

# Current Status of Renewable Energy Development in China and its Environmental Impact

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**Abstract.** Based on the “double carbon” proposal, the application area of renewable energy is becoming more and more extensive. The development of renewable energy sources inevitably has some drawbacks and even environmental impacts. In this paper, we analyze solar, hydro, geothermal and wind energy, and further explore their applications and impacts on the environment. The current renewable energy sources include solar, wind, hydro, geothermal, hydrogen and many others. These energy sources are frequently used to generate electricity in order to reduce the pollution caused by fossil fuels. At present, solar-related industries can pollute water and soil during production. The use of water energy requires the construction of power stations or dams, causing disruptions to fish migration and damaging watershed ecosystems. Wind power generation relies mainly on wind turbines, which generate noise that affects human life and hinders the survival of birds due to their large size. The application of geothermal energy has the potential to produce thermal and air pollution, and even lead to geological disasters. There is no denying that these energies pose many problems that cannot be ignored, so this paper intends to attract more scholars to pay attention to renewable energy and its drawbacks, and to further improve the use of renewable energy and reduce its environmental impacts by exploring. During China's energy development, hydrogen energy should be given priority since it has different advantages over other renewable energy in aerospace, electricity, and new energy vehicles, etc.

**Keywords:** Renewable energy; environmental impacts; solar energy; wind turbines; watershed ecosystems.

## 1. Introduction

Energy provides the basic support for human life and production. With the increase of living demand and the expansion of production scope, human beings have made predatory exploitation of non-renewable energy, which accounts for the main part of production capacity, and the resulting environmental pollution problems cannot be ignored. China's high energy production and consumption have brought the national energy security strategy to a new level. In the post-epidemic era, adhering to the green recovery program with the goal of carbon peaking and carbon neutrality has become a new global consensus. Promoting the clean and low-carbon energy production in China, as well as continuing to improve the energy system, is of great significance to the overall national development strategy.

In China's energy development strategy, water energy development is steadily advancing, becoming the most mature technology and also the most economic renewable energy; wind power has entered the stage of large-scale development, has achieved many years of continuous rapid growth; solar energy is becoming increasingly popular, the basic formation of a complete photovoltaic power generation industry chain.

However, renewable energy also brings environmental problems that cannot be ignored. In the process of construction and use of power generation facilities will cause some damage to the local ecological environment, in addition, the pollution problems in the process of producing materials and the recycling of power reserve facilities cannot be ignored. In view of this, this topic outlines the

current situation of renewable energy development in China and its advantages and disadvantages, and also points out the hidden environmental problems in the development process, in order to provide scientific reference for academic research and trend analysis in related fields.

## **2. Classification of Renewable Energy**

### **2.1. Solar Energy**

Solar energy is the energy transmitted to the Earth in the form of radiation from the large number of hydrogen atoms within the sun, which generate large amounts of nuclear energy through the fusion of hydrogen nuclei. China would need to burn  $2.4 \times 10^4$  billion tons of standard coal to produce the equivalent of the annual solar energy transmitted to the Chinese land by the sun. More than two-thirds of China's land area has radiation levels exceeding  $5,000 \text{ MJ}/(\text{m}^2 \cdot \text{a})$ . The highest total radiation and sunshine hours are found in Tibet, Sichuan, Qinghai and Inner Mongolia in China. Xinjiang, Shanxi, Hebei and Yunnan, and coastal areas such as Fujian and Guangdong are rich in solar energy resources, while only Hunan, Hubei, Sichuan and Guizhou receive less solar radiation.

### **2.2. Wind Energy**

Due to the rich topography of the Earth's surface, the ground receives uneven solar radiation and generates different amounts of heat. This heat causes a differential distribution of atmospheric pressure which can lead to air movement. The kinetic energy generated by the air during this process is wind energy. China is a vast country. The southeast coast, the plains of north China, the northeast plains and the Tibetan plateau are rich in wind energy resources. Some provinces in the north-west also have more tremendous advantages for the use of wind energy. At a height level of 70 m on land in China, the wind power density reaches  $300 \text{ W}/\text{m}^2$  with a technically exploitable capacity of 2.6 TW. The volume of offshore wind energy is also not to be underestimated, as China has a rich territorial sea area and a coastline from south to north. The actual installed capacity of offshore wind turbines can be up to 500 GW in waters over 50 m deep, extending 50 km from the coastline [1].

### **2.3. Water Energy**

The kinetic energy, potential energy and hydrostatic energy generated by the fall of the topography of water flows constitute water energy. This energy source is abundant in rivers, ocean currents and tides. China ranks first in the world in terms of the amount of hydro energy resources it contains, with the southwest and Tibetan regions accounting for most of the water resources in China. Meanwhile, the Pearl River, Yangtze River and Yellow River basins have been intensively developed and a number of hydropower stations have been built.

### **2.4. Geothermal Energy**

The Earth's interior contains a large amount of magma deep inside, and the magma itself contains a large amount of thermal energy at extremely high temperatures, thus becoming a source of geothermal energy. Geothermal energy is transmitted in different ways in different geographical locations and structures, and the ways in which it can be utilized vary greatly. According to these differences, geothermal energy is classified into shallow geothermal energy, hydrothermal geothermal energy, and dry heat rock. Most areas in China contain shallow geothermal energy. The western parts of Tibet, Yunnan, Sichuan and other regions as well as Taiwan are dominated by hydrothermal geothermal energy. The remaining areas are mainly distributed by medium and low temperature geothermal resources. There are about 336 geothermal energy-rich cities in China.

### **2.5. Hydrogen Energy**

The source of hydrogen energy is mainly some substances containing hydrogens, such as water, water gas and petroleum, which are processed and extracted in different ways to make. Hydrogen is

a spotless energy source with a very high calorific value, its combustion product is only water. China ranks first in the world for hydrogen production. According to statistics, the annual hydrogen production in China is already as high as  $3 \times 10^7$  t, of which about 36.4% of the total hydrogen production meets the industrial hydrogen production standard [2]. The hydrogen energy industry chain is relatively well-developed, and the relevant technologies are mature. In East China, South China and the capital business district, there are about 300 industrial enterprises above the scale of the whole industrial chain.

## 2.6. Marine Energy

Because the ocean is influenced by many geographical factors and has a complex composition, ocean energy exists in many forms. Marine energy includes tidal energy, wave energy, temperature difference energy, salinity gradient energy, etc. Our country has great potential for the rational application and sustainable development of our abundant marine energy, as shown in Fig. 1.

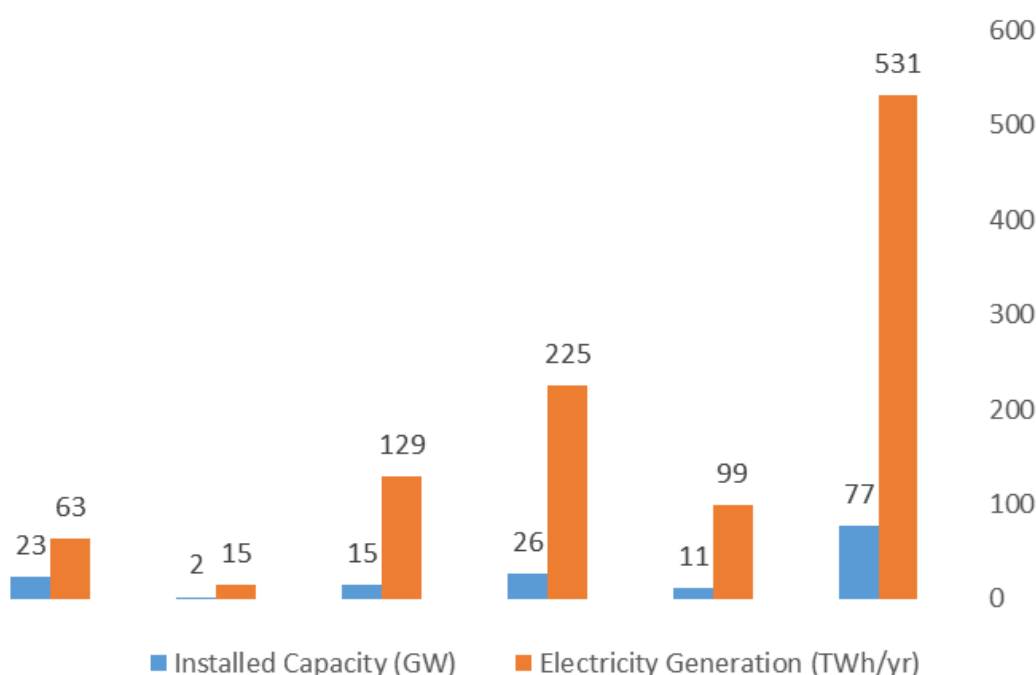


Fig 1. Resources available for marine energy development in China [3].

## 3. Renewable Energy Applications

### 3.1. Applications of Wind Energy

Wind power generation has high economic efficiency and is technically mature. Because of its low cost of use, it has shown more outstanding results in alleviating environmental pollution, regulating energy structure, and solving the problem of electricity consumption in remote areas, etc., and thus has been very widely developed and utilized. China is bordered by the Pacific Ocean in the east, the Siberian plain in the north, and the Indian Ocean monsoon in the south, forming a very vast area of wind energy resources, with about 20% of the national territory available for efficient development, mainly concentrated in the southeast coast and the northwest, north and northeast China [4]. Relevant data show that China's total onshore wind energy resources at 10 m height above the ground are about 4.35 billion kW, ranking first in the world. The wind energy reserves that can be developed and utilized at 10 m height offshore are about 750 million kW [5].

#### 3.1.1. Onshore wind power generation

The operation of onshore wind turbines is mainly divided into joint operation and grid-connected operation and independent operation, in which the energy conversion efficiency between wind

turbines and generators is the key technology of wind power generation equipment, and China mainly uses grid-connected technology, which is simple to operate and cheap, but the shock voltage generated at the moment of grid connection is larger [6]. From the aspect of variable speed, wind power generation system can be divided into constant speed wind power generation and variable speed constant frequency wind power generation, variable speed constant frequency wind power generation is more flexible and also greatly improves the efficiency of power generation, the efficiency of this system is generally 60%-70% [7].

### 3.1.2. Offshore wind power generation

Offshore wind turbines are based on onshore wind turbines, which are modified to better adapt to the sea wind environment, and according to relevant studies, the nearshore sea wind is about 25% higher than the land wind speed [8]. Offshore wind turbines are mainly divided into bottom fixed type and suspended type, where the suspended type is less affected by waves and more stable.

## 3.2. Application of Geothermal Energy

### 3.2.1. Current status of geothermal energy application

The Earth was born about 4.6 billion years ago and is now in its prime, with the temperature of the Earth's core reaching 4500°C. Since the exploitation of human use of geothermal energy is not large, geothermal energy can be recovered naturally to a certain extent and is therefore a renewable energy source, and the life span of thermal fields is generally up to 100-300 years [9]. Meanwhile, using heat from the Earth's interior causes little atmospheric pollution and emits no greenhouse gases. According to the data published by our relevant authorities, the amount of shallow geothermal energy resources in China is equivalent to 9.5 billion tons of standard coal, and the amount of hydrothermal geothermal energy resources is about 835 billion tons of standard coal. 3000-10000m depth range of dry thermal geothermal energy resources class is equivalent to 870 trillion tons of standard coal [10]. Undoubtedly geothermal energy has extremely huge storage. Table 1 shows the development goals of direct geothermal energy application and power generation at different time points proposed by the Chinese Academy of Engineering.

**Table 1.** Strategic targets of geothermal energy development in China [11].

Year	Geothermal power generation/MWe			Direct use/MWt	
	High Temperature Geothermal Power Generation	Medium Temperature Geothermal Power Generation	EGS Geothermal Power	Medium Temperature Geothermal Direct use	Shallow Geothermal Utilization
Current Status	25.18	0.5	N/A	3239	3000
2020	75	2.5	During the test	4000	10000
2030	200	20	25	6500	20000
2050	500	100	200	10000	50000

### 3.2.2. Examples of geothermal energy applications

There are currently three types of geothermal energy resources, namely shallow heat, water heat and dry heat, which are used to generate electricity in a variety of ways, from direct steam generation for higher temperature steam fields to flash steam and other methods for medium temperature hot water type geothermal fields, with a thermal efficiency of about 5%-20% [12]. In addition, the direct use of geothermal energy also presents great advantages for heating, acting as a heat pump is a common construction method with thermal efficiencies of up to 50-70% [12]. Thus, it is necessary and efficient to divide geothermal energy into different exploitation methods according to temperature intervals. Table 2 shows the division of hydrothermal geothermal resources by temperature.

**Table 2.** Hydrothermal geothermal resources classified by temperature range [13].

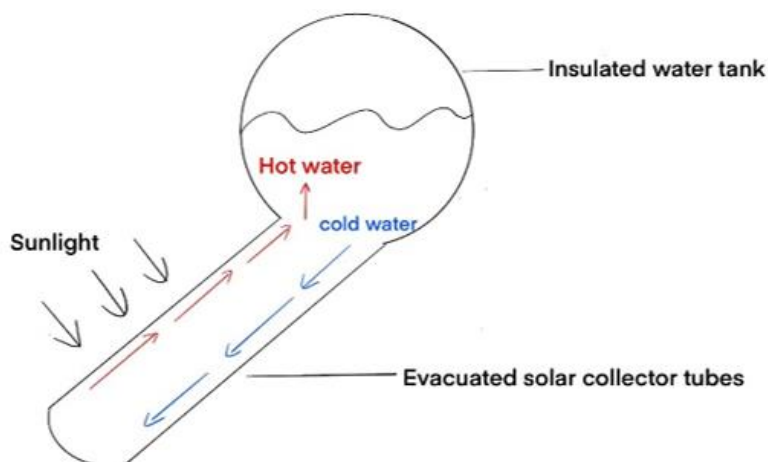
Classification	Temperature/°C	Fluid form	Main Uses
Low temperature type	25~40	Warm water	Agricultural farming, greenhouse, bathing
	40~60	Warm water	Construction farming, breeding, greenhouse, recreation
	60~90	Hot water	Building heating, bathing
Medium temperature type	90~150	Hot water or water vapor	Drying, power generation, industrial
High temperature type	≥150	Water vapor	Electricity generation

The geothermal energy application system is the generation of electricity through a thermal cycle process, and the most widely used is the duplex generation, including: organic Rankine cycle and Kalina cycle [14]. The key technology is the rechargeable development technology in hydrothermal geothermal fields, while this involves more disciplines and is difficult, considering not only the transfer of groundwater, but also the transfer of thermal energy, which can greatly affect the life of geothermal fields and even damage the local ecological environment if not handled properly [15].

### 3.3. Applications of Solar Energy

#### 3.3.1. Solar water heaters

The vast majority of solar water heaters in China's towns or rural areas are vacuum tube-type solar water heaters. The basic principle of this type of water heater consists of absorbing solar radiation through the heat-absorbing coating of the collector tube and converting solar radiation into heat. The heat is used to raise the temperature of the water in the glass tube, and the density of the water is reduced, which then flows through the glass tube into the insulated water tank. The denser cold water then flows into the glass tube for heating, creating a cycle [16]. Fig. 1 shows the operating principle of a vacuum tube solar water heater.



**Fig 2.** Schematic diagram of a vacuum tube solar water heater.

#### 3.3.2. Solar photovoltaic

Solar lighting is frequently used on municipal roads or rural roads in China. The road lights are equipped with 1 or 2 sets of solar cells, which absorb the solar radiation during the day and convert it into electricity stored in the battery to ensure sufficient power for continuous lighting at night. Lighting needs to work at night for long periods, and because of the sheer size of China's roads, the construction of lighting and power generation consumes enormous amounts of money. Solar lighting

solves the problem of high consumption caused by long hours of illumination brought about by traditional street lighting, saving energy to the greatest extent, reducing the cost of power generation and highlighting the environmental friendliness and economy of solar energy.

### 3.4. Application of Water Energy

Water energy resource is a kind of physical energy into electrical energy resources. The kinetic energy from the flow and fall of the water can be converted into electricity and stored without consuming or polluting the water or emitting greenhouse gases. China has abundant hydro energy resources, with a per capita share of 55.1% of the world's per capita [17].

The hydraulic turbine is the key equipment for the utilization of hydro energy resources, and usually the hydraulic turbine is divided into two categories, one is the impact turbine, which is commonly known as the nozzle converts the water flow into a high-pressure jet and drives the rotation of the runner, thus making the generator rotate and generate electricity; the second is the counter-attack turbine, which is a fixed curve outlet pipe in the conical cylinder, and when the water flows through, it generates acceleration and uses the phase reaction force of the water to drive the conical cylinder rotation, thus making the generator generate electricity.

The construction of hydropower plants not only takes into account the local human and natural environment, but also requires extra attention to whether the planning and design are flawed, as exemplified by the Sanmenxia hydropower plant, which was started in 1957, where a single consideration of power generation efficiency ignored the necessary measures for sand discharge, causing the water level of the Weihe River to rise and threatening the flood safety of Xi'an city [18].

Due to the abundance of watersheds in China, in addition to the development of large hydropower stations, it is necessary to carry out the development of small hydropower stations, which not only avoid the difficult financial problems of developing hydropower stations in more economically backward areas, but also provide new possibilities for the supply of electricity in remote areas, small hydropower stations with small investments and simpler construction have a positive effect on the improvement of the energy structure, according to the National Bureau of Statistics data, 2013 -2021, China's hydropower investment grew by 22.5% [19].

## 4. Environmental Impact of Renewable Energy

### 4.1. Environmental Impacts of Solar Energy

Solar Photovoltaic requires solar panels, the production of solar panels is mainly based on monocrystalline or polycrystalline silicon and acidic solvents [20]. The production of crystalline silicon is an energy-intensive process, requiring 460kWh of electricity to produce a 160 wp polysilicon PV module [21]. Polysilicon produces  $\text{SiCl}_4$ , a by-product harmful to human health, during the production process. Once leaked,  $\text{SiCl}_4$  will be incorporated into water bodies to form HCl, causing acidification of the surrounding water bodies and soil and damaging the ecological environment. Acidic solvents such as hydrofluoric acid are used in the process of pickling and etching of polysilicon, resulting in highly concentrated acidic wastewater containing many elements after absorption in the absorption tower. In addition, the construction of structures for Solar Photovoltaic generates waste water, waste, noise. At the same time, heavy metals such as lead and cadmium contained within photovoltaic facilities are also one of the primary sources of harm to water bodies and soil.

### 4.2. The Impact of Water Energy on the Environment

Water energy on the environment can be broadly divided into geological impact, human impact and ecological impact. Geological impact is mainly reflected in the reservoir water storage, due to soil loosening or other reasons caused by the collapse of the accident, to a large extent will endanger people's lives and property safety, Gansu Province, Zhuanglang County, a reservoir as an example [17], due to the dam head soil is loess, coupled with the washout of heavy rain, resulting in the

collapse of the dam, resulting in a large number of casualties. Furthermore, it is worth noting the possibility of seismic activity induced by the change in ground forces due to massive water storage.

The human impact is mainly reflected in the pre-construction phase of large hydropower plants. The location of reservoirs that flood existing farmland and villages will result in the cost of relocation and resettlement facilities, as shown in Table 3, and will develop new land and change the natural conditions.

**Table 3.** Immigration of some hydropower plants and water conservancy hub projects in China [22]

Project Name	Reservoir area/km <sup>2</sup>	Flooding affects arable land/hm <sup>2</sup>	Number of immigrants	Compensation investment / million yuan
Wuqiangxi Hydropower Station	170	2971	120407	151000
Ertan Hydropower Station	101	1593	42215	170704
Lotus Hydropower Station	133	7367	40725	100233
Liji Xia Hydropower Station	31.6	456	4206	9219
Daxia Hydropower Station	12.6	318	4818(Production placement)	8500
Wanjiashai	28.11	250	5326	43836
Jiangya Hydropower Hub	35.8	936	16317	44718

The ecological impact is mainly reflected in the impact of hydropower plants on water flow, which is the direct driving force in shaping the geomorphology of the river and downstream ecosystems, and which determines the hydrological characteristics of the river, which may not only cause siltation of the lake bottom, but also may lead to the smooth evolution of the deltaic geomorphology downstream. Changes in water flow can also lead to changes in downstream biodiversity, with hydroelectric power plants blocking access to migratory fish; in the case of Dongting Lake, for example, the Three Gorges power plant has directly caused a massive reduction in fish fry in the lake, with some valuable fish on the verge of extinction [23]. Furthermore, the reduction of water flow downstream will reduce the wetland area to a certain extent, which directly affects the stability of the wetland ecosystem.

#### 4.3. Environmental Impacts of Wind Power Generation

Birds have the highest chance of being disturbed or injured or even killed during the operation of a wind farm. In wind-rich areas of China, there are a large amount of power generators with long rotor blades, birds can be disturbed during their migration. As a result, some birds have to find alternative habitats or feeding areas. During foggy days, birds have reduced visibility and are extremely sensitive to and attracted to lights emitted from wind farms within their field of vision. Migratory birds lower their altitude when they encounter heavy rainfall during their flight. These lousy weather events increase the possibility of bird crashes with rotor blades and turbines [24]. The height of blades is typically around 20m or more, and within this range, nearly one in five birds are susceptible to collision with rotor blades [25], as shown in Table 4. Birds that do not maintain a distance of more than 16 m from the turbine will have an increased chance of impact [25].

**Table 4.** The proportion of birds flying at various altitudes and distances from the turbines [25].

Proportion of birds	Flying altitude (m)	Proportion of birds	Distance from turbine(m)
70-75%	<21	74.8-80%	>31
16-17.5%	21-51	5-14.1%	<16

#### 4.4. Environmental Impacts of Geothermal Energy

The environmental impacts of geothermal energy development are divided into three main areas, namely atmospheric pollution, chemical pollution and geological impacts. Due to the large amount of steam and fluids extracted from geothermal reservoirs, and they contain a large number of chemical substances, including the toxic gas H<sub>2</sub>S as well as the greenhouse gas CO<sub>2</sub>. In the geothermal exhaust, CO<sub>2</sub> accounts for about 85% of the non-condensable gases.

Chemical contamination is reflected in the excessive harmful elements or salt contamination contained in geothermal water. Geothermal water generally circulates deeply in the ground, and through a certain water-rock effect, its salt content and heavy metal element content are too high, and if geothermal water is used as irrigation water or farming water, it may aggravate the enrichment of toxic substances in crops and fish.

The geological effects are mainly manifested in the ground subsidence that may be caused by pumping the original fluid from the ground. Taking the Wairaki thermal area in New Zealand as an example (Table 5), the ground subsidence in the area was about 4.5 m in 1964-1974, and was accompanied by horizontal movement up to 0.4 m.

**Table 5.** Subsidence caused by some geothermal plants [26].

Geothermal fields	Total settlement/mm	Annual sedimentation/mm	Mining time/a
Wairakai	7600	400	19
Svalbardine	130	11	12
Ladrillo	1850	29	63

## 5. Conclusion

Fossil fuels as a non-renewable energy source will be depleted in the next few decades or even centuries, and human production and development will always be supported by energy. This paper gives examples of several renewable energy sources and describes their applications in different fields while also specifically analyzing the negative environmental impact of their use. Renewable energy, as the mainstream energy source of the future, is bound to be used in large numbers, and the related industries will be developed on a large scale. The application of renewable energy has always been based on the concept of low carbon and environmental protection, but many unavoidable adverse effects have also become apparent in the process of application. Therefore, we should pay attention to these adverse impacts and seek ways to reduce or eliminate them, continuing the concept of low carbon, environmental protection and making renewable energy better for humankind.

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