Research on the Development Status of Biomass Energy Serving the Construction of Ecological Civilization: A Case Study in Henan Province, China

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The development and utilization of biomass energy based on the thermochemical conversion of crop biomass to produce hydrogen are of great significance for promoting China's ecological civilization construction, energy revolution, and low-carbon economic development. Henan province is one of the largest agricultural and pasturage provinces in China. Based on the analysis of the status and trends of Henan's biomass energy (BE) development, this paper summarizes the present status of the construction of ecological civilization (CEC) and the factors restricting its development. Challenges in developing biomass energy are analyzed systematically, and strategies and key technical directions for future biomass energy development are discussed. Finally, the paper presents countermeasures and suggestions for CEC based on the development of BE, which will vigorously promote the development and utilization of BE and the process of CEC. This research provides a reference for the further development of BE and CEC in the future.

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INTRODUCTION

Ecological civilization is a Chinese concept also known as eco-civilization (Zhang *et al.* 2018). It refers to cultural and ethical reform with the basic purpose of harmonious symbiosis, virtuous circles, all-around development, and sustainable prosperity between humans and nature (Zeng and Wu 2013; Yao and Xie 2016). The goal underlying the construction of ecological civilization (CEC) is to raise this form to the height of green development (Magdoff 2011; Wei *et al*. 2011), and for future generations to "enjoy the cool" and "plant trees" (Liu 2008; Lu *et al*. 2015), just as "prosperity of ecology leads to the prosperity of civilization, and the decline of ecological leads to the decline of civilization" (Qi *et al*. 2016). Therefore, the CEC has become a key strategy for addressing China's resource and environmental issues, which is important to achieve sustainable development

(International Paper Board Industry group 2014). As an important part of renewable energy, biomass energy is considered to be an important way to achieve carbon emission reduction (Kaygusuz 2002). China has a vast territory, rich in product resources, and has a rich supply of raw materials for biomass energy (Tian *et al*. 2021). According to statistics (Ma *et al*. 2019; Shi 2017), the number of straw resources that may be sourced in China is 1.45×10^8 t, which is equivalent to 7.25×10^7 tce (conversion coefficient is 0.5 kgce/kg). The annual output of available forestry tending and the wood cutting residue is about 1.95×10^8 t, equivalent to 9.75×10^7 tce (conversion coefficient is 0.5 kgce/kg). The annual treatment capacity of municipal solid waste is 1.21×10^8 t, which is equivalent to 1.21×10^8 tce (the conversion coefficient is 0.2714 kgce/kg). Coupled with livestock manure and industrial wastewater, the total amount of biomass resources in China is about 3.26×10^8 tce. If these biomass resources can be maximized for development and utilization, it will effectively solve the current problems such as resource shortage and environmental pollution. At present, the utilization technology of biomass energy has gradually matured, which is mainly divided into four categories (Yang *et al*. 2019): biomass combustion technology, bioconversion technology, physical and chemical conversion technology, and thermochemical conversion technology (Fig. 1).

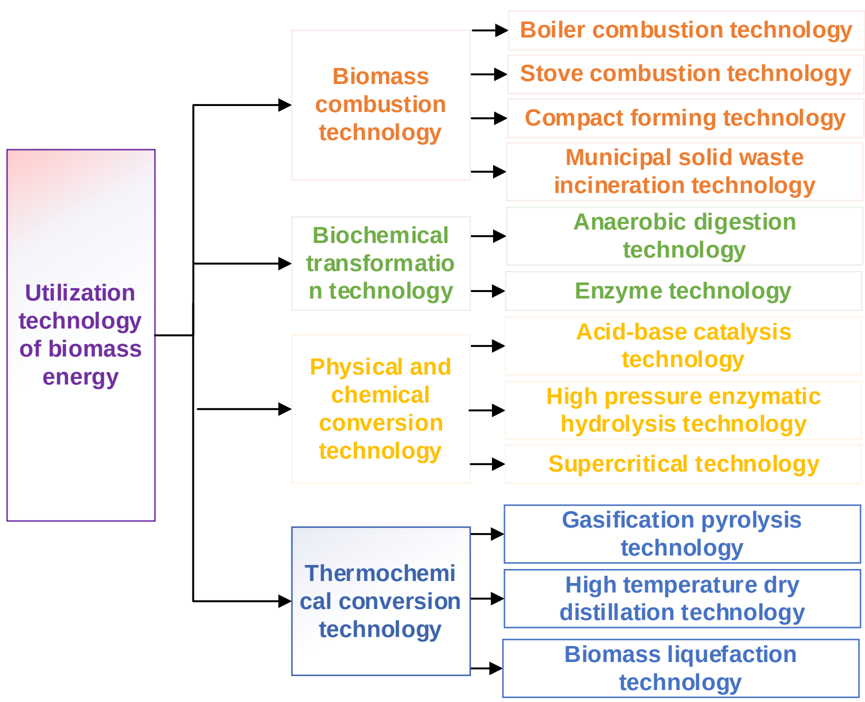

Fig. 1. The classification of biomass energy utilization technologies

However, the diversified development and utilization of biomass energy are realized through biomass thermochemical conversion technology. including agricultural and forestry biomass heat-electricity co-production, waste incineration power generation, biomass molding fuel, biological natural gas, biological liquid fuel, biological hydrogen production, biomass carbon-based materials, and other forms of utilization. Take the highly efficient, clean, and widely used pyrolysis/gasification technology as an example, it is the process of transforming biomass into solids, liquids, and gases by increasing temperature under the condition of isolating air or a small amount of air. But biomass tar is produced in this process, and the condensation accumulation of biomass tar at low temperatures will block pipelines and cause energy loss (Zainal 2011). Therefore, how to improve the conversion and utilization efficiency of biomass, especially the yield and quality of gases such as H_2 and CH_4 produced during pyrolysis/gasification, and how to remove biomass tar have become hot issues in the field of biomass energy.

Henan is one of the main agricultural provinces and food-producing regions in China, where agricultural residue is available in large quantities. With the construction goal of a "prosperous Henan province, beautiful Henan Province, safety Henan Province, and civilized Henan" (Gao 1999; Eryao 2014), the Henan Province has put forward a series of policies to promote the CEC since the 12th five-year Plan period (Ranganathan and Kumar 2014; Xie 2015; Chun 2015), and the construction of beautiful Henan Province is completely in line with the major deployment of the CEC (Yu *et al*. 2014; Wen *et al*. 2015).

Kennedy *et al*. (2016) pointed out that China's situation, as an ecological civilization country, is based on the infrastructure policy and path study of China's 2050 high proportion of renewable energy development. Yao *et al*. (2010) studied aquatic and soil environmental problems associated with the construction of an agricultural ecological civilization in Henan Province and suggested that such problems are key issues impeding sustainable agricultural development. Wang *et al. (2*015) noted that Henan Province faces severe internal environmental problems and a complex external environment, with limited policy support. Therefore, the CEC must be realized through scientific assessment of the carrying capacity and resources provided by the environment, vigorous promotion of ecological culture, and the CEC performance evaluation index system. Based on the current index system of the CEC in China, a framework CEC index system was released that characterized the economic development and environmental resources of Henan Province (Wu *et al*. 2015; Bangshan 2016). Li *et al*. (2018) considered the development of BE in Henan Province from the perspective of CEC and proposed countermeasures and suggestions. Li *et al*. (2019) analyzed the temporal dynamics and correlates of the ecological civilization level of Henan Province from 2005 to 2015, and showed that the overall level of ecological civilization was gradually improving. However, Henan Province is in the stage of accelerated development of urbanization and industrialization. It is facing the double task of rapid development and environmental protection, the situation of energy structure in which coal is the main source of energy and a large number of pollutants, which are discharged directly, has not been changed fundamentally. Problems such as low utilization efficiency of renewable energy, a large number of waste emissions, serious environmental pollution, and so on are still prominent (Zuo 2015). At the same time, this development path of high carbon and high pollution also violates the basic goal and concept of the CEC (Ma 2013; Jia *et al*. 2014). Thus, a low-carbon economy is a basic economic condition required for the CEC (Liu and Feng 2011), and its core lies in the saving of energy, the reduction of pollutant emissions, and the innovation of industrial structure (Chen and Wang 2011).

Strategically, traditional energy sources must be replaced by gradually increasing the proportion of alternative energy sources. As a large agricultural province, Henan Province, as one of the largest agricultural provinces in China, is the core area of China's national grain yield, which accounts for 1/10 of China's total, and its wheat yield exceeds 1/4 at present. Agriculture, especially grain yield, plays an important role in China. Agricultural residues can be converted to biofuels, which include liquid fuels, briquettes, and gaseous fuels (Wang *et al.* 2019). However, open burning of agricultural residues has resulted in huge CO_2 emissions and large of CO, $PM_{2.5}$, and black carbon releases in China, especially for three major crops (rice, wheat, corn) (Zhang *et al*. 2015; Sun *et al*. 2016). Therefore, China's low-carbon economic development and the CEC should follow a path based on BE, with Henan Province playing a critical role (Zhang 2017).

Based on the problems described above and the regional characteristics of Henan Province, this paper explores the present situation, existing problems of the CEC and terrestrial environments, and various factors influencing the CEC. The relationship between BE development and CEC is discussed from a dialectical perspective, and a development plan is proposed using low-carbon BE as the major component of CEC, making full use of the development of BE innovation technologies to support the CEC. This plan provides a new path for green low-carbon development.

Current Status and Existing Problems of Ecological Civilization

Henan Province is an important region supporting energy production in China. In 2018, Henan Province produced 108 million tons of raw coal, 1.96 million tons of crude oil, and 200 million m^3 of natural gas. The total installed capacity for electric power has reached 86.8 million kW, while biomass power generation has reached 19.2 million kW, accounting for 22.2% of total installed power capacity, which is important for the continued development and utilization of biomass energy (Zhou *et al*. 2015). Henan Province is an important transportation hub and a center for the flow of people, products, and information. In the process of China’s CEC, Henan Province has the advantage of abundant resources and is in a superior geographical position in the economic and social development of China. It is the key area for the construction and development of ecological civilization. Henan Province is the only province in China that spans the four major basins of the Yangtze, Huaihe, Yellow, and Haihe rivers, so its topography and distribution of water resources are a microcosm of China. The pollution situation of water resources from 2007 to 2018 was reported in the ecological and environmental status bulletin of Henan Province in 2018. In recent years, these basins have maintained a large proportion of class III water resources. Industrial sewage, domestic sewage, and non-point-source pollution from farmland have caused the deterioration of the quality of surface water resources.

According to the GB 3095-2012 (Ke 2012), the factors that influence the quality of urban air environments are particulate matter ($PM_{2.5}$), respirable particulate matter (PM_{10}), sulfur dioxide (SO_2), nitrogen dioxide (NO_2), carbon monoxide (CO), and ozone (O_3). The concentrations of various factors of different cities are shown in Fig. 2. The annual average concentrations of $PM_{2.5}$ and PM_{10} in 18 cities exceed the second-level standard, and the city has the highest annual average concentration is Anyang. The annual mean concentration of SO_2 in Anyang and Jiyuan reach the second-level standard, and the annual mean concentration of SO_2 in other cities reached the first-level standard. The annual mean concentration of NO_2 is above the second-level standard, and the concentration of O_3 and the 95th percentile of CO reached the second-level standard. Throughout the province, the ambient air quality level of Jiaozuo and Anyang is medium pollution; the ambient air quality level of other cities is light pollution. Therefore, the primary pollutant of Henan Province is $PM_{2.5}$, and the atmospheric quality requires improvement. In addition, with the continuous development of economy, and the improvement of people's life quality, the quality of the ecological environment has become the focus of people's attention (An 2016).

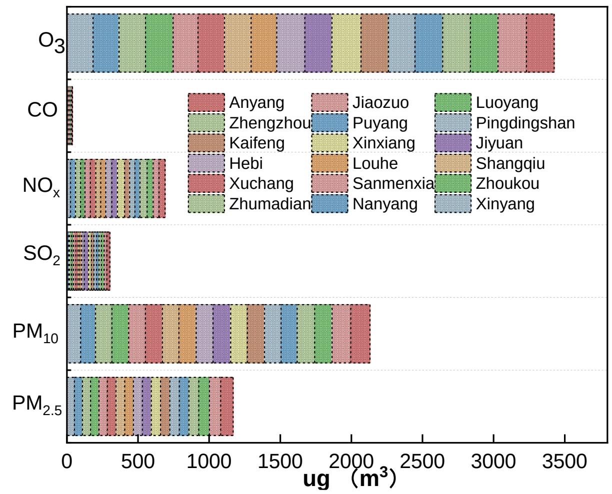

Fig. 2. Urban ambient air quality in various regions of Henan Province in 2018

Backward development of renewable energy

Coal is the most important primary energy in China and the largest source of greenhouse gas and air pollutant emissions (Chang *et al*. 2016). The energy supply is mainly coal in Henan Province, and the proportion of oil, natural gas, and hydropower is small. According to Fig. 3, the total amount of energy production in Henan Province has increased year by year from 1978 to 2013. When the total energy production reached the maximum of 174.4 million tons of standard coal, the total amount of energy production began to decline gradually from 2013 to 2017, and the total amount of energy production was 100.9 million tons of standard coal by 2017. Coal accounts for the largest proportion of total energy production, while the production of natural gas accounts for only 0.38%. Especially, renewable energy accounted for 6.6% of the total, and the consumption of BE only accounted for 1.9% of the consumption of total primary energy and 7.6% of the consumption of renewable energy. The level of development and utilization of biomass energy is extremely backward, and the production of a large amount of coal and crude oil deteriorates the environmental quality. It is urgent to develop the utilization of biomass energy and increase its proportion in the structure of renewable energy is the key to solving environmental problems.

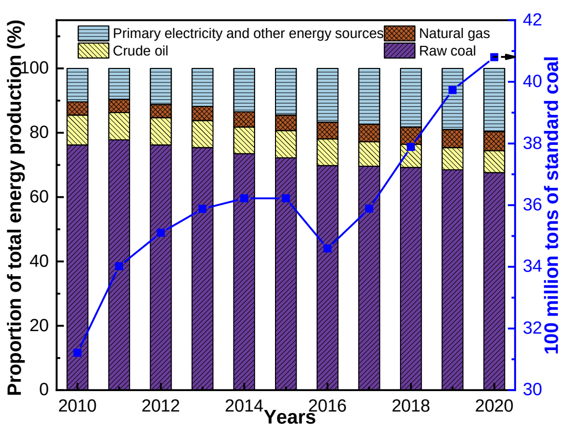

Fig. 4. Proportion of total energy consumption

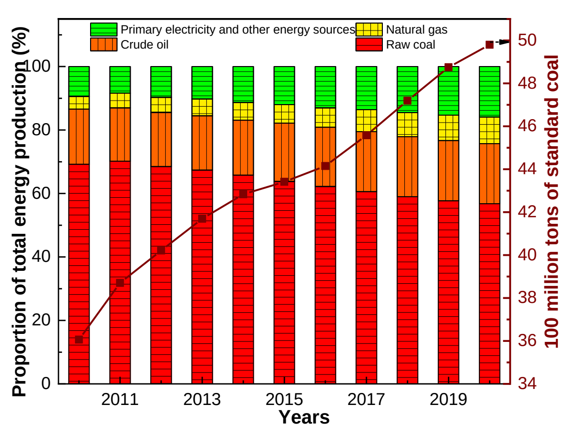

Fig. 3. Proportions of total energy consumption

The energy consumption in Henan Province is shown in Fig. 4. As shown, the total energy consumption has gradually increased, and the structure of energy consumption is dominated by coal, which was over 80% before 2012 and showed a slight decrease in the period 2013 to 2017, mainly due to a shortage of energy resources. In 2017, the consumption of coal, oil, natural gas, and hydropower accounted for 73.3%, 14.1%, 5.9%, and 5.8% of the total energy, respectively, illustrates the irrationality of the energy structure. Coal combustion generates a large amount of pollution. Therefore, it is important to optimize energy structures by utilizing renewable energy represented by BE.

High pollution discharge and serious environmental pollution

The pollution of water resources, the discharges and treatment of wastewater, exhaust gas, and solid waste in different years are shown in Fig. 5. In 2017, the discharge of wastewater was 4.1 billion tons, the discharge of COD was 4.3 million tons for the whole province, the discharge of COD in municipal domestic sewage was 3.9 million tons, and the emission levels of major pollutants based on all indicators decreased, compared with 2015 was not obvious. The pollution problems of surface water and groundwater, and the safety of drinking water safety are becoming increasingly serious.

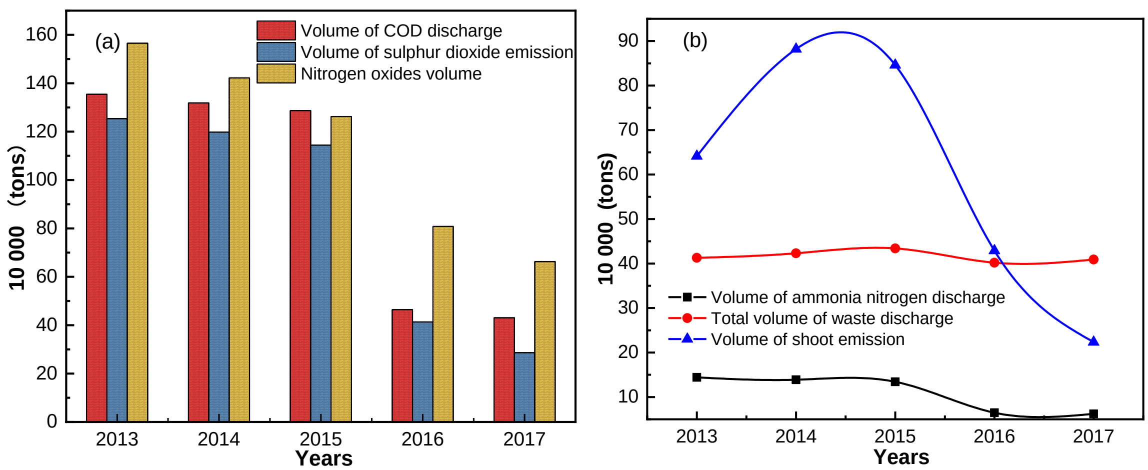

Fig. 5. Production and utilization of wastewater, toxic Emissions, and industrial solid wastes

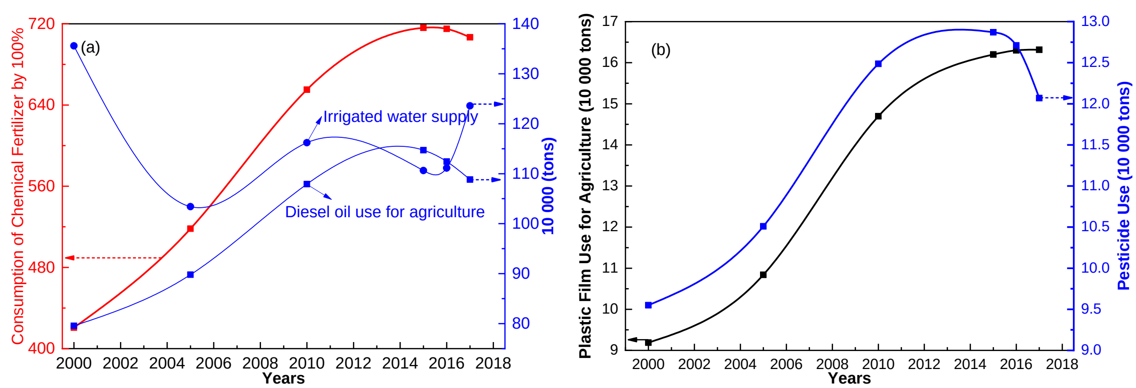

Fig. 6. Agricultural energy resources and the consumption of major materials for (a) consumption of chemical fertilizer by 100%, irrigated water supply, diesel oil used for agriculture, and (b) pesticide use, plastic film use for agriculture

As shown in Fig. 6, in 2015, the maximum level of agricultural chemical fertilizer application was 71.6 million tons, and the pesticide application was 1.29 million tons. In 2016, the use maximum amount of agricultural plastic film and agricultural diesel oil was 1.63 and 1.1 million tons. While the use of fertilizers and pesticides can increase grain production, most of them remain in the air, soil, and rivers. Thus, the consumption of energy resources and pollutant emissions continue to increase, and the carrying capacity of the ecosystem faces severe challenges.

Analysis of Causes of the Problem

Guided by the 13th 5-Year Plan of Energy Development, the consumption of non-fossil energy in China will increase to more than 15% by 2020, the consumption of natural gas should reach 10%, and the proportion of coal consumption should be reduced to less than 58% (Ren 2016). Henan Province has changed from a major coal export province to a net coal transfer province, facing a serious gradual depletion of resources and a preliminary crisis of reserve resources. At the same time, it is a province with large agriculture and population, lacks wind energy resources, and cannot have land to develop solar energy resources to ensure food production. Therefore, in the process of CEC, the development of BE will be an inevitable trend.

Low utilization of biomass resources

The total output of grain for Henan Province in 2017 reached 65.3 million tons, the total output of cotton reached 4.4 million tons, and the total output of oil plants reached 5.9 million tons. These crops can produce up to 100 million tons of straw; if the straw which was used as feed is taken out, the remaining straw will reach 50 million tons, which can be used as energy, and the output of forestry waste is more than 10 million tons. Thus, the total amount of rural energy production reaches more than 80 million tons of standard coal equivalent (He 2014). The resource advantages of rural energy remain underdeveloped.

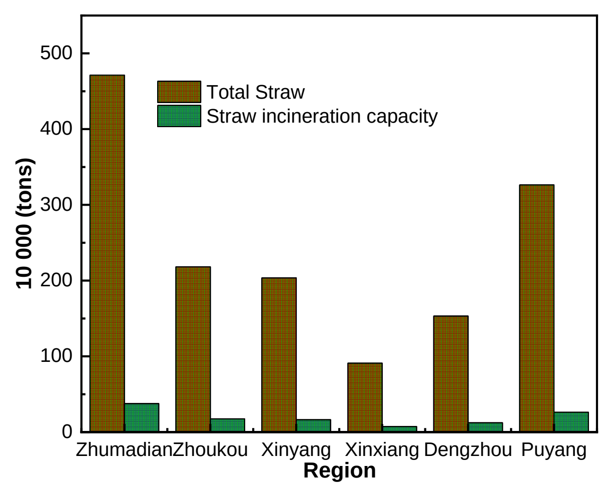

Fig. 7. Total amount of straw burned in some cities

One of the outstanding characteristics of utilization of biomass resources is to adjust measures to local conditions and to carry out efficient development according to the distribution of local renewable resources (Xu *et al*. 2013). Biomass straw, which constitutes a resource of low energy density and wide dispersion, is not suitable for collection and storage, which increases the collection cost (Wang 2016). With the rapid economic development, the widespread use of commercial energy leads to the direct combustion of a large number of biomasses; which not only causes the loss of a potential energy resource but also seriously pollutes the rural environment. The cities with serious straw burning in Henan Province are shown in Fig. 7. The phenomenon of biomass straw burning is very serious. Therefore, it is urgent to develop and make rational use of agricultural and forestry wastes, which is an important way to solve the ecological environment.

Limited development and utilization of BE

The effective forms of BE utilization mainly include biomass direct combustion power generation, biomass pyrolysis/gasification, and biogas. The unstable supply of biomass straw increases the operating burden of power generation enterprises, which makes most biomass power generation enterprises unreliable. Biomass biogas technology is a complex microbiological process, the goal of which is to obtain clean combustible gas by anaerobic fermentation (Achinas *et al*. 2017). Due to the limitations of many conditions, projections for the development of biogas technology are not optimistic. Figure 8 shows that the establishment of household biogas digesters and biogas projects is not obvious, and the number of domestic sewage purification biogas digesters is decreasing. Biomass pyrolysis/gasification technology can transform biomass into solid (biochar), liquid (bio-oil), and main gas (H_2, CH_4), effectively realizing the resource utilization of biomass energy (Hu *et al*. 2017; Milne *et al*. 1998). However, tar is a challenge in the application of the technology. Tar produced during pyrolysis and gasification will block pipes after condensation, resulting in equipment damage, energy loss, and environmental problems (Dayton 2002; Park *et al*. 2018).

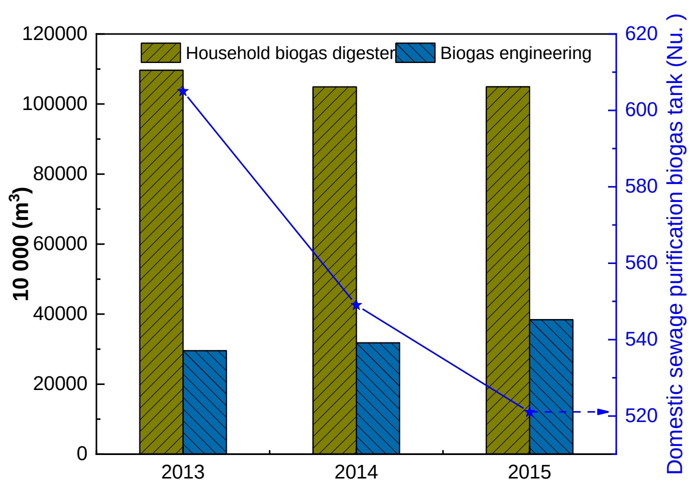

Fig. 8. Status of biogas digesters in recent years

Analysis of the Present Situation of BE Development

Henan Province is extremely rich in biomass resources. It is of great significance that abandoned biomass resources can be in full use for effectively alleviating the shortage of energy resources and protecting the ecological environment. This will be conducive to the CEC. Therefore, the analysis of the present situation of BE development is of great significance to exploring a new way for the CEC. Therefore, according to the Statistical Yearbook of Henan Province, the output of agricultural and forestry products in Henan Province from 2010 to 2017 are shown in Figs. 9 and 10. Biomass resource potential can be expressed through the index of biomass resource reserves (Wang *et al*. 2015). The ratio of grass to grain is the key to estimating the reserves of biomass resources. Because the growth conditions and technical conditions are different in different years, the ratio of grain to grass is constantly changing. Therefore, by referring to the ratio of grain to grass in Henan Province (Table 1) and the conversion coefficient of domestic forestry residues (Table 2), the reserves of biomass resources from 2010 to 2016 in Henan Province were estimated (Fig. 11). The reserves of biomass resource were 171.6 million tons in 2016.

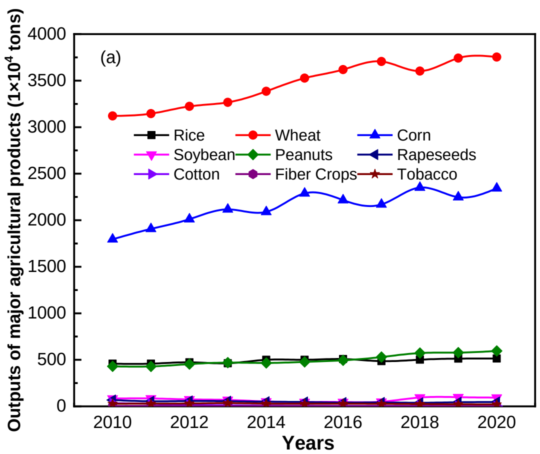

Fig. 9. Outputs of major agricultural products

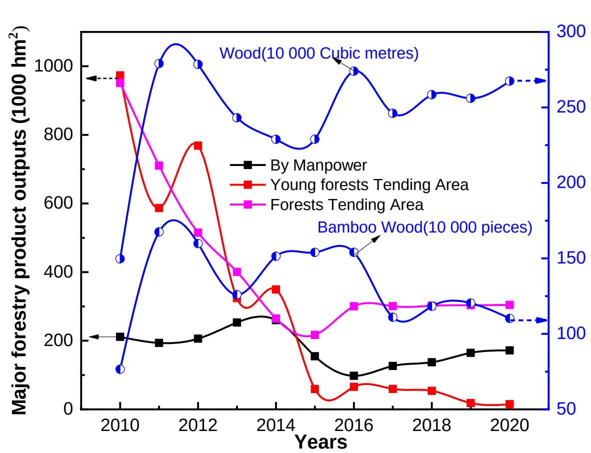

Fig. 10. Major forestry product outputs

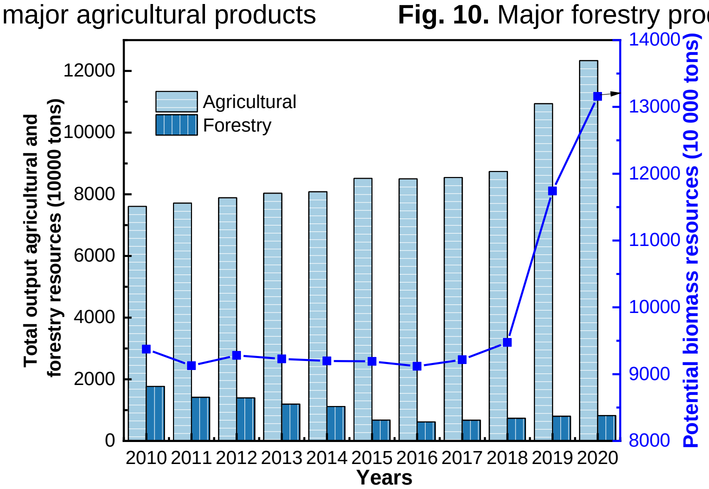

Fig. 11. Potential biomass energy resources (10,000 tons)

Table 1. Grain-to-Grass Ratios of Major Crops

Crops	Ratio of Grain to Straw	Crops	Ratio of Grain to Straw
Rice	1.2	Peanuts	0.8
Wheat	1.1	Rapeseeds	1.5
Corn	1.7	Sesame	2.2
Others	1.6	Cotton	9.2
Soybean	1.6	Fiber Crops	1.7
Mung Bean	2	Tobacco	1.6

Table 2. Conversion Coefficients of Forestry Residues

Forestry Work	New Forest	Area of Seedling Management	Forests Management Area	Wood	Bamboo
Conversion Coefficient	2.5 t/hm^2	0.5 t/hm^2	0.72 t/hm^2	0.45 t/m^3	0.005 t/root

Analysis of the Present Situation of Development and Utilization of BE

The technologies for the development and utilization of BE in Henan Province include biomass briquetting fuel, liquid fuel, gas fuel, and biomass power generation.

Technology of biomass power generation

At present, the scale power generation technology of biomass in Henan Province is basically at the forefront, and the common scales of generator sets are 12, 15, and 25 MW (Zaitao *et al*. 2011). An example is shown in Fig. 12. The project utilized 35 million tons of agricultural and forestry waste such as crop straws, peanut shells, and bark from the surrounding area. The project invested 220 million, which generates more than 80 million of income for farmers, and an average annual power generation of 210 million kWh. This design involves a rural industrial chain employing 1060 people and would reduce carbon emissions by 22 million tons of CO_2. Therefore, biomass power generation promotes renewable energy and has benefits for people's livelihood.

Fig. 12. A biomass power plant in Henan Province for (a) Biomass collection, (b) Biomass power generation (outside view), and (c) Biomass power generation(inside view)

Technology of biomass liquid fuel

Henan Province is the leading producer of cellulosic ethanol in China (Fig. 13). Henan Province has filled the gap in the straw ethanol industry and created a new system of straw ethanol production in accordance with national conditions. Dong *et al*. (2008) analyzed the energy and energy budgets of a typical wheat plantation/alcohol distillery system in Henan Province, showing that bioethanol from food crops is not a sustainable source of fuel. The industrialization of cellulosic ethanol has been developed to provide a new method of producing biological liquid fuel from non-food raw materials, which is an important method for the replacement of fossil fuels.

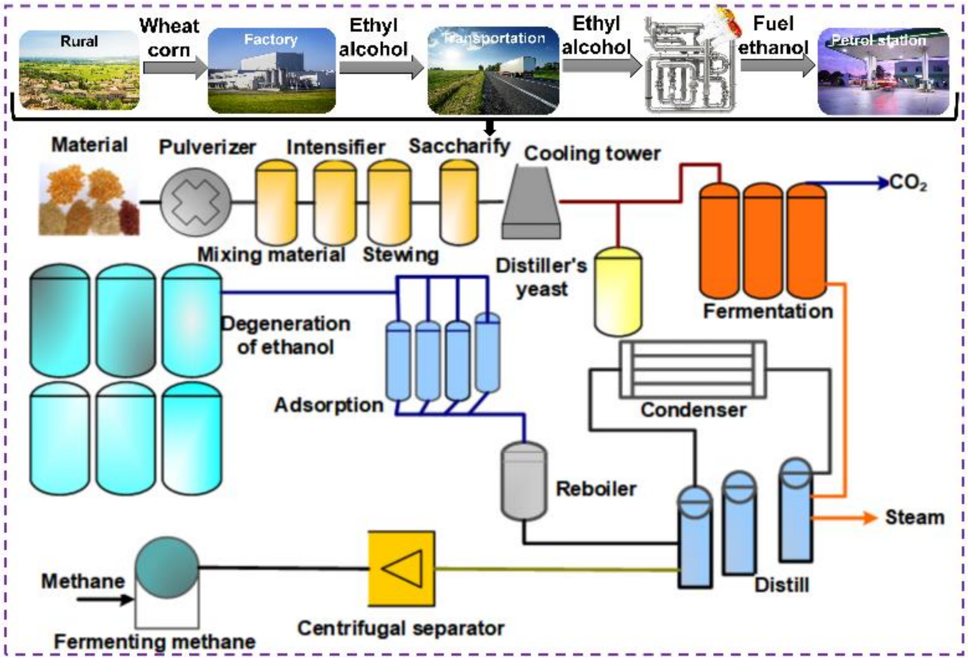

Fig. 13. Process of ethanol production from biomass fuel in Henan Tianguan Company

Technology of biomass briquetting fuel

An enterprise in Henan Province has designed four pilot briquetting fuel plants using corn stalks as the main raw material, and has reached a stable annual production base of 50,000 tons of briquetting fuel from crop straw. The production line is shown in Fig. 14. The development of this project provides a net income of more than 4 million per year and an income of more than 10 million for local farmers and provides employment for more than 300 people. This facility can replace 25,000 tons of standard coal per year, reduce greenhouse gas emissions by 55,000 tons, and sulfur dioxide emissions by 500 tons. It strongly promotes the large-scale utilization of BE and is of great significance for CEC. In summary, the development prospect of BE industrial of Henan Province has broad development prospects and obvious economic, social, and environmental benefits, which can improve the quality of the water environment, atmospheric environment, and ecological environment, promote regional development and increase farmers' income. the improvement of these aspects will be conducive to the CEC.

Fig. 14. Biomass briquette fuel production line in Henan Qiushi Company (Wang *et al*. 2017)

An Approach to the CEC Linked by BE

Dialectical relationship between the development of BE and the CEC

The relationship between the development of BE and the CEC is shown in Fig. 15. First, the inherent requirement of these, which contribute to the ecological civilization, optimize the structure of energy. Renewable energy is under vigorous development in the BE industry. Second, the quality of the natural environment is an important index of the CEC, and biomass is an important part of the environment. The exploitation and utilization of BE should be strengthened during CEC, which is conducive to increasing incomes and alleviating the pressure on employment, which provides benefits in the social, environmental, ecological, and economic sectors. Therefore, the CEC is the inevitable result of clean and efficient development and utilization of BE, and the development and utilization of BE is the only route for the CEC; at the same time, the development of BE provides the environmental foundation and cultural guarantee for CEC, and in turn, CEC is the ultimate goal of BE development.

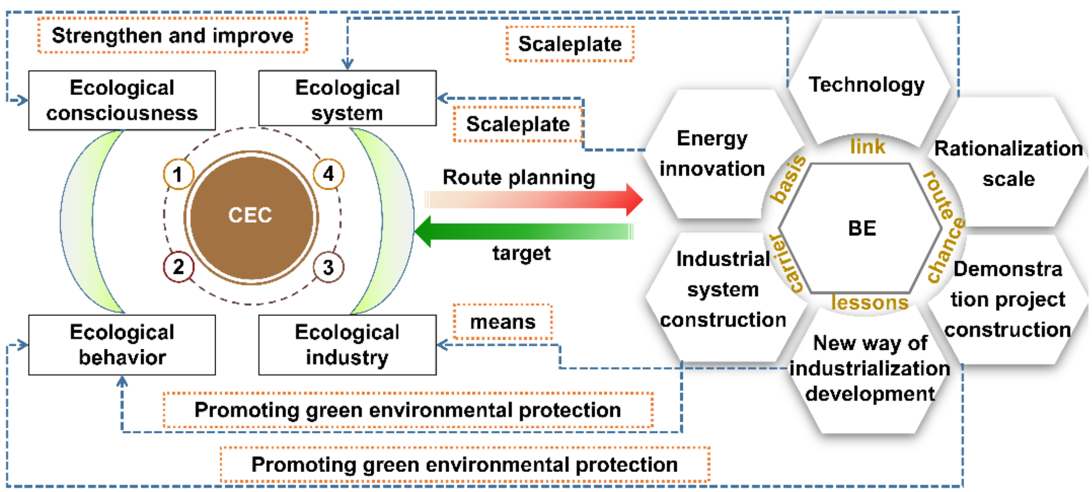

Fig. 15. Relationship between the development of biomass energy and the construction of ecological civilization

To increase the investment of BE as the driving force

Due to the low density of BE and the lack of a perfect collection-storage-transportation system of raw materials, it will consume a lot of manpower and material resources in the process of collection and transportation, which results in a high cost of collection and transportation of biomass resources (Cai and Zhao 2010). At the same time, the ups and downs of coal prices have a great impact on the operation of BE industry, but the investment should not be reduced or not because of the high cost of the development and utilization of biomass energy. Therefore, financial support should be increased by establishing special subsidies or discount loans for BE-related projects to accelerate low-carbon green development through the support and utilization of BE technologies. Thus, the capital investment that is increased for the BE industry is a powerful tool for the realization of CEC.

To take the development and utilization of BE as the core link

Science and technology are the primary productive forces. However, one should not only rely on the progress of technology to promote the clean and low-carbon development of BE industry. It is necessary also to realize the organic unity of the development of a green and low-carbon development economy. Based on the actively developed and utilized BE technology, the new technologies for clean and low-carbon BE development should be studied, so as to promote the transformation and improvement of the BE industry. This process will provide the foundation for further optimizing the energy structure.

To take the typical demonstration project of BE as an opportunity

Based on the improvement of the system of CEC, which is bolstered by the advantage of abundant biomass resources, we must identify the key links needed to develop the CEC with BE, and work hard to attain several ecological, scientific, and technological achievements. Through analyzing the economic, social, ecological, and environmental benefits of developing BE to the CEC by typical cases, quantifying the benefits of CEC based on BE, and comprehensively embodying the concept that "Clear waters and green mountains are as good as mountains of gold and silver". Vigorous promotion of the construction of green projects, which optimize the structure of ecological industries, and attention to the leading and exemplary role played by demonstration counties of CEC based on the development and use of BE are essential, and their results should be summarized using advanced models for the construction of a model of CEC in Henan Province.

To carry out international cooperation as a condition

Because a number of global environmental issues have emerged, it is necessary to establish international cooperation based on "different tasks, common responsibilities". The literature (Wang *et al*. 2019) explored the development and utilization of BE technology in Sweden and summarizes the main measures and experiences of BE development in that country. In recent years, Sweden has vigorously developed the technology and industry needed for BE utilization, and they have transitioned from the use of fossil energy sources to renewable energy sources. Thus, we should seek the support of international financial and technical and build upon the successful experiences of other countries, the purpose is to provide methods and ways to seek common ground for the development of biomass energy in China, so as to promote the rural energy revolution and the CEC.

To take the policy recommendations of the development of BE as the guarantee

The important guarantee of a low-carbon development path is policy and law, and only policy and law can protect low-carbon development (Erning 2010; Li 2013). It is necessary to strengthen legal support and issue policy recommendations related to BE to further improve the institutional management system. It is also important to accelerate the formulation and revision of laws and regulations related to green and low-carbon energy development that are conducive to CEC. Increasing the proportion of renewable energy in the structure of energy and achieving energy restructuring are also essential. Relevant policies and laws can guide and encourage outstanding scholars in China and abroad to participate in research and development of clean technologies and utilization of BE.

Countermeasures and Suggestions on the CEC Based on the Development of BE

Three groups of countermeasures are outlined in this section relative to challenges that fact the development of the CEC based on BE utilization.

Strengthening research and development of BE technology

1) The first class of countermeasures involves research and development. The idea is to build a batch of research and development platforms with BE as the main body to promote the comprehensive utilization of biomass resources, and vigorously promote the development of BE in the direction of energy and resource. 2) The next step is to establish a carbon-based magnetic solid acid catalyst based on biomass and direct catalytic biomass conversion to multi-functional platform compounds, integrate the research program to form a technical route, and carry out the industrial model of biomass directional conversion to multi-functional platform compounds. 3) A third phase involves research on the technology of clean heating and efficient power supply with biomass as raw material to realize efficient and clean development of biomass resources.

Make full use of the innovative technology of BE to support the CEC

1) It is necessary to persist in the implementation of BE technology innovation to promote the development of BE, which relies on scientific and technological progress to improve the quality of workers and management innovation to reduce the pressure on the ecological environment. 2) New technology should be used actively to carry out the ecological transformation of the development and utilization of BE, and realize resource saving and environmental protection through clean production. Challenges involving key technologies will need to be overcome to realize the goals of CEC. 3) It will be necessary to speed up and improve the laws and regulations for the processes related to biomass energy development and utilization as soon as possible, but the contents of laws and regulations must be consistent with the requirements of CEC.

Improve the evaluation system of the CEC index

1) Based on the policy suggestions of BE development, according to the requirements of CEC, the indicators of biomass resource consumption, environmental damage, and ecological benefit need to be fully integrated into the assessment and evaluation system of ecological civilization. 2) The transformation coefficient between the benefit brought by the development and utilization of BE and the assessment index of CEC has been designed, and the economic, ecological, and environmental benefits brought in the process of the development and utilization of BE have been transformed into ecological indicators to promote the CEC.

CONCLUSIONS

1. This paper explored the present status of ecological civilization (CEC) in Henan Province from the perspectives of the aquatic, atmospheric, and terrestrial environments. The factors that affect CEC are analyzed from the perspective of energy resources. It was noted that the development of high-carbon energy leads to an irrational energy structure and that the unbalanced energy distribution and inadequate

development and utilization of bioenergy (BE) are important obstacles to CEC.

2. Based on the characteristics of abundant potential biomass resources, this paper analyzed on the present situation of BE development. It is known that biomass resources are extremely abundant and the reserves of biomass resources are huge in Henan Province. At the same time, BE industrial of Henan Province has broad development prospects and obvious economic, social, and environmental benefits, which can promote regional development and promote the CEC. Therefore, the dialectical relationship between the development of BE and CEC was analyzed and puts forward the idea that the development of low-carbon BE is in accordance with the concept of CEC. Thus, this article has considered the development of BE as a novel and essential method to realize CEC. Promotion of the CEC can be brought about by increasing the investment of biomass energy funds, using the development and utilization of biomass energy technology as a link. Typical demonstration projects can be explored for biomass energy development and utilization. Policy suggestions for biomass energy development and utilization can be implemented in the context of international cooperation in the biomass industry. These factors are in line with the regional economic development, regional characteristics and objectives, and needs of ecological civilization construction in Henan Province. The path which will cover the target, path, and strategy of three aspects is very comprehensive. This will provide a new method and reference for the CEC of Henan Province, and will further promote the development and utilization of biomass energy.
3. Thorough in-depth analysis is needed for the problems inherent in the development and utilization of BE and needs in the CEC. The countermeasures and suggestions for the CEC based on BE development are further proposed. These efforts should give full play to the development of BE support for the CEC, to realize low carbon energy development of a new way of CEC, which will provide a new basis for the CEC.

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DECLARATION OF COMPETING INTEREST

We declare that we have no financial and personal relationships with other people or organizations that can in appropriately influence our work. And the contents of this manuscript have not been copied righted or published previously.

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