serious air pollution, causing the province, and especially the large urban hinterlands of the Sichuan Basin, to suffer some of the highest levels of haze pollution in China [3]. Therefore, Sichuan, as the most important growth pole in western China, should make a more concerted and systematic effort in low-carbon development and emissions reduction.

This study couples Sichuan's energy policy with a model of its energy use to better understand the interactions between energy consumption and policies. Based on this improved understanding, we assess the role of energy in the development of western China and make policy recommendations for the optimization of both local and national energy policy.

## 2. RESEARCH DESIGN

### *2.1 Analytical framework*

This study first decomposed the drivers of energy consumption variation, including total consumption and the consumption of four specific energy types, in Sichuan province from 2002 to 2016. At the same time, the study systematically searched and organized the provincial energy policies that may have influenced energy consumption during this period. On this basis, the energy decomposition results and energy policy provisions were coupled to find out the primary characteristics in variations of the policy-energy nexus. Particularly, did the policies realize their objectives? Through the analysis, we will then put forward policy suggestions to optimize energy consumption and energy policy-making and implementation in Sichuan Province.

### *2.2 Data and processing*

Considering the data availability and the consistency of data format across different sources, energy was divided into four types: 1) coal, including coke and coal; 2) petroleum, including crude oil, gasoline, kerosene, diesel, fuel oil and liquefied petroleum gas; 3) natural gas; and 4) hydropower and nuclear power. The physical quantity of different energy types was converted to a standard quantity according to China's national standard, "General principles for calculation of comprehensive energy consumption" (GB/T 2589-2008).

In addition, the Sichuan economy was classified into six sectors: 1) Agriculture, including agriculture, forestry, farming and fishery; 2) Industry, including mining industry, manufacturing, chemical industry, etc.; 3) Construction, 4) Transportation, including transport, storage and post; 5) Hotel and catering, including wholesale, retail trades, hotels and catering Services; and 6) Other services, including finance, education and real estate. The sector classification is in accordance with official energy statistics, which currently do not have more detailed sectoral data at the provincial level.

### *2.3 Energy policy compiling*

Using government documents to interpret the intention and design of policymaking is particularly useful in China because of the difficulty of conducting interviews with government officials and because of the importance of the policy documents themselves [4].

The energy policies compiled in this paper include policies issued by the Sichuan provincial government and provincial departments. National energy policies are not included in the policy analysis although they are binding for all the regions. This is because any national policy has to be translated into provincial policies by the provincial government to be implemented within that province. The provincial government is not only the implementer of national policies, but more importantly the designer of local policies. Additionally, national policies are aimed at the country as a whole and thus are not exactly applicable for a single region. For example, in the "11th FYP for Energy Development", the proportion of coal, natural gas and hydropower in primary energy consumption in 2010 was planned to decrease by 3.0%, increase by 2.5%, and increase by 0.6%, respectively, compared with 2005. But in the "Sichuan Energy Development Plan for the 11th Five-Year Period and 2020", the same targets were planned as decrease by 6.3%, increase by 6.1%, and increase by 1.7%, respectively.

The primary source of the policy documents analyzed in this study was *pkulaw.cn*, which is a comprehensive database documenting Chinese laws and regulations since 1949. To ensure the exhaustiveness of

the policy data, this article also retrieved documents from the official websites of the Sichuan Provincial Government and the Sichuan Development and Reform Commission, which is in charge of energy affairs, along with popular search engines, as a reference check and to fill in potentially missing policies. Finally, after excluding irrelevant policies such as the safety production regulation of coal mines and the property regulation and management of state-owned energy companies, this paper obtained 193 policy documents that included provisions on energy consumption of Sichuan province from 2002 to 2016.

## 3. RESULTS

### *3.1 The evolution of the energy policies*

According to policy targets, this paper classified energy policies into seven categories. "General" refers to general energy laws and policies, such as the "12$^{th}$ FYP for the Economic and Social Development of Sichuan Province", which included energy targets as a main socioeconomic development indicator. "Sector and corporate" refers to policies aimed at specific industries or companies, such as the "Notice on Further Strengthening Energy Conservation Work in the Service Industry" in 2007. "Coal", "Petroleum", "Natural gas", "Electricity" and "Hydropower" respectively denote the policies managing different energy types, e.g., the "Electricity-Coal Supply Assessment Method for Sichuan Province" in 2005, and the "Opinions on Further Strengthening and Regulating Hydropower Construction Management" in 2016.

During 2002-2016, general energy policies and policies targeting specific industries were the most important policy types. For policies affecting different energy types, the number of natural gas-related policies even surpassed the number of relevant policies for coal – perhaps not surprising given the fact that Sichuan is one of the largest natural gas-consuming provinces. As a prerequisite for socioeconomic development, the number of electricity policies basically remained stable through the study's timeframe except for 2010, when the government adopted several more policies to achieve the energy-saving target set in the 11$^{th}$ FYP, and to regulate the noncompliant behavior of local governments. The number of petroleum policies appeared to have roughly been the same as coal and electricity policies, but all 21 policies issued in 2014 and 2015 were price adjustment notices. Understandably, for petroleum consumption, Sichuan government adopted a more market-oriented policy mechanism. Although Sichuan province has been the largest source for hydropower in China since 2011, the government did not issue any special policies for hydropower until the end of 2014.

According to Figure 1, overall, with increasing frictions between energy, economy and environment, the number of energy policies in Sichuan province gradually increased over the years. If we were to exclude the large number of oil price adjustment notices in 2014 and 2015, 2010 was the year with the most energy policies. After the 11$^{th}$ FYP of China, i.e., in 2006, the central government began to impose binding targets on provincial governments for energy intensity reduction. Therefore, 2010 was actually the first year that provincial governments accepted national assessments on their target fulfillment in terms of energy conservation. Against this political backdrop, Sichuan provincial governments issued a series of decrees to ensure the achievement of said target.

Due to the growing prevalence of energy-related issues across the province, 14 government departments have participated in energy consumption management. According to Figure 2, the provincial government (including its general office) and Sichuan's Development and Reform Commission have been leading promulgators in Sichuan's energy policies. In addition, Sichuan's Economic and Information Department and Sichuan's Housing and Urban-Rural Development Department have also been deeply involved in policy-making. Sichuan's Development and Reform Commission has been in charge of the overall energy affairs of the province. The Economic and Information Department mainly regulated the energy use of enterprises and industries. The Housing and Urban-Rural Development Department mainly focused on energy conservation in construction.

### *3.2 The evolution of energy consumption*

As shown in Figure 3, from 2002 to 2016, the total energy consumption of Sichuan province increased from 31.85 to 139.12 mtce, with an average annual growth rate of 24.06%. The increasing rate of petroleum consumption constituted the largest share (37.87%), followed by coal (26.06%) and hydropower and nuclear power (17.86%). However, as of 2016, coal was still the largest energy source of Sichuan province, accounting for 44.59% of total energy consumption.

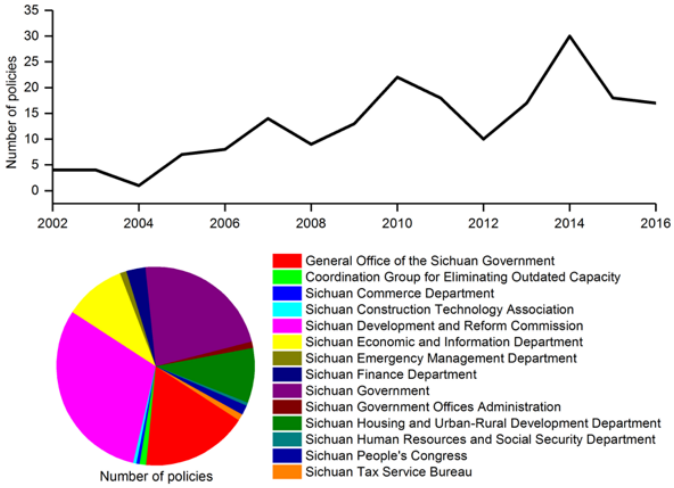


Figure 2. The number of policies by year and by departmental promulgator (2002-2016)

At the sectoral level, industry and transportation were the largest energy consumers, although the growth rate of the construction sector was the highest. The industrial sector was the largest consumer of coal and the transportation sector was the largest consumer of petroleum. As of 2016, the energy consumption of the industrial and transportation sectors respectively accounted for 76.04% and 11.38% of total consumption. Through 2002-2016, the energy consumption of the industrial sector increased from 24.31 to 105.78 mtce, with an average annual growth rate of 23.94%. The energy consumption of the transportation sector increased from 3.72 to 15.83 mtce, with an average annual growth rate of 23.25%.

In 2001, the "10th 5-Year Key Special Plan for Energy Development" stipulated that by 2005, the proportion of coal in China's primary energy consumption should decrease by 3.88%. In November 2004, the NDRC issued the first energy conservation plan after China's epochal, late 1970's-era of "Reform and Opening Up", termed the "Special Plan for Medium- and Long-Term Energy Conservation". However, for Sichuan province, not only did energy consumption rise sharply by 2005, but the proportion of coal in energy consumption grew continuously during 2002-2005. By the beginning of the 21th century, energy production was still determined by the imperatives of economic growth in Sichuan and many other provinces, and energy conservation was not yet a systematic government strategy. Out of the 16 energy policies published from 2002 to 2005, only four were about energy conservation.

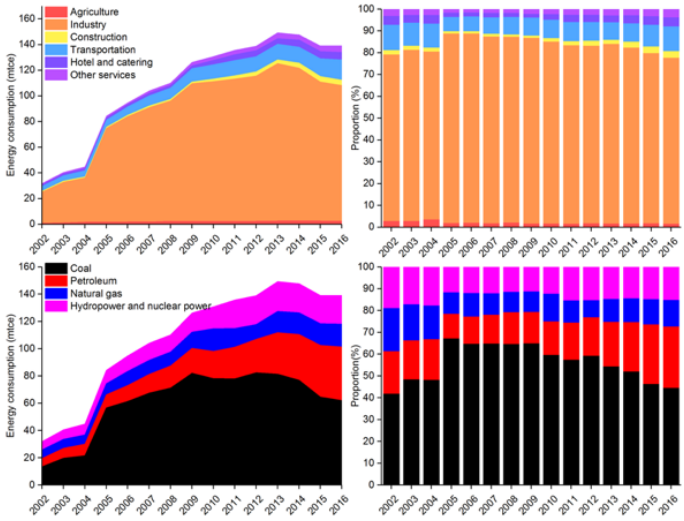


Figure 3. The energy consumption of Sichuan province (2002-2016)

As mentioned above, since the start of the 11th FYP in 2006, energy conservation has been operationalized as binding targets on energy intensity reduction. Accordingly, in Sichuan province energy conservation and energy intensity targets were listed in the "11th FYP for Sichuan Province" in 2006. In the same year, Sichuan issued four additional energy policies, covering the issues of a resource tax for crude oil and natural gas, eliminating outdated production capacity and economic restructuring, and the closures of coal mines as well as thermal power units. As a result, the proportion of coal in total energy consumption declined by 2.48%. Although the amount of coal consumption and total energy consumption still increased, the increase was slower than in the previous year. In fact, 2007 saw a peak in the number of energy policies. In that year, out of 14 energy policies, 12 were focused on energy conservation. Nonetheless, total energy consumption, industrial energy consumption and the proportion of coal all increased from 2007 to 2008, and even accelerated in 2009. Supposedly, meeting the rapidly growing energy demand was still an important political imperative for the provincial government.

2010 was the last year of the 11th FYP. From the end of 2009, Sichuan's government issued a number of energy conservation policies in rapid succession. In particular, the government released its notice on coal mine shutdowns both in 2009 and 2010. At the beginning of 2010, Sichuan's government further issued the "Notice on Further Intensifying Efforts to Ensure the Achievement of the Energy Conservation and Emissions Reduction Targets of the 11th FYP". Finally, in 2010, coal consumption declined for the first time and the proportion of coal in total energy consumption also

showed a significant decrease, down by 4.41% compared with the 2005 level. The total energy consumption still grew but the growth rate was lower than in 2008 and 2009.

In 2011, with the release of the "12th FYP for Economic and Social Development of Sichuan Province", the provincial government published a series of special policies for energy conservation, which were more systematic and ambitious than those in 2006. These new policies included the "Summary of Sichuan's Energy Conservation Work in the 11th FYP and the Plan for the 12th FYP", "Comprehensive Work Plan of the 12th FYP for Energy Saving and Emissions Reduction" and the "12th FYP for Energy Conservation of Sichuan Province", etc.

Since 2012, both coal consumption and the proportion of coal in total energy consumption started to show in a monotonically downward trend. The "12th FYP for Energy Development of Sichuan Province" in 2011 proposed to prioritize the use of hydropower, petroleum and natural gas, and anticipated that the proportion of coal consumption in Sichuan's total energy consumption would drop to 40.69% by 2015. Although provincial coal consumption fell by 24.68% and its proportion fell by 25.09% between 2012 and 2016, by 2015, the proportion of coal in the total energy consumption still accounted for 46.40%.

In 2013, the total energy consumption of Sichuan province reached its peak during the 2002-2016 timeframe and declined for the first time in 2014. In 2015, the last year of the 12th FYP, the total energy consumption decreased at an even faster ate and showed only a slight rebound in 2016.

*3.3 The socioeconomic drivers of energy consumption*

From 2002 to 2016, as shown in Figure 4, energy intensity was the only factor exerting downward pressure on energy consumption in Sichuan, by itself causing a 98.90 mtce drop in energy consumption than would otherwise be the cause, accounting for -91.72% of the total change. Except improvements in production efficiency, all the other factors drove up energy consumption. GDP per capita was the most significant driver, increasing consumption by 199.66 mtce, accounting for 185.16% of the total change, followed by economic structure (4.02%), population scale (2.02%) and energy consumption structure (0.51%).

Through the years, the consumption-reducing effect of changes in energy intensity was not stable. In 2005 and 2009, the change in energy intensity even boosted energy consumption to a considerable degree. Similarly, although the central government has continuously stressed the importance of economic restructuring in guiding China's sustainable development, with the exception of 2009 and 2011, the change in economic structure promoted energy consumption.

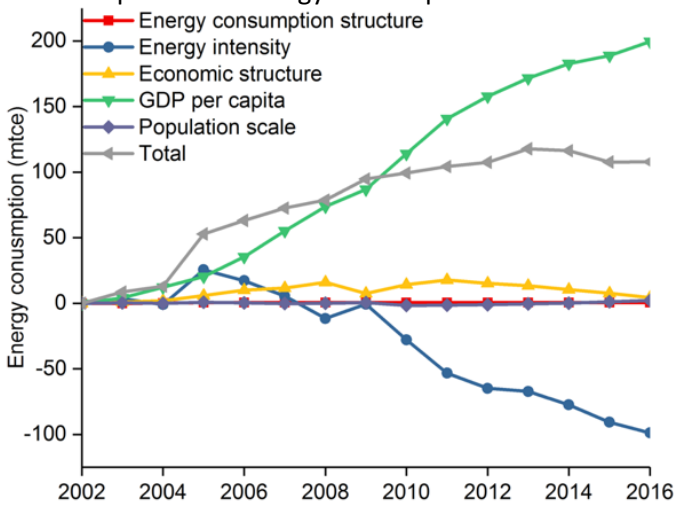


Figure 4 The impact of different factors on the energy consumption change of Sichuan province (2002-2016)

## 4. CONCLUSION AND DISCUSSION

From 2002 to 2016, the energy consumption of Sichuan province increased 3.37-fold, in which the petroleum, coal and natural gas increased by 5.30-, 3.65- and 1.69-fold respectively. As of 2016, coal was still the largest energy source for the provincial economy, accounting for 44.59% of total energy consumption. Similar to the country as a whole and to most other provinces [5, 6], GDP per capita was the major driver for growth in energy consumption, causing an increase of 199.66 mtce of energy consumption, accounting for 185.16% of the total change, which was followed by changes in economic structure (4.02%), population scale (2.02%) and energy consumption structure (0.51%). Energy intensity was the sole factor reducing energy consumption, contributing -91.72% of the total change.

Following the national policy, energy intensity has been at the center of Sichuan province's energy policies. With its flexibility in balancing energy reduction with economic growth, the intensity target has been regarded as the best focal point in China's energy and environmental policymaking. By contrast, although the government has continuously stressed the importance of economic restructuring in energy conservation, compared with 2002, Sichuan's economic structure in 2016 still promoted energy consumption growth. Until 2011, and except for 2009, the energy-increasing effect of changes in economic structure even increased. In addition, during 2002-2016, Sichuan's Housing and Urban-Rural Development Department published 19

special policies for energy conservation in the construction sector, which was the most among all economic sectors; nonetheless, the energy performance of the construction sector was the worst. The lack of success in economic restructuring in Sichuan may imply that economic structure is more the result of market dynamics than of policy making, due to the numerous interrelationships among different sectors.

The evolution of coal consumption was similar to that of total energy consumption. Coal has been at the center of China's energy dilemma, including for Sichuan province, which has one of the largest provincial endowments in clean energy. Economic development depends on large amounts of coal input while energy-saving and pollution-reduction demand limiting and reducing coal consumption. Therefore, coal policies have been crucial to changing the energy mix in a more sustainable direction. Different from coal, economic structure was the largest decreasing factor for petroleum consumption, while petroleum intensity increased consumption of that fuel. This indicated the growth of less petroleum-intensive sectors in the overall economy. For petroleum, Sichuan's government basically adopted a market-oriented strategy, focusing on stable supply and consumption instead of conservation. For natural gas, GDP per capita and natural gas intensity were respectively the largest increasing and decreasing factors. However, the efficiency of natural gas use across different sectors varied significantly. From 2002 to 2016, the natural gas intensity of the industrial sector fell by 75.14%, while that of the transportation sector increased by 455.09%. As a type of "clean" energy, the government has been encouraging the development and consumption of natural gas, so the efficiency change is likely a result of the overall improvement of production technology.

Furthermore, it was found that several key indicators of energy consumption control, such as coal of energy consumption control, such as coal consumption, industrial energy consumption, and industrial energy intensity, showed cyclical trends with respect to the provincial FYP – i.e., increasing (or decreasing slowly) in the first three to four years of a FYP and then decreasing (or decreasing more rapidly) during the last one to two years. Therefore, the behavior of local government is key to policy target fulfillment, since such administrative efficacy is a benchmark for political advancement. In this sense, quantitative and binding policy targets are instructive, as progress towards them are more readily assessed than qualitative description and advocacy. In addition, for Sichuan, there were too many policies without sufficient coordination or with excessive redundancy, leading to underperformance or inconsistencies of implementation across the province.

Without a developed market economy and a mature civil society, government policy plays a dominant role in controlling energy consumption in China. Given the central position and efficacy of the FYP, it is advisable that future FYPs integrate various policies issued by different departments. With fewer but more systematic policies, the administrative efficiency and effectiveness can be expected to improve. For the economic restructuring for energy reduction, an overall energy objective set by the government with proper allowance allocation and trading rules may be more effective in promoting efficient market dynamics and reducing uncertainty and risk than by directly intervening in corporate behavior.

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