

Research Article

Research on the Transformation from Intensity Control to Total Amount Control in Energy Consumption-An Exploration of Practice in Zhejiang Province

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Abstract: This study proposes practical control methods for energy consumption based on amounts used within Zhejiang, based on the conflict that the energy resources of Zhejiang Province are limited while its economic contribution to China is huge. China declared in its National Eleventh Five-Year Plan on Economic Development (2006-10) that its attention had shifted from energy supply to constraining energy consumption. However, global awareness of climate change and the need for action, coupled with pressure on domestic resources and the environment, means that a change from intensity control, to total amount control in energy consumption, is not only necessary for China's continued economic development, but also reflects its need to apply more progressive energy policies.

Keywords: Constraint and control, intensity of energy consumption, total amount of energy consumption

INTRODUCTION

In the period of the National Tenth Five-Year Plan (2001-05) China's energy consumption elasticity coefficient decreased from 1.04 to 0.59, it consumed 0.63 billion tons of standard coal, carbon dioxide emissions reduced by 1.46 billion tons and the energy gap between supply and demand narrowed (National Development and Reform Commission, 2011). The National Eleventh Five-Year Plan (2006-10) proposed restrictive indicators focusing on the environment and use of natural resources. One mandatory indicator relates to the comprehensive energy consumption intensity of ten thousand Yuan output value. This has had the positive effect of transforming China's economic development model and upgrading its industrial structure. During this period, China made astonishing achievements in energy saving and emission reduction. The 6.6% annual growth rate of energy consumption supported an 11.2% annual growth rate in the nation's economy. The National Twelfth Five-Year Plan Outline (2011-15) proposes "controlling the total amount in energy consumption; strictly managing the using of energy; accelerating the establishment of an energy development plan; and clearly defining both the controlling goal of total energy consumption and, the mechanism of decomposition and implementation." Making reference to total energy consumption in the plan is a first and indicates that the change in emphasis in energy consumption from intensity control, to total

amount control, forms an essential element in China's future economic development. This change is understandable given the need to actively deal with climate change and reduce carbon emissions. Though it is the restrictive indicator of energy consumption intensity rather than the total energy control constrained in Twelfth Five-Year Plan, Zhejiang Province, as a developed region in China's south-east coastal area, owns not only theoretical value, but also practical significance for leading to the exploration, practice and research of total energy consumption control.

This study proposes practical control methods for energy consumption based on amounts used within Zhejiang, based on the conflict that the energy resources of Zhejiang Province are limited while its economic contribution to China is huge.

INTENSITY CONTROL IN ENERGY CONSUMPTION IS THE CHANGING SIGNAL OF THE TRADITIONAL INDUSTRIALIZATION MODE

The scale of economic development expansion means energy resources will face shortages and the environment will meet the constraints of capacity. Improving energy efficiency therefore, is fundamental in transforming the nation's approach and creating a new industrialization model. China's first proposition of energy consumption intensity control in the National Eleventh Five-Year Plan marked its determination to

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Table 1: Comparing the intensity of energy consumption in major countries of the world during 2001 to 2005

Countries	2001	2002	2003	2004	2005
Germany	137	133	135	134	131
US	198	196	192	189	184
Japan	140	140	137	138	134
British	125	120	119	115	113
France	149	148	149	148	145
China	299	296	307	324	316

Table 2: Ranking list of primary energy consumption in 2010

Countries	2006	2007	2008	2009	2010
China	1,858.1	1,996.8	2,079.9	2,187.7	2,432.2
US	2,332.7	2,372.7	2,320.2	2,204.1	2,285.7
Russia	675.3	685.8	691.0	654.7	690.9
India	381.4	414.5	444.6	480.0	524.2
Japan	528.3	523.6	516.2	473.0	500.9
Germany	339.5	324.2	326.6	307.4	319.5
Canada	323.6	329.0	326.6	312.5	316.7
Korea	222.7	231.3	235.3	236.7	255.0
Brazil	212.7	225.4	235.1	234.1	253.9
France	259.2	256.7	257.8	244.0	252.4

take this new approach and highlighted its intention to follow the road of sustainable development.

Intensity control in energy consumption to improve energy efficiency is objective requirement: Energy intensity is an energy-efficiency indicator reflecting the level of energy consumption and energy saving. In 1978, the level of energy consumption per 10,000 Yuan GDP was as much as 15.7 tons of standard coal; in 2000, the level was 1.47 tons. In the National Tenth Five-Year Plan period, energy requirements grew rapidly and energy consumption also showed a strong ascendant trend. Energy saving and emission reduction therefore became the key work of government in managing resources and the environment during the National Eleventh Five-Year period. The intensity of energy consumption significantly decreased through energy saving and emission reduction. In 2010, the integrated energy consumption intensity per 10,000 Yuan was 0.82 tons of standard coal. This represents a reduction of 14.88 tons over the 30 year period, with an average decrease of 8.35% per annum. However, there was still a huge gap between China and developed countries in energy utilizing efficiency (Table 1).

Calculated using 2005 constant price terms of PPP, energy consumption intensity in the US, Germany, Japan, UK, France and other developed countries was lower than China whose energy consumption per unit product was 20%-30% higher than the world average level (Zhang *et al.*, 2009). During the Eleventh Five-Year period, the Chinese government signaled the change from the traditional industrialization model by stressing energy consumption intensity control be taken into the assessment of binding targets as part of national development planning, as determined by China's current environment development stage.

Energy intensity control is the only way of "restructuring" of traditional industrialization: Historically, one common characteristic of traditional

industrialization among countries, including China, is that of the resource consumption and environment-polluting development model. Resource and energy consumption cannot go beyond the rigid requirements of economic and social development in the process of industrialization. Kuznets "inverted U-curve" is used for describing the changes of income distribution conditions in the process of economic development. Subsequently, it was found that it can also describe the inverted U-curve characteristics of a regional society's dependence on natural resources and environment quality whilst in the process of industrialization, namely: in the initial stage of industrialization, the regional community's dependence on natural resources grows and the environmental quality decreases; in the middle stage of industrialization, the regional community's dependence on natural resources and the environmental quality decreases to the bottom line; and in the post stage of industrialization, the regional community's dependence on natural resource gradually weakens and the environment quality gradually increases. According to Kuznets inverted U-shaped curve, developed countries have adopted the turning point, while China is still in the middle stage of industrialization for economic growth is still seriously dependent on energy resources and the pressure on resources and the environment has reached near the peak line. China's National Eleventh Five-Year Plan proposition of "Energy intensity control" is the only way therefore, of "restructuring development" for traditional industries, it have a scientific basis and is appropriate given the stage and conditions of China's economic development.

From intensity control to total control is the inevitable choice for progressive energy policies: In 2010 China's GDP reached 5.87 trillion dollars (World Bank, 2011), exceeding Japan's 5.49 trillion dollars (World Bank, 2011) for the first time, thus making China the second largest economic entity. However, Japan only consumed 0.66 billion tons of equivalent coal, whereas China's consumption had increased to 3.25 billion tons. From a review of energy policy changes in developed countries such as Japan, these can be divided into three stages. First, energy policy in the early industrialization period is concerned with ways to develop energy and ensure energy demand for the economy and society. Next, the middle stage of industrialization pays attention to energy efficiency and energy intensity. Finally the post-industrial era, focus on restricting consumption of fossil energy by controlling greenhouse-gas emissions. China's policy change from energy intensity control to total energy consumption control is consistent in following these stages having moved from stage one to two. The Statistical Review of World Energy 2011 shows that in 2010, China's primary energy consumption exceeded

the United States, ranking the first in the world. The world's top ten primary energy consumption countries are listed in Table 2.

The total energy consumption of these developed countries remained fairly stable over the five year period. Indeed, consumption in the US, Japan, Germany, Canada and France even fell. Only the so called BRIC countries (Brazil, Russia, India, China) and other emerging countries are in the rising channel for their energy consumption. These developing countries will have to bear the responsibility for future greenhouse-gas emissions and will face enormous pressure to control fossil-fuel consumption. From this day forward, more attention should therefore be paid to ways and methods of controlling energy consumption.

TOTAL AMOUNT CONTROL IN ENERGY CONSUMPTION IS THE OBJECTIVE REQUIREMENT IN THE TRANSFORMATION OF THE ECONOMIC DEVELOPMENT MODEL

Planned construction of large thermal power plants has been set into motion to ease the gap between energy supply and demand in the National Eleventh Five-Year Plan. In Zhejiang Province, energy supply was equal, relatively, to consumption throughout this period, with great success in energy savings and emissions reduction. However, during the period of the National Twelfth Five-Year Plan, the construction of large-scale thermal power plants in Zhejiang Province is going to grow slower in response to the constraints of energy saving and carbon emission, coal transportation and environmental protection. The contradiction between energy supply and consumption will become worse, challenges and opportunities will coexist, difficulties and hopes will be together.

Total energy control is the fundamental way of responding to climate change: For the first time, the National Twelfth Five-Year Plan proposed "the proper control of total energy consumption," which will be the direct driving force to transform the economic development model. The variation of energy consumption intensity per unit GDP and total energy consumption for China over the period 2000-10 can be seen in Table 3 and Fig. 1. Between 2003 and 2004, total energy consumption in China increased steeply, growing by nearly 0.3 billion tons of standard coal. After 2005, the energy consumption intensity figures steadily decline from 1.28 tons of standard coal/10,000 Yuan to 0.82 tons (Table 3).

Total energy consumption however continues to rise from 1.455 billion tons of standard coal in 2000 to 3.25 billion tons in 2010, an increase of 2.23 times over 10 years, an annual growth rate of 8.35%. The bifurcation changes per unit GDP energy consumption intensity and total energy consumption (Fig. 1) reflects

Table 3: The variation of energy consumption intensity and total energy consumption from 2000 to 2010

Year	Energy consumption intensity(Tons of standard coal/10,000 Yuan)	Total energy consumption (billion tons of standard coal)
2000	1.47	1.455
2001	1.37	1.504
2002	1.32	1.594
2003	1.35	1.838
2004	1.34	2.135
2005	1.28	2.360
2006	1.20	2.587
2007	1.06	2.805
2008	0.93	2.914
2009	0.90	3.066
2010	0.82	3.250

the importance and urgency to control the total energy consumption for China.

Study conducted by IPCC has shown that: energy systems are for most economies largely driven by the combustion of fossil fuels, the energy sector is usually the most important sector in greenhouse gas emission inventories and typically contributes over 90 percent of the CO₂ emissions and 75 percent of the total greenhouse gas emission inventories (Intergovernmental Panel on Climate Change, 2006), so there is a positive correlation between a country's total energy consumption and carbon emissions if the energy structure does not change significantly. Total energy control therefore, is not only the fundamental way to cope with climate change, but also an effective way to reduce total carbon emission. Furthermore, China consumed 428.6 million tons oil in 2010, which is much higher than the number of 224.2 million tons in 2000. The dependence rate of foreign oil resources is nearly 54.5% in 2010 while the rate in 2000 is 27.5%. From 2005 to 2009, this data reached 44.7%, 47.4, 49.6, 49.4 and 51.2%, respectively (Table 4). This not only shows China has a huge demand for international fossil fuels, but also highlights China's security of energy supply is worsening.

The control of total energy consumption is the driving force and pattern of restructuring and upgrading of industrial construction: The restrictive indicators of energy consumption intensity link GDP with energy consumption, indicating that total energy consumption rises inevitably as GDP increases and energy consumption intensity declines. They do not however curtail energy-consuming and/or pollution-producing industries, which face little pressure of being restricted or closed. Using Zhejiang Province as an example, the industrial output of petrochemical, cement, thermal power, metallurgy, printing, dyeing and study making traditional industries occupy 32.6% of total output; not a particularly large proportion. However, they are all energy-consuming and pollution-producing industries accounting for nearly 80% of total industry energy consumption. It indicates there is much can be done to reduce energy consumption and carbon emissions by adjusting the industrial structure. However, this adjustment is difficult for the energy

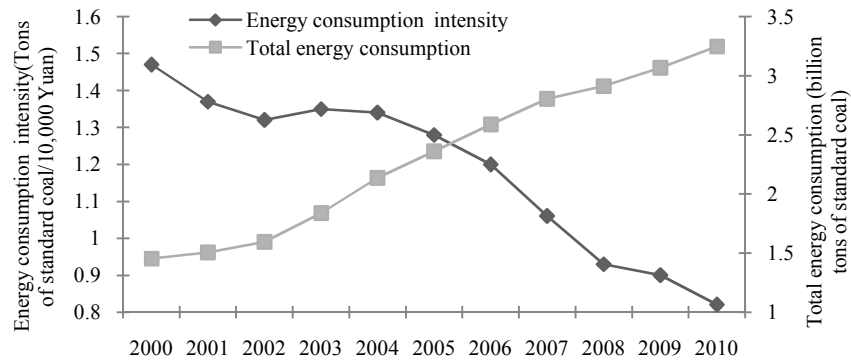


Fig. 1: The variation of energy consumption intensity and total energy consumption from 2000 to 2010

Table 4: Oil dependency in China (2000-2010)

Year	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
Oil production (million tons)	162.6	164.8	166.9	169.6	174.1	181.4	184.8	186.3	190.4	189.5	203.0
Oil consumption (million tons)	224.2	228.4	247.5	271.7	318.9	327.8	351.2	369.3	376.0	388.2	428.6
Oil dependency ^a (%)	27.5	27.8	32.6	37.6	45.4	44.7	47.4	49.6	49.4	51.2	52.6

consumption intensity meets the criterion of national goals and requirements. As a result, the driving force and pressure for adjustment are weakened. Thus, the effects are limited to promoting the transformation and upgrade of industrial structure by constraining energy consumption intensity. For this purpose, two restrictive indicators were added into the national "Twelfth Five-Year" Plan. The first is the amount of CO₂ emission per 10,000 Yuan. The second is the share of non-fossil energy as primary energy. In putting forward a reasonable control of total energy consumption, the Plan has a profound strategic significance. The change from energy intensity control to total energy consumption control is the "Forced Mechanism" of the upgrading and restructuring of industrial structure. It is also an essential element in promoting the transition from traditional and high-carbon industries towards low carbon. Whilst it is right that high-carbon production techniques and backward production facilities should be eliminated or closed down, high technology approaches should be considered to transform traditional carbon-intensive industries, using advanced carbon reduction technology to enhance the efficiency of energy consumption in the production process. Meanwhile, strategic emerging industries which are energy-saving, advanced and making high value-added in products should be encouraged. High-tech industries and low carbon industries should also be promoted and increased along with leading other industrial restructuring and upgrading. According to estimates, the contribution energy savings and emission reductions to total energy saving following restructuring can be 60-70% (Wei and Liao, 2010). It indicates that industrial restructuring and upgrading are the dominant factors to the promotion of energy saving and emission reduction. The important means and main direction in energy saving and emission reduction in the "Twelfth Five-Year Plan" is promoting the level of the industry

value chain, transforming traditional industries, developing strategic emerging industries and boosting the transformation of economic development mode.

Carbon emission control plays a crucial role on promoting the total energy control and optimization of energy structure: At present, there are no measures taken in the developed countries to control the amount of energy consumption. It is only through the various ways of reducing greenhouse-gas emissions (CO₂) the control of total fossil energy consumption is being realized. In the Kyoto Protocol, the requirements of carbon emission reduction to annex I countries (mainly developed countries) takes 1990 as the base year and targets a 5.2% summation reduction-2008 to 2012 being the first commitment period. Carbon emission control is therefore an effective path and method to control the amount of total energy consumption. The carbon emissions control targets force developed countries included in the protocol to optimize their energy supply and energy consumption structures and develop low-carbon energy alternatives, such as wind power, nuclear power, solar photovoltaic power generation, biomass energy and geothermal energy. According to statistics for 2009 from the International Energy Agency, 78.8% of France's primary energy came from nuclear power comparing favorably with 31.2% for Japan and Germany's wind power contribution of 24.6%. What's more, each is making relevant policies and regulations to promote the development of non-fossil energy. China is a developing country and does not take international responsibility for greenhouse-gas emissions. However, rising fossil energy consumption will reach a point where it is producing and emitting much greater carbon levels and will then bear more international pressure. Thus, increased awareness and actively exploring ways to address the total amount of energy consumed and optimizing the energy structure are effective ways

Table 5: Changing of total energy consumption and comprehensive energy consumption in Zhejiang province (2003-2010)

Index type	Total energy consumption (100 million tons of standard coal)	GDP (100 million Yuan)	GDP comprehensive energy consumption (Tons of standard coal/10,000 Yuan)
2003	0.76	9705	0.81
2004	0.92	11649	0.82
2005	1.20	13418	0.90
2006	1.32	15718	0.86
2007	1.45	18754	0.828
2008	1.51	21463	0.782
2009	1.56	22990	0.741
2010	1.63	27227	0.72

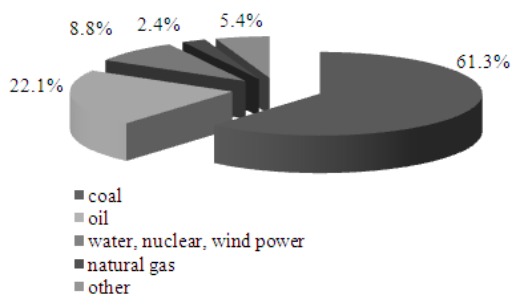


Fig. 2: Energy consumption structure in Zhejiang province

to change China's economic development model, boosting new industrialization and achieving greener, low carbon developments.

THE PATHS AND METHODS OF TRANSFORMATION FROM ENERGY INTENSITY CONTROL TO TOTAL AMOUNT CONTROL OF ENERGY CONSUMPTION IN ZHEJIANG

Zhejiang Province is the developed area, which has not received a mandate to control total energy consumption so far, but it is supposed to take the leading position in exploring and practicing change from energy consumption intensity control to total energy consumption control. By containing the total amount energy consumption used, promoting transformation and upgrading of the industrial structure, changing the traditional model and improving the quality and efficiency of economic development, Zhejiang Province can transform from an economically prosperous, to an economically strong Province.

The conflict between small Provinces with resources and large Provinces with economic power requires that Zhejiang must take the lead to explore the total energy consumption control: Zhejiang has a large population within a limited geographical area. It greatly lacks natural resources such as coal, oil and natural gas and must rely on 99.1% of its requirements being transferred from other Provinces or imported. In 2010, Zhejiang's total primary energy production was only 14.9 million tons of standard coal (equivalence), whilst energy transferred from other Provinces and imported reached 152 million tons. Zhejiang Province is highly

depending on external energy resources and its energy structure, which is dominated by coal, is not ideal. Coal makes up 61.3, oil 22.1, natural gas 2.4, water, nuclear and wind power 8.8 and other varieties of energy the remaining 5.4% respectively (Fig. 2).

In 2010, the GDP of Zhejiang Province was 2.7227 trillion Yuan, which accounted for 6.8% of China's GDP and 5.0% of the country's total energy consumption (Table 5). It indicates that the total energy consumption in Zhejiang is still high and the pressure for carbon reduction is tremendous.

The ability of transporting energy resources and supporting environmental capacity; the working pressure of energy conservation and emission reduction coupled with the objective requirements of ecological civilization, all suggest Zhejiang's current situation should be to make it clear there is a pressing need for the amount of energy available to be conserved and when used controlled. Zhejiang should break down energy consumption control targets scientifically and give strong policy-oriented signals to its cities, enterprises, institutions and citizens to promote the transformation of its economic development model to deliver the "Forced mechanism" of green, low-carbon development. It should be able to call on the whole of society to form an awareness of total energy consumption control and act responsibly, strengthening the concepts of controlling energy consumption and improving governments, institutions, industries, enterprises and the public's awareness of energy saving and carbon reduction. It must let the public participate in the process to become energy conscious and thereafter take action to become practitioners using green low-carbon options.

Promote the transformation and upgrade of industry structure, achieve the control of total energy consumption: Adjustments and transformation of regional industrial structure have a significant impact on the control of total energy consumption. Industrial structure can be classified into two types: one is large, where the proportion and structure is of three main industries-agriculture, manufacturing and service. The other is the different industries or industrial structures within each of the main industry fields. According to statistics from a macro perspective, the output proportion of the three main industries of Zhejiang

Province in 2010 was 5.0 : 51.9: 43.1 and the energy consumption proportion was 2.4: 81.5: 16.1. The second industry in Zhejiang Province, manufacturing, is over-weighted. It is obvious that it is the key target for adjustment and upgrade due to its very high energy consumption. From a microcosmic perspective, the output of traditional industries (such as petrochemical, cement, thermal electricity generation, metallurgy, printing and studymaking) occupied 1/3 of total industry output, while the correspondent energy consumption weighted nearly 80 percent of total consumption. It is clear that the energy-consuming and pollution-producing industries have a disproportionate balance between industrial output and energy consumption in Zhejiang Province. Therefore, the adjustment of industrial structure is the most effective way in controlling the rise in energy consumption. In the next 5-10 years, Zhejiang Province should focus mainly on the control of energy consumption using the following two methods. The first is to develop the tertiary and modern service industries and strive to reach a proportion of 50 percent by 2020, which will exceed the second industry. The second is restricting and eliminating traditional industry which is high energy-consuming, pollution-producing, using low technology, low economic benefits using a step by step approach and strive to develop dominant strategic emerging industries such as alternative energies, new materials, biology, the internet, efficiency power, advanced equipment, new energy cars, exploiting options from ocean development, nuclear power and allied industries, consistent with Zhejiang's characteristics.

Controlling total energy consumption by strengthening energy saving and carbon reduction of end users: Energy saving and carbon reduction is the most effective way and method to control the total energy consumption in the Twelfth Five-Year Plan. Generally, significant industries are identified as namely, iron and steel, cement, chemical and petrochemical, oil and gas, sugar, fertilizer, pulp and study, glass, ceramics, aluminum and textile (Zafer and Arif, 2007). During the Eleventh Five-Year Plan, industry in Zhejiang Province achieved good results in reducing energy consumption, with a highlight in the industries of pulp and study, dyeing and finishing, which eliminate backward production capacity for 50,000 tons and 2 billion meters respectively (Hong, 2011). Many manufacturing and service businesses are among the largest and most successful in China. However, during the Twelfth Five-Year Plan, energy saving in some industries face a decreasing marginal benefit, as it becomes more and more difficult as the 'easy-done' aspects have already be realized and the benefits already gained. It now needs new, more

innovative ways and measures to continue saving energy. According to international experience, the final way to achieve the amount control of carbon emission can be as follows. First, aim at how to deal with global warming. Second, make energy-saving and carbon-reduction a target. Third, get all the stakeholders to take part in the plan. Notoriously, in an open system, energy loses in each link of its consumption. According to the study of Zafer and Arif (2007) the total energy efficiencies ranged from 35 to 70 % (Zafer and Arif, 2007). Thus, theoretically, the saving quantity in primary energy consumption is larger than that of end users. The energy saving from end users is highly efficient, which reaches the key point of becoming a low-carbon development.

Introduce innovative energy management systems to achieve the goal of total energy consumption control:

Both the control of consumption intensity and the total amount of energy consumption has characteristics of strong administrative directives; extensive influence; multi-fields involvement; difficulties in assessment and weak supervision. In its exploration of total energy consumption control in Zhejiang, the government should primarily focus on the following aspects when promoting institutional innovation. First, define the target of regional total energy consumption control. Second, reasonably define in detail what the target of total energy consumption control means. Third is to explore pre-warning mechanisms for the control of energy consumption. Fouth is defining the rights of users in energy consumption (or rights of carbon-emission) and the trading thereof, making the minimal energy input and maximum energy output through a drive for profits from trading (Xiao, 2010). Fifth is to establish an evaluation and management system of energy consumption. Finally, accomplish the management and supervision mechanism of energy consumption.

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