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# Geographical and environmental perspectives for the sustainable development of renewable energy in urbanizing China

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ABSTRACT

With rapid urbanization and industrialization, China has become both the largest energy consumer and $CO_2$ emitting country in the world. As a clean and low-carbon energy source, renewable energy is a good choice to substitute for the exhausted fossil energy. The Chinese central and local governments have made a series of policies and optimistic plans to promote a rapid development of renewable energies. China's renewable energy development has become a key to the sustainable development of socio-economic system. Unlike most of the current studies which mainly identified the challenges regarding policies and technologies around renewable energy or performed specific analyses for a certain kind of renewable energy, this paper summarizes the spatial disparity and consistency among the major renewable energies, coal resources, energy consumption and its major influencing factors in China, and reviews the positive and negative environmental impacts of major renewable energies. Based on the geographical and environmental perspectives, this paper recommends that the Chinese government: constructs the national energy production bases according to the resource distribution; integrates different energies on the basis of their natural features and spatial consistency; adjusts the overall layout of socio-economic development consistent with renewable energies; and promotes a moderate renewable energy development to maximize the environmental benefits.



**Contents**



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## 1. Introduction

China, with more than 1.3 billion people and 1/5 of the world population, has experienced rapid urbanization and industrialization since the reform and open policy in 1978. It has a significant impact on economic growth and environmental change, making China one of the largest economies and consumers of resources in the world [1,2]. Specifically, the energy consumption in 2011 is reported to be 3.48 billion tons of standard coal equivalent (tce), 7.1% higher than in 2010 [3]. The $CO_2$ emissions in 2011 have reached 9 billion tons, 28% of the world total [4]. China has become both the largest energy consumer and $CO_2$ emitting country in the world. As China's high-speed economic growth is still dependent on massive energy consumption [5], and per capita energy consumption and $CO_2$ emissions are much lower than in developed countries, i.e. per capita $CO_2$ emissions is 6.6 t in China and 17.2 t in USA [4], the increasing trends of energy consumption and $CO_2$ emissions are most likely to continue with China's plan to accomplish its socio-economic development goals. China is facing severe energy-related challenges, such as resources depletion and great pressure to reduce $CO_2$ emissions [6]. To cope with these challenges is of benefit not only to China but also to the world.

It is recognized that energy that is secure, environmental friendly, and produced and used efficiently is essential for sustainable development [7]. Renewable energy (i.e. hydropower, wind power, solar energy, biomass energy, geothermal power, ocean energy, etc.) is considered to have a high potential to be cost-efficient, reliable, not damaging to the environment and designed appropriately for local conditions [8]. It has become a driving force in the effort to sustain the earth's natural resources and to improve the users' quality of life [9]. Therefore, a mass of studies highlighted the need for evaluation of renewable energy as alternatives for energy [10–13]. Even some scholars proposed a 100% renewable energy system for China [14]. The Chinese central and local governments have made a series of policies and optimistic plans to promote the renewable energy development. Consequently, China's renewable energy system has made progress at an unprecedented pace with the annual consumption increasing from 166 million tce in 2005 to 286 million tce in 2010. In 2015 the annual consumption of renewable energy has been planned to reach 478 million tce [15]. All kinds of renewable energies in China will continue to develop fast (see Table 1).

With a rapid development in recent years and a broad prospect in the future, China's renewable energy development has become a focus of world's attention. A mass of studies have introduced the current situation in China, focusing particularly on the barriers and opportunities [16–21]. Some scholars have circumstantiated the development situation for a certain kind of renewable energies in China, such as hydropower [22,23], wind power [24–28], solar energy [29] and biomass energy [30,31]. The above studies have reached a consensus that China's renewable energy resources are abundant and renewable energy development is the key to China's energy security, environment protection, and $CO_2$ emissions reductions. The above studies also provided some valuable insights on the sustainable development of renewable energy itself, e.g. some technical, economic and environmental problems that prevent us from being optimistic about China's renewable energy development have been fully discussed. However, prior studies mainly identified the challenges regarding policies and technologies of renewable energies, or performed specific analyses for a certain kind of renewable energy, or emphasized the disadvantages of the spatial disparity between energy supply and demand, or stressed the positive environmental impacts of renewable energy in China. Therefore, this paper summarizes the spatial distribution of major renewable

**Table 1**
Achievements and goals for China's renewable energy use in the 11th and 12th five-year period [15].

| Year | 2005 | 2010 | 2015 |
|---|---|---|---|
| Annual consumption of renewable energy (million tce) | 166 | 286 | 478 |
| Share of renewable energy in the total energy consumption (%) | 7.5 | 8.9 | > 9.5 |
| Installed capacity of hydropower (GW) | 117.39 | 216.06 | 290 |
| Installed capacity of grid-connected wind power (GW) | 1.26 | 31.00 | 100 |
| Installed capacity of solar PV power (GW) | 0.07 | 0.80 | 21 |
| Annual consumption of solar water heaters (million $m^2$) | 80 | 168 | 400 |
| Installed capacity of biomass power (GW) | 2.00 | 5.50 | 13 |
| Annual consumption of biogas (billion $m^3$) | 8 | 14 | 22 |
| Annual consumption of biomass fuel (million tons) | 1.07 | 2.30 | 15 |
| Annual consumption of geothermal power (million tce) | 2 | 4.60 | 15 |