

# Application of Bioenergy and Its Impact on Sustainable Development

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**Abstract.** In recent years, the rapid growth of global energy demand and the irreversible impact of traditional fossil energy on the environment have made the need for sustainable energy increasingly urgent, and bioenergy has attracted much attention as an important renewable energy source. However, bioenergy has received far less social attention than other energy sources in China. In this paper, starting from the types, benefits use, and uses of bioenergy development at home and abroad, we study the current misunderstandings and challenges in sustainable development and put forward countermeasures for the sustainable development of clean, low-cost, and high-efficiency bioenergy industry in China. As a kind of clean energy, bioenergy is widely used in power generation, transport, and chemical industries, and thus has economic and social benefits that cannot be ignored. The benefits of bioenergy can only be maximized by solving the problems of coordinating the supply of feedstock resources and food security, introducing internationally advanced technologies and facilities, and improving relevant policies laws, and regulations. This paper broadens the field of research on bioenergy and sustainable development at the macro level and provides new development ideas for China's bioenergy development. Through in-depth research on bioenergy technology, strengthening international cooperation, and optimizing the policy environment, the bioenergy industry can be promoted to develop in a healthier direction and create a better future for human society.

**Keywords:** Bioenergy, biomass, biofuel, dual carbon target, sustainable development.

## 1. Introduction

In recent years, the rapid growth in global energy demand and the irreversible impact of traditional fossil energy sources on the environment have made the need for sustainable energy increasingly urgent. Bioenergy is attracting attention as an important renewable energy source. Bioenergy is the energy obtained through the use of biomass materials such as plants, animals, or micro-organisms, and includes forms such as biomass, biofuels, and biogas. Compared with fossil fuels, bioenergy has several advantages: first, it is a renewable energy source that can be recycled through regular planting and harvesting of crops or the use of waste plant material; second, the use of biomass materials can significantly reduce greenhouse gas emissions, which is important for combating climate change; in addition, bioenergy resources are relatively abundant, which effectively reduces dependence on traditional energy sources.

Despite the many advantages and potential of bioenergy, its development still faces several challenges. For example, the issue of feedstock supply is an important constraint to the expansion of the bioenergy industry. Currently, it mainly relies on crop residues and waste as feedstock, but these resources are limited and the efficiency of their use needs to be improved. In addition, the technical level and facility construction of the bioenergy industry need to be further upgraded, and related policies and regulations need to be further improved. China put forward the development requirements of bioenergy in the 1990s, but compared with developed countries such as the United States, China's bioenergy started late, and the overall technological development of bioenergy has

been slow, and the current production scale is small, and the number of related researches is small. As a result, bioenergy has received much less social attention than other energy sources in China [1].

Starting from the types, benefits, uses, and uses of bioenergy development at home and abroad, this paper examines the current misunderstandings and challenges in sustainable development, and proposes countermeasures for the sustainable development of clean, low-cost, and high-efficiency bioenergy industry in China.

## **2. Bioenergy**

### **2.1. Definition and Types of Bioenergy**

#### **2.1.1. Definition of bioenergy**

Bio-energy, also known as green energy, is a renewable and clean energy source, its development and use are in line with the concepts of sustainable development and circular economy. Therefore, the use of high-tech means to develop bioenergy has become an important part of the energy strategy of today's developed countries. Currently, the four main forms of bioenergy are biomass, biofuels, biogas, and other bioenergy resources.

#### **2.1.2. Types of bioenergy**

Biomass is an important renewable energy source, directly or indirectly from the photosynthesis of plants, generally taken from agricultural and forestry wastes, domestic wastes and animal manure, etc. [2]. Due to its environmentally friendly, low-cost, and carbon-neutral characteristics, governments have attached great importance to the development and utilization of biomass resources in response to the dual pressures of energy shortage and environmental degradation.

Biofuel refers to solid, liquid, or gaseous fuels composed of or extracted from biomass, which can replace petrol and diesel produced from oil, and is an important direction in the development and utilization of renewable energy. It includes plants, animals, and microorganisms, and unlike traditional fuels such as oil, coal, and nuclear energy, these emerging fuels are renewable [3, 4].

Biogas, or biochemical gas, refers to the gas produced by fermentation or anaerobic digestion of manure, sewage, municipal solid waste, and other biodegradable organic matter in an oxygen-poor environment, which mainly contains CH<sub>4</sub> and CO<sub>2</sub>, and is also known as "biogas" or "landfill gas". It is also called "biogas" or "landfill gas". Biogas can have the same characteristics as natural gas once it has been purified. The gas supplier removes impurities such as H<sub>2</sub>O, H<sub>2</sub>S, and particulates from the biogas, and reduces the CO content of the gas to make it more completely combustible. Gases that have not been subjected to the above purification process are sometimes mixed with natural gas for combustion. Once the biogas has been purified to a quality that can be transported by pipeline, the gas is called "renewable natural gas".

### **2.2. Characteristics of Bioenergy**

Bioenergy is a renewable resource with good prospects for the development of human society. Therefore, the vigorous development of bioenergy plays an important role in improving the environment and alleviating the energy crisis. Compared with other energy sources, bioenergy has some unique features, which can reasonably reuse waste, generate effective energy, improve the living environment, and is a new way of energy development, meanwhile, bioenergy is renewable, environmentally friendly, resource-rich, and substitutable. Therefore, bioenergy is regarded globally as an important strategy for future development, looking for energy outlets, developing new energy growth points, and realizing sustainable development strategies [5].

### 3. Relationship Between Bioenergy and Sustainable Development

#### 3.1. Environmental and Economic Benefits

##### 3.1.1. Environmental benefits of biomass energy

Biomass is the only renewable energy source that can be stored and is also a green energy source. The efficient use of biomass can save fossil energy and reduce the emission of pollutants, which is of great significance for environmental protection. China is extremely rich in biomass resources, and the development of efficient biomass utilization technology is an important measure to ensure the long-term sustainable development of the country [6].

##### 3.1.2. Reduce emissions of hazardous substances and incremental greenhouse gases

Fossil fuels make the original fixed carbon mobile through combustion and accumulate it in the form of CO<sub>2</sub> in the atmosphere, thus forming the greenhouse effect. Table 1 is a comparative analysis of emissions from fossil energy and biomass using the life cycle approach, from which it can be seen that replacing fossil fuels with biomass resources reduces the supply of fossil fuels on the one hand, and on the other hand reduces the emission of pollutants, such as CO<sub>2</sub>, SO<sub>2</sub>, and NO<sub>x</sub>, and improves the quality of the environment. Therefore, the rational and full use of bioenergy is an important way to reduce the consumption of fossil energy, improve the structure of energy use, reduce greenhouse gas emissions, and at the same time help to achieve the goal of "carbon neutrality" and "carbon peak".

**Table 1.** Comparison of emissions from fossil energy and biomass [7].

renewable energy	CO <sub>2</sub> /[g/kWh <sup>-1</sup> ]	SO <sub>2</sub> [g/kW-h]	NO <sub>x</sub> [g/kW-h]
Energy crops (2009)	17-27	0.07-0.16	1.1-2.5
Coal (optimal)	955	11.8	4.3
Oil (best)	818	14.2	4.0
Natural gas (optimal)	430	-	0.5

As far as ethanol petrol is concerned, due to the addition of fuel ethanol, the oxygen content of ethanol petrol is increased, and the combustion of carbon monoxide and hydrocarbons as exhaust gases is more complete, resulting in a decrease in the two indicators in the exhaust gases of automobiles, and a significant reduction in the emission of pollutants. Moreover, corn and wheat, which are renewable resources for fuel ethanol production, absorb large amounts of carbon dioxide during their growth. The residual straw can also be used to develop bioenergy. For every 10,000 tonnes of straw used to replace coal, 14,000 tonnes of carbon dioxide emissions, 40 tonnes of sulfur dioxide emissions and 100 tonnes of soot emissions will be reduced. The digestion and utilization of agricultural residues have become an urgent need to improve the environment. Straw gasification technology will contribute to the protection of the rural ecological environment together with field return, feed application, and other technologies.

##### 3.1.3. Reduction of solid waste pollution and improvement of environmental quality

Mining and industrial solid waste not only destroy arable land but also seriously damage the ecological environment of rural settlements. China's current rubbish utilization rate is very low, specifically for industrial, and domestic waste. In addition to very little power generation, pyrolysis use, most of the landfill and landfill methods, the city appeared in the phenomenon of rubbish surrounded by the city, the development and use of biomass resources can be effectively used in the rubbish in the organic components, reduce the land occupation caused by the rubbish piles and the occurrence of other pollution, such as burning straw not only causes serious waste of resources, but also cause traffic and traffic congestion, and the development of biomass resources. For example, burning straws not only causes a serious waste of resources but also causes traffic congestion, aircraft landing, and take-off delays in malicious accidents. The development and use of biomass energy to collect crop residues through gasification to provide farmers with gas, electricity, or power generation online, the rational use of energy, can greatly improve the quality of the regional environment.

### **3.1.4. Benefits of biomass economy**

The development of a biomass economy can eradicate organic pollution crop residues, animal manure, forest waste, organic waste, and other agricultural and forestry waste and environmental pollutants as raw materials so that it is harmless and resourceful, the light energy stored in plants and biomass resources in-depth development and recycling [8].

## **3.2. Social Benefits**

### **3.2.1. Social benefits of bioenergy**

The development of bio-energy can not only reduce the emission of harmful substances and greenhouse gases, increase the greening area of the country, but also make effective use of agricultural rubbish and solid waste, etc. It also has far-reaching social significance on energy security, agricultural structure adjustment, farmers' income, and increasing employment opportunities.

### **3.2.2. Relieving energy pressure and enhancing national oil security**

With continuous economic development and population growth, the world's energy consumption and demand for rising, in terms of the world's coal, oil, and natural gas reserves, coal can only be used for 230 years, oil can only be used for 44 years, natural gas can only be used for 62 years, the problem of oil security is becoming more and more significant. As China's oil reserves are very limited, the large amount of imported oil is a threat to China's energy security. Bio-energy, led by ethanol petrol, and biodiesel, is renewable and can be produced on a large-scale using China's diversified and prolific plant distribution, and is expected to become the pillar of China's long-term energy consumption in the future.

### **3.2.3. Improvement of living conditions**

The development and utilization of biomass energy is mainly concentrated in rural areas, in addition to the cost of raw material supply and other reasons, mainly due to the existing energy structure in rural areas is unreasonable. In the vast rural areas of northern China, firewood, straw, and coal is still the main source of living energy, and direct combustion conversion efficiency is low, with the continuous improvement of living conditions, rural electricity, gas, and other energy use has increased, the development and use of biomass energy for the rural areas to provide a cleaner life, in the construction of energy to solve the energy problems in the development of rural small towns and cities, and to lay the energy foundation for the construction of new small towns and cities [7].

## **4. Bioenergy Utilisation**

### **4.1. Conversion of Biomass to Liquid Fuels**

Energy plant oils are a class of oily substances stored in plant organs that can be directly or indirectly processed into fuel oils (hydrocarbons and alcohol compounds), which are formed through a series of physiological and biochemical processes in plant organisms and exist in energy oilseed plants in a certain structural form. Modern research on energy oilseed plants began in the 1960s and developed in the 1970s. Since the 1980s, including plant fuel oil, biomass energy research has developed rapidly. Many plants can be used to produce fuel oil, such as the green jade tree, trillium, and sequestrum, which contain large amounts of petroleum-like hydrocarbons. The bitter dubbing tree in Brazil, the sap can be used as diesel fuel with only simple processing; there is a kind of nuclear tree in Australia, with an oil content of up to 4.2 percent; the trees in Southeast Asia, the secretion of the milk in the hydrocarbon content is also very high; there is a kind of rubber tree in Brazil, the bark of which can be cut open to get the chemical composition extremely similar to that of petroleum, and it can be used as a direct substitute for diesel fuel. In addition to trees, but also found that many weeds also contain "fuel oil", such as the United States of America, California, the growth of yellow sagebrush is rich in hydrocarbons, each hectare of wild yellow sagebrush can be extracted 1 tonne of "fuel oil" [9].

## 4.2. Bio-oil Applications

### 4.2.1. Utilisation of bio-oils in transport sector

Alcohol or mixtures of alcohol and petrol are used as a vapor. After the oil crisis in the 1970s, many countries began the development of fuel alcohol and profit. At present, Brazilian cars generally use a mixture of alcohol and gasoline or 100% fuel alcohol, the country to cane sugar and molasses (sugar industry by-products) as raw materials to produce about 12.5 billion liters of alcohol per year; the United States in 2000 to produce 5 billion liters of corn alcohol, and its transport sector consumes the equivalent of 1% of the gasoline consumption of alcohol per year. China has also developed the application of fuel alcohol in recent years and has established three pilot plants in Jilin, Heilongjiang, and Henan to produce fuel alcohol from aged grains, which is then blended with gasoline to form a fuel mixture (gasohol) for automotive use [9].

In addition, biodiesel can be produced from vegetable fats and oils by the methyl esterification process. Biodiesel produced by this method is very similar to natural diesel in terms of technical indicators. It can be used in diesel-driven vehicles and engines at any time without any modification. Its combustion indexes are similar to those of ordinary diesel, and it meets the European No. 2 emission standard. It is a kind of green fuel with a low greenhouse effect, which is good for environmental protection [9].

### 4.2.2. Bio-oil applications in industry

So far, more than 300 compounds have been found in bio-oil, mainly pyrolytic derivatives of lignin, cellulose, and hemicellulose, enriched mainly in acetic acid, acetone, levoglucosan, hydroxyacetaldehyde and hydroxyacetone. Research is now underway to recover and utilize these chemicals. Pyrolysates of lignin are also known as natural resins, with phenol-formaldehyde resins and urea-formaldehyde resins accounting for 60 percent of natural resins. Refining natural resins has revealed that bio-based synthetic resins have similar properties to today's commercial resins. Bio-oil contains glucuronide, glyceraldehyde, dihydroxyacetone, acetone, and butanedione, so bio-oil can be used as a raw material for the production of edible condiments and flavors, and also for the production of biodegradable anti-icing agents, such as calcium acetate or manganese acetate, of which the production of edible condiments has the best market prospects. A new study now shows that bio-oil reacts with nitrogen-containing raw materials, including ammonia, urea, and protein materials to produce fertilizers with a slow-release function. This kind of fertilizer has a complexation effect on the carbon in the soil, which can significantly reduce the emission of greenhouse gas CO<sub>2</sub> into the atmosphere, in addition, it can also reduce the nitrogen loss problem caused by the use of animal fertilizer. Recently, many countries in Europe have been trying to develop the application of bio-oil, and with the increase in the price of crude bio-oil, the reports on the commercial application of bio-oil have been increasing. In conclusion, there is great potential for the development of chemicals using bio-oil [10].

## 4.3. Biogas Use

Biogas power generation is with the continuous development of comprehensive utilization of biogas technology and the emergence of a biogas utilization technology, which uses industry, agriculture, or urban life in a large number of organic waste generated by anaerobic fermentation of biogas, drive generator sets to generate electricity and take full advantage of the generator set of residual heat so that the integrated thermal efficiency of 75% or so, to achieve the purpose of environmental protection and energy saving. The purpose is to achieve environmental protection and energy saving.

## **5. Challenges and Solution Strategies for Bioenergy Development**

### **5.1. Raw Material Supply Problems and Solution Strategies**

#### **5.1.1. Supply of raw material resources cannot be guaranteed**

At present, the production of alcoholic diesel fuel in China relies to a large extent on food. As the world's most populous country, China has a relative shortage of arable land and food resources, and unrestricted development of bioenergy could lead to a food crisis. The development of non-food-producing alcohols has been difficult, and the scale of production has been small, making it difficult to reach commercialization. Aggregation of raw materials for production, such as straw, is also one of the problems that need to be solved. If alcohol is produced using a combination of food and non-food methods, the production of non-food alcohol requires a large amount of cassava, while China's demand for cassava comes from countries such as Vietnam and Thailand, with Thailand alone accounting for 80 percent of China's imports, and Thailand's restrictive export policy has led to a constant rise in its price, which has increased the cost of production significantly. At the same time, considering the cost of transport, labor costs, etc., many enterprises find it difficult to afford the production costs, so bioenergy has no advantage in the energy competition [11].

#### **5.1.2. Development of bioenergy may pose threat to China's food security**

With the rapid development of bioenergy in the world, especially the introduction and implementation of the policy of large-scale development of biomass energy in the United States, we should re-examine the basic situation of China, which has a population of 1.6 billion people and limited arable land resources, and the maintenance of national food security is a top priority. The use of a large number of food crops as raw materials for bioenergy has had a certain impact on China's food security. A large amount of land has been used to grow energy crops for bioenergy production, resulting in a shortage of supply of some agricultural products, increasing prices, and placing a burden on low-income people. Maize and sugar have increased in price in some regions for this reason. The development of bioenergy has also led to an intensification of bioenergy manufacturing in the population's food consumption and livestock feed consumption. At the same time, the extensive use of feed maize for bioenergy development has led to an increase in the cost of farming, represented by the pig industry, which has a high demand for maize feed, and a rapid contraction of the pig industry. Insufficient supply of pork and rapid increase in pork prices have affected the security of the country's main animal food and caused inconvenience to the lives of the population [12].

#### **5.1.3. Strategies for solving raw material supply problems**

Future biofuels must take non-food agricultural and forestry resources as their main raw materials, such as sorghum, cassava, and sweet potatoes, especially sweet sorghum, which is suitable for cultivation in saline and alkaline land, barren land and other poor-quality land, and in arid climatic areas. Properly handle the relationship between the development of food crops and energy crops, adjust the various national subsidies for agricultural cultivation, and incorporate industrial by-products and organic waste such as urban rubbish into the development of biofuel feedstock supply, so as not to compete with food for land, and to promote a "win-win" situation for both energy and food.

### **5.2. Technical and Facility Problems and Solution Strategies**

At present, the biggest bottleneck restricting the development of biomass energy in China lies in the low technical efficiency of biomass conversion the lack of independent intellectual property rights, and insufficient innovation capacity. China and developed countries compared with the gap in bioenergy technology are mainly reflected in three aspects, The first is China's biomass energy use is very small scale, to reduce investment, most of the projects use simple processes and rudimentary equipment. Equipment utilization efficiency and conversion efficiency are low. Secondly, some important core technologies still have not made breakthrough progress. Finally, the investment in

scientific research is too small. The low investment makes the technical content of the research too low, mostly low-level repetitive research, and ultimately fails to solve some key technologies [12].

Therefore, China should mobilize all forces to develop technological research on bioenergy. Firstly, there is a need to increase investment in science and technology. Establish a national bioenergy development fund, merge the national science and technology research programs and major basic research programs, increase funding, and focus on solving outstanding major problems, to achieve the optimal allocation of resources and guarantee the research and development of bioenergy technology. Secondly, strengthen international technical cooperation. Closely cooperate with foreign countries in relevant fields, especially in today's most advanced science and technology innovation fields. Finally, it is also necessary to strengthen the research of basic technology. Improve the productivity of the processing technology and the comprehensive use of bioenergy raw material processing products [12].

### **5.3. Policy and Regulatory Issues**

From the experience of foreign countries, government support is the original driving force in the early stage of bioenergy market development. Whether in developed or developing countries, the development of bioenergy cannot be separated from government support, such as a series of preferential policies on investment and financing, taxation, subsidies, market development, and so on. Although China generally encourages the development of bioenergy, advocates the use of waste, and advocates the development of new energy policies that can replace oil, there is no matching policy, and the incentive mechanism has not been fully established [12].

Therefore, China needs to establish a more perfect policy to promote the development of bioenergy, first of all, it needs to establish and improve the relevant laws and regulations to ensure the development of bioenergy. China's bioenergy economic organizations should be set up, the rights and obligations of the relevant subjects, the supervision and management system model, financial and fiscal support measures, the manifestations of illegal acts and their legal responsibility, to effectively promote the development of China's bioenergy to lay a good legal foundation. Secondly, improve the biotechnology patent system. China should actively adjust and improve the legal system in this regard and insist on using an effective patent system to promote the rapid development of biotechnology. At present, the development of bioenergy in China is in its infancy and may not be able to bring good economic benefits to all links in its industrial chain. Therefore, China should establish appropriate financial incentives to make bioenergy a farmer and enterprise behavior supported by government-promoted policies to promote its better development [12].

## **6. International Case Studies**

### **6.1. U.S. Bioenergy Development Experience**

In 1999, the United States issued a Presidential Decree on the Development and Advancement of Biobased Products and Bioenergy, which set a development goal of replacing 30 percent of current petroleum consumption with biomass fuels by 2030. 2005, the United States Department of Energy submitted a report showing that: Biomass providing 100 million tonnes of standard coal energy in 2003, or 3 percent of total United States energy consumption, surpassing hydropower as the largest source of renewable energy.

To achieve these goals, the United States has increased its funding for biomass research and development every year, including a \$100 million investment by the Department of Energy (DOE) in December 2008 to support commercial research and practices for the production of advanced biofuels from biomass feedstocks. Even after the financial crisis, biomass research has become an important part of the economic recovery and reinvestment program in the U.S. In May 2009, the U.S. Department of Energy announced that \$786.5 million of the recovery program would be used to accelerate research and development of advanced biofuels, as well as demonstration projects for commercial-scale biorefineries, among other things [13].

## 6.2. European Experience in Bioenergy Development

The European Commission proposes to replace 5.75 percent of transport fuels with fuel ethanol and biodiesel in 2010 and to increase this proportion to 20 percent by 2020. Currently, Italy is one of the countries in Europe where biodiesel is used the most. In the financial law enacted in 2001, Italy plans to increase the biodiesel production quota from 125,000 tonnes to 300,000 tonnes in three years. The German government encourages the use of biodiesel by granting full tax exemption to biodiesel producers, making its price lower than that of ordinary diesel. In 2003, Germany enacted a regulation permitting the addition of up to 5 percent of biodiesel to petrochemical diesel from 2004 onwards without the need for labeling. Spain issued a decree on 30 December 2000 exempting all biofuels from a special tax. On 23 April 2009, the EU's biofuels policy was also finalized and its biofuels have a clear goal and direction of development. The creation of the Renewable Energy Directive (RED) and the Fuel Quality Directive (FQD), two directives related to biofuel policy, will be decisive for the future development of the biofuel industry in Europe and influence the global biofuel market [13].

## 7. Conclusion

Bioenergy, as an important component of sustainable development, has great potential for addressing global energy challenges and achieving sustainable development goals. As a clean energy source, it has a wide range of applications in power generation, transport, and the chemical industry, and thus has environmental, economic, and social benefits that cannot be ignored. Efficient use of biomass can not only save fossil energy, but also reduce the emission of pollutants, reduce the emission of harmful substances, and greenhouse gases, as well as reduce the pollution of various solid wastes, the effective use of agricultural waste, and improve the quality of the regional environment, which is of great significance to environmental protection. The development of a biomass economy can eradicate organic pollution, certain agricultural and forestry waste, and environmental pollutants as raw materials, so that the harmless and resourceful, economic development is of great significance. The development of bioenergy can also effectively use agricultural waste, solid waste, etc.; energy security, agricultural restructuring, farmers to increase income, increase employment opportunities, etc. also has far-reaching social significance. In the future, China still needs to solve the problems of raw material supply, technology and facilities, and policies and regulations to develop bioenergy. Under the current severe situation of the world energy situation, the development of bioenergy has more advantages than disadvantages. As a major energy-consuming country, China is facing increasingly serious energy security problems and should grasp the rare opportunity to accelerate the development of bioenergy in China, so that China can achieve sustainable development.

## Authors Contribution

All the authors contributed equally and their names were listed in alphabetical order.

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