Prospect of the upper limit of the energy demand in China from regional aspects

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A R T I C L E   I N F O

A B S T R A C T

The aim of this article is to indicate the upper limit of the annual energy demand in China, taking into consideration regional demand trends and projecting these trends into the distant future. The upper limit of energy consumption is not strictly the maximum amount of consumption. It means that the actual consumption will possibly exceed this level but not by much.

Consumption was calculated using the current energy consumption in the US and Japan as a reference, whose energy demands have already almost reached their upper limits. Scenario analysis was conducted for both semiquantitative and numerical models. Scenarios were developed taking into account the situation in rural regions. The prospect of regional population growth was also taken into consideration.

The results revealed large differences between the estimates in this study (2810–14,450 Mtoe), which means that if the energy consumption per capita in low-consumption areas increases, the total consumption in China will also increase significantly. According to the OECD prospect rates, our estimated upper limit will be surpassed in China around 2032–2073.

1. Introduction

China's recent economic growth has been quite rapid, and China's economy has recovered quickly after the financial crisis of 2008. The growth rate of the gross domestic product (GDP) in China has been approximately 10% over the last decade [1]. In addition, the present population of China is over 1.3 billion, and this number will also clearly continue to increase for an extended period of time. The United Nations reports that population growth in China is expected to continue at least until 2030 [2].

Because such dynamic expansions of the economy and the population are expected to increase energy consumption, China's energy demand has a strong impact on the global energy balance [3,4]. At the end of the 1990s, around the time Hong Kong was returned to China, energy consumption began to increase rapidly [5]. However, regardless of future improvements in the standard of living or future increases in the level of industrialization, the upper limit of energy consumption will follow the historical experience of many industrially advanced countries such as the US and Japan [6].

Although a number of studies have calculated the future energy demand of China, many of these studies analyzed the time-series shift in energy demand for the near or relatively distant future. These analyses examined the past trends in energy consumption, extracted efficient parameters, and then predicted the future transition of annual demand by mathematical modeling [3,7]. Some studies discussed the energy demand in China as a whole, but in recent years, analyses have been conducted by separating the huge market of China into several factors. This separation shows great variety, e.g., industrial sectors [7,8], regional aspects [9,10], primary energy resources [11,12], and final consumption patterns [13]. Furthermore, analytical models become more complex when they interconnect individual analyses. The credibility of these analyses has improved along with the development of model precision and computer technologies. These studies indicate that many people are interested in the energy consumption of China and its impact to the world. However, the methodology for establishing the estimated value in this study is not completely consistent with that of many other studies. The starting viewpoint looks at what kind of influence such a huge country will ultimately have on the world.

The upper limit of the energy demand in China is predicted, taking into consideration regional demand trends. The upper limit of energy consumption is not strictly the maximum amount of consumption. This level means that actual consumption will possibly exceed this level but not by much.

As a regional consideration, the 31 province-level divisions, including 22 provinces, 5 autonomous regions, and 4 municipalities,

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were analyzed [1]. Some of these administrative districts have a larger area and larger populations than other Asian countries. The populations, climates, environments, resources, industrial structures, and economic situations of these administrative districts vary considerably. Therefore, it is difficult to predict China's energy consumption by viewing the country as a whole. For a more accurate prediction, energy consumption can be analyzed based on regional characteristics or trends.

The estimate of China's energy consumption upper limit was calculated using the current energy consumption in the US and Japan as references, which have already reached their upper limits. Certain scenarios were assumed in both the qualitative and quantitative cases. It is imperative to study the future energy scenario in China because of the large scale of this country's energy consumption.

2. Estimate of the upper limit using consumption trends

2.1. Methodology

In general, the total energy consumption within an area E is described as

$$E = \sum_i e_i p_i$$

where, e_i and p_i are energy consumption per capita and population in subarea i, respectively. The energy consumption per capita is a good parameter of living standards. It is possible to quickly estimate future energy consumption when the prospects of these two parameters are individually given. Therefore, to estimate the upper limit of energy consumption, the energy consumption tendency of each province is classified into several patterns according to geographical features or industrial structures, etc. and then the

energy consumption per capita is determined for each pattern. However, some scenarios must be assumed for areas where energy consumption per capita is difficult to determine. The upper limit of energy consumption Es, when only one classified area is assumed by a scenario, is calculated by

$$E_s = \sum_c e_c \sum_i p_i + e_s \sum_j p_j$$

where e_c is the energy consumption per capita in a province that is classified as pattern c, p_i is the population in a province that is classified as pattern c, e_s is the estimated energy consumption per capita for scenario s, and p_j is the population in a province where scenario s is assumed. The maximum population in each province is estimated using the UN prediction.

2.2. Classification of provinces by energy consumption patterns

2.2.1. Current energy consumption trend in each province

The energy consumption in each region was analyzed by observing the energy consumption trends in all provinces, except the Tibet Autonomous Region because the energy data in this province have not been made public [1,14]. In 2005, Tibet had a population of approximately 2.7 million (0.2% of the China's population) [1]. In other provinces, many statistical data such as indices of economic conditions, energy production, and energy consumption have been made available since 1991.

First, the economic conditions and energy consumption trends in each province were considered based on the gross regional product (GRP) per capita and the energy consumption per capita [1,14]. Fig. 1 shows the ranking of energy consumption per capita in each province. After sorting the provinces in descending order based on energy consumption, a set of five consecutive provinces are represented in this map by a single color, with six colors used in
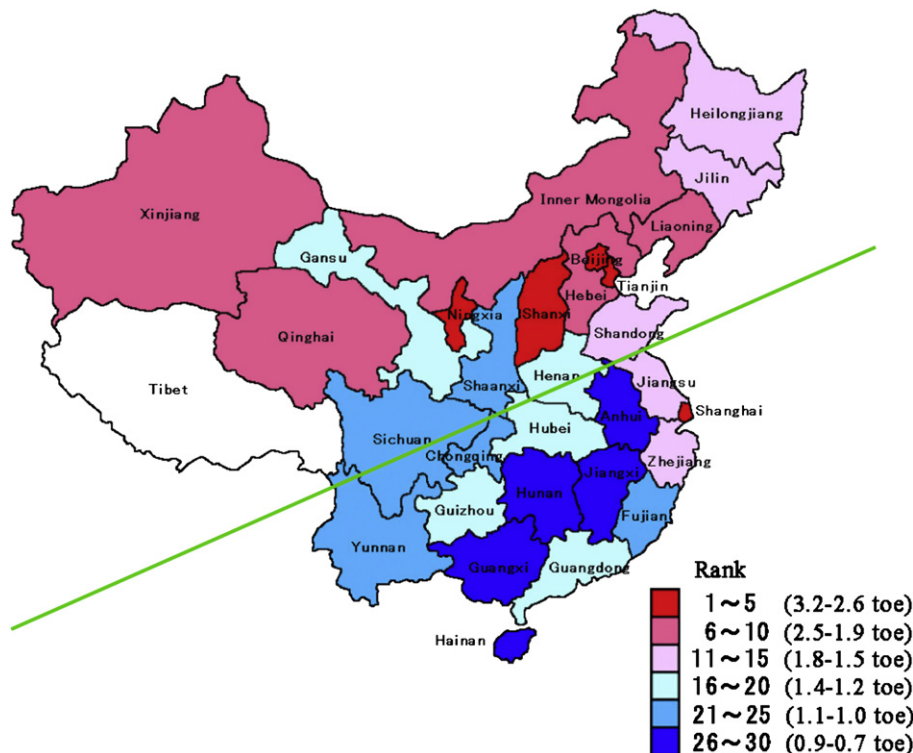

Fig. 1. Ranking of energy consumption per capita by province (2005). Thirty provinces are classified into six categories by rank. The green line is the hypothetical border of the northwest lower-consumption region and the southeast higher-consumption region.