



Article

Emergy-Based Assessment and Suggestions for Sustainable Development of Regional Ecological Economy: A Case Study of Anhui Province, China

Cui Wang ^{1,2} , Yingyan Zhang ^{1,*}, Conghu Liu ^{1,3} , Fagang Hu ¹, Shuling Zhou ¹ and Juan Zhu ¹

¹ Business School, Suzhou University, Suzhou 234000, China; wangcui@ahszu.edu.cn (C.W.); lch339@126.com (C.L.); hufg@ahszu.edu.cn (F.H.); szzhoushuling@126.com (S.Z.); zhujianxuzhou@163.com (J.Z.)

² Center for International Education, Philippine Christian University, Manila 1004, Philippines

³ School of Economics and Management, Tsinghua University, Beijing 100084, China

* Correspondence: zhangyy0557@163.com

Abstract: In view of the coordination of economy, society, and environment in the process of the rapid development of the regional economy, this study proposes the evaluation method of sustainable development of a regional economy on the basis of emergy. The study also constructed an evaluation index system of sustainable development of regional ecological economy from four aspects, namely, structural, functional, and ecological efficiency, and sustainable development index. The objective was to comprehensively evaluate the quality and environmental friendliness of regional economic development. On this basis, this study measured and evaluated the sustainable development of the ecological economy in Anhui Province by using emergy to analyze the statistical data of the economic development of Anhui Province, China, from 2010 to 2018. The study also provides targeted decision-making suggestions for the sustainable and high-quality development of the Anhui economy. Furthermore, this study provides a measure and evaluation method for the sustainable development of the regional economy and effective policy recommendations, which have important theoretical and practical significance.

Keywords: emergy; sustainable development; regional ecological economy; assessment



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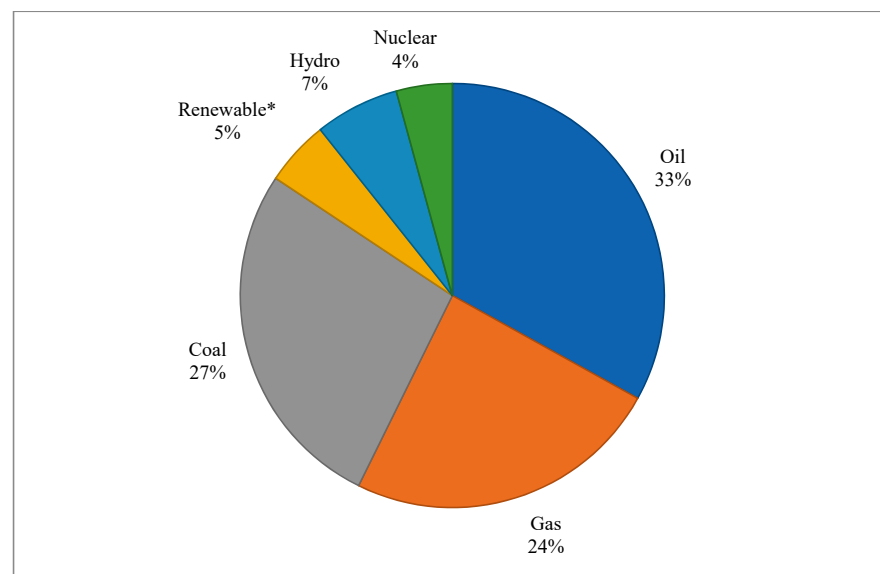
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1. Introduction

In recent years, the process of global industrialization and urbanization has been accelerating, and this rapid economic growth has brought enormous pressure to the ecological environment. On the one hand, the industrial production process increases the development and utilization intensity of natural resources. According to the BP Statistical Review of World Energy 2020, the world primary energy consumption in 2019 is 583.9 exajoules, and Figure 1 shows the main energy consumption. On the other hand, several wastes are produced, and carbon dioxide emissions are increasing [1]. According to the report of global CO₂ emissions in 2019 released by the International Energy Agency, the global CO₂ emissions in 2019 were approximately 33 billion tons. The continuous increase of carbon dioxide emissions leads to global climate change. Moreover, the melting of the polar ice sheet and the aggravation of hurricanes threaten the harmonious relationship between humans and nature, the economy, society, and the environment, thereby affecting the balance among social, economic, and environmental goals [2], which is not conducive to the sustainable development of the eco-economic system. The way in which to understand the role of various natural resources correctly and intuitively in economic development and balance the relationship between the natural environment and economic development is a hot topic in the field of ecological economics.



* Renewable power (excluding hydro) plus biofuels.

Figure 1. Fuel shares of global primary energy in 2019.

With the development of the economy, the contradiction between resources and the environment is further highlighted. Moreover, the ecological environment is deteriorating, which has a serious impact on the sustainable development of the regional economy. Scholars have studied how to coordinate the relationship among the economy, society, and the environment to achieve sustainable development of the regional economy. For instance, Jing and Wang [3] introduced the complex network method and proposed the theoretical framework of resource-based cities' sustainable development from three aspects, namely, social harmony, economic development, and environmental improvement. They also established the evaluation index system of sustainable development. On the basis of the panel data of 114 cities in China, the authors constructed a sustainable indicator by using the non-directional distance function method [4]. The ecological efficiency is evaluated by adopting the difference-in-differences method. Then, Gao and Zhang [5] used the theory of sustainable development and low-carbon cities as a guide; analyzed urban planning from multiple perspectives and levels; and strived to create a healthy, ecologically balanced environment. According to the interactive relationship between ecological livability and rural sustainable development, Li et al. [6] constructed a rural sustainable development index system with a universal value from two dimensions, namely, rural ecological sustainability and rural livable sustainability. Moreover, an organization index system of an "ecological-factor conceptual framework" is presented [7], and they also comprehensively evaluated the ecological environment of the upper Hanjiang River in Shaanxi province, China, using spatial principal component analysis. In addition, they used the matrix of principal components to quantitatively analyze the driving forces that affected the ecological environment. By synthesizing the economic, environmental, and social pillars, the authors established an evaluation framework of sustainable performance for the industrial sector of the Capital Economic Circle, using the global principal component analysis to assess the progress of industrial performance in each region from a time-series perspective [8]. Nilashi et al. [9] first attempted to employ country sustainability assessment using fuzzy clustering and supervised machine learning. Then, the environmental efficiency of Belt and Road countries and non- Belt and Road countries from 1990 to 2014 was estimated and compared by using the super-slack-based measure (SBM) model that considers undesirable outputs [10]. Moreover, other scholars used the SBM model to evaluate the sustainable development ability of some cities in China [11–13]. Zhang et al. [14] adopted the SBM model to eliminate the influence of scale factors using the three-stage

data envelopment analysis (DEA) method to calculate the sustainable development efficiency of 31 provinces and cities in China. The weighted SBM considering energy substitutability was used to evaluate the regional energy efficiency (EE) of 29 provinces in China from 1991 to 2015. The comparison and convergence analyses were carried out from different perspectives, and the sustainable evolution characteristics of EE were discussed [15]. Then, the key urban neighborhood sustainability concepts and characteristics were used to develop a comprehensive neighborhood sustainability assessment tool/model (successful neighborhood model) [16]. Allen et al. [17] presented the experience of the United Nations in conducting an indicator-based assessment for the Arab Sustainable Development Report. On the basis of a condensed system of sustainable development indicators proposed by the UN in 2001, Maksimova et al. [18] formulated relevant sustainable development index and evaluated the sustainability of social-ecological and economic development in Kashan City. Quantitative assessment was used to develop the Composite Sustainable Development Goal (SDG) Index from four dimensions (society, economy, environment, means of implementation and cooperation) to represent the comprehensive performance of achieving SDGs [19]. Furthermore, Topsis and Vikor methods attempt to study sustainable development by using a selected index out from the objectives defined by SDGs [20].

The above literature shows that sustainable development of the regional economy has qualitative and quantitative methods, where the latter are mainly principal component analysis and SBM mode. However, regardless of the kind of method, they lack a unified standard in the evaluation of economic input and output, natural resource consumption, and ecological environment loss. The reason is that economic, material, and energy flows cannot be converted into a unified standard, which does not objectively reflect the value of ecosystem services. H.T. Odum, an American ecologist, proposed the emergy theory, which converts the energy of all materials into solar energy. This theory connects the economic system with the ecological one and is an effective way to solve the difficulties of sustainable development research [21]. Emergy theory is widely used in the study of ecological efficiency and sustainable development of various ecosystems. An eco-efficiency model has been proposed on the basis of emergy synthesis and slack-based measure data envelopment analysis [22]. Moreover, the authors discussed the characteristics of emergy metabolic flow and eco-efficiency using a questionnaire survey and statistical analysis. Then, emergy analysis was used to evaluate the integrated sustainability of biogas power plants and to investigate how the emergy indicators of sustainability depend on the boundary selection [23]. The wastewater treatment system of straw pulp papermaking and that of printing, dyeing, and papermaking were selected to assess the sustainable level of sewage treatment systems in China [24]. Through an emergent analysis, the emergy analysis method was used to evaluate the sustainability of the gas fractionation unit process at Refinería Cienfuegos S.A [25]. Emergy analysis was also used in the comprehensive evaluation of the environmental sustainability of the hydropower projects [26,27]. In the field of industrial manufacturing, an emergy-based sustainability evaluation method was proposed to outsource machining resources to improve resource utilization efficiency [28]. Then, a novel method based on emergy theory was proposed to perform the comprehensive evaluation and improvement of manufacturing systems and remanufacturing machining systems [29,30]. Using emergy analysis, a sustainability evaluation method of logistics parks was conducted to improve the sustainable development ability of logistics parks [31]. Meanwhile, emergy synthesis was implemented to evaluate the environmental support to a building, called Smaragden, which is located in a certified “green” urban district in Uppsala, Sweden [32], and the environmental performance in the environmentally fragile area [33]. Emergy analysis is also widely used in the agricultural ecosystem. The potential development of sustainable biotechnological processes fed by biowaste and bioresidues is studied using emergy evaluation and life cycle assessment [34]. Emergy and economic analyses are used to evaluate the overall performance of three agricultural production types [35]. The ecological sustainability of rice production in Mazandaran Province, Iran, was evaluated by using the emergy analysis approach and fuzzy logic [36].

The sustainability of four greenhouse systems located in Jiroft city, Iran, were evaluated to increase the sustainability of production by using emergy sustainability index [37]. Then, emergy analysis was applied to assess the sustainability of grass-based livestock husbandry in the experimental area and the traditional pastoral area of Hulun Buir [38]. In the fields of the national and regional economy, combined emergy theory, and system dynamics (SD), an emergy-flow SD model of an urban eco-economic system has been established [39]. In addition, emergy theory was adopted to comprehensively evaluate the sustainable development level in China from 2006 to 2016 [40]. Lee and Liao [41] also evaluated the contribution of material flows triggered by urban tourism into the urban ecological-economic system by using emergy analysis. Other scholars also used emergy analysis to evaluate the sustainability of the eco-economic system in different regions [42–44].

This study took Anhui Province of China as the research object, using the emergy analysis method from the two aspects of the economic system and ecological environment. The study also constructed the sustainability index system of Anhui Province's ecological economic system and evaluated the sustainable development ability of the region by sorting and calculating the basic data of Anhui Province from 2010 to 2018. To achieve the research objectives, we framed this study as follows. The second part is the method, which mainly introduces the emergy flow of the eco-economic system and constructs the sustainability evaluation index. The third section takes Anhui Province as an example to evaluate the sustainability of the eco-economic system in this region and verifies the effectiveness and feasibility of the method. The fourth part concludes the study.

2. Emergy Model and Evaluation Index

The emergy method was founded by Odum, a famous American ecologist, in the 1980s. It breaks through the barriers of unified evaluation between different forms and levels of energy; makes them measure and compare under the same standard scale, so as to quantitatively analyze the actual value of resources, environment, and economic activities; overcomes the defects of previous analysis of the eco-economic system from the single angle of economy or ecology; and objectively describes the relationship between ecological environment and human production activities.

The emergy method provides a new method to quantitatively study the contribution of an ecosystem to regional social and economic development. This paper uses this method to construct evaluation index to evaluate the sustainable development level of the regional ecological economy. The specific method and evaluation indexes are as follows.

2.1. Method

The emergy method converts different kinds of materials and energy that flow and are stored in the ecological economic system, such as rain, wind, coal, oil, natural gas, capital, technology, and labor, into a unified solar energy value. The calculation formula is as follows:

$$EM = UEV \times N \quad (1)$$

where EM is emergy, UEV is the emergy conversion rate of different materials or energy, and N is the input stream of different units (mass g or energy J).

The main input emergy of regional economy includes the following: first, renewable energy, such as solar, wind, and rainwater energy from the natural environment; second, unrenewable natural resources, such as topsoil loss, coal, oil, and natural gas in the production process; third, raw materials, information, technology, labor, and other means of production and human services from the economic system outside the natural boundary, that is, economic feedback emergy. The output emergy of the regional economy mainly refers to various products and services, including wastewater, waste gas, and solid waste formed in the process of production and service. According to the activity process and characteristics of the regional economy, one can determine the boundary, and the emergy flow chart of the regional eco-economic system can be drawn, as shown in Figure 2.

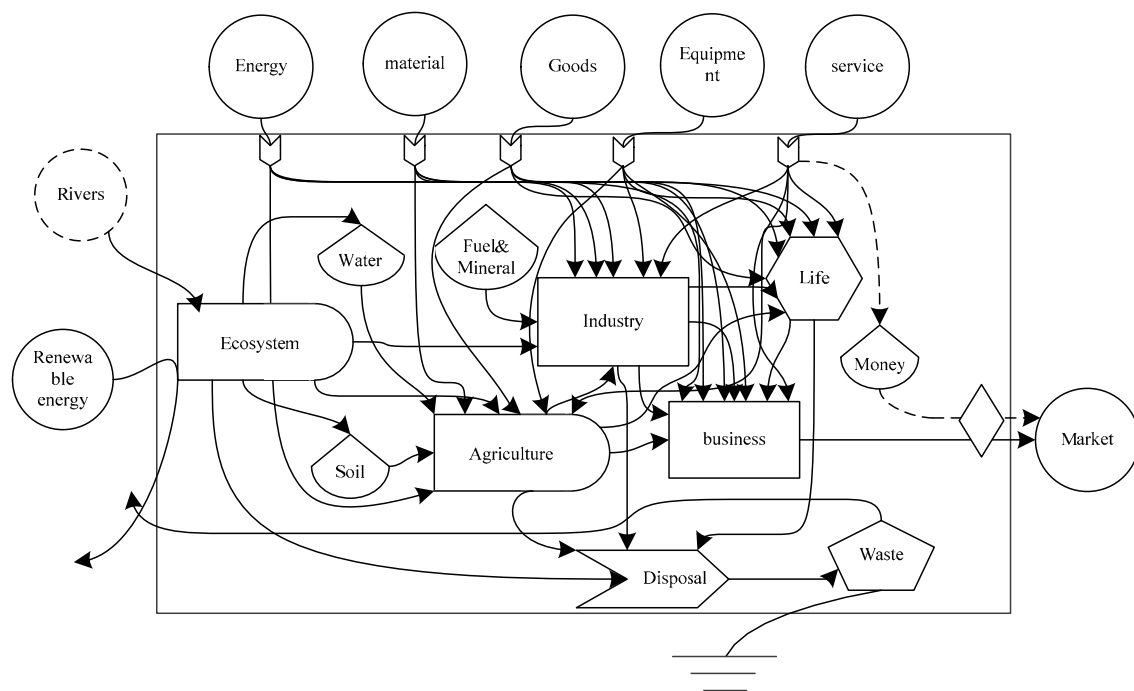


Figure 2. Energy flow chart of the regional eco-economic system.

2.2. Evaluation Index

The following energy evaluation index is constructed by combining the relevant references of energy with the actual situation of the regional economy to evaluate the ecological efficiency and sustainable development of the regional eco-economic system.

2.2.1. Structural Index

Structure index refers to the proportion of different types of energy in the total energy of the eco economic system and the proportion of total energy to population and land area, so as to determine the main source of energy and whether the energy structure is reasonable. The specific indexes mainly include the following aspects.

- (1) Energy self-sufficiency ratio (ESR) is the ratio of the local energy input to the total input energy of a region. The formula is

$$ESR = (EMR + EMN)/EMU \quad (2)$$

This index is used to describe the degree of regional economic development and foreign exchange. Any country, region, or enterprise keeps communication with the outside world while being self-reliant. The ESR reflects the degree of energy self-sufficiency in the region. As the ratio increases, the ability of self-sufficiency becomes stronger, and the degree of development of internal resources increases.

- (2) Energy purchasing ratio (EPR) is the ratio of the energy input from outside the region to the total energy input from the region.

$$EPR = EMI/EMU \quad (3)$$

This index is corresponding to the ESR, which reflects the degree of dependence on external resources in the process of foreign exchange. As the EPR increases, the dependence of the region on the outside world strengthens. The low EPR will lead to the inability to best use the local resources, thus reducing the level of regional development.

- (3) Energy per area (EPA) refers to the ratio of the total energy utilization of a region to the land area of this region.

$$EPA = EMU/A \quad (4)$$

This index reflects the land-use efficiency in the process of economic development and the intensity and level of economic development in the region. As the index increases, the degree of land use becomes greater, the output increases, the economy becomes more developed, and the rank of the region becomes higher.

- (4) Energy per person (EPP) refers to the per capita utilization of energy in a region, which is an index to evaluate people's standard of living. The calculation formula is as follows:

$$EPP = EMU/P \quad (5)$$

Compared with the per capita income index, this index is more scientific and comprehensive because it includes not only the economic energy reflected by money but also the environmental energy provided free by nature and the exchange energy formed by exchanging with others. If the index is large, then the per capita energy and the average living standard are high.

2.2.2. Functional Index

Functional index, namely, economic index, is mainly an index for comprehensive evaluation of the main functions of the eco-economic system—economic benefits, including input-output ratio; gains and losses of foreign trade, so as to judge the efficiency; and development degree of the eco-economic system.

- (1) Energy money ratio (EMR) refers to the amount of energy corresponding to the unit currency of a region, that is, the value of wealth measured by energy. The calculation formula is the total energy of the region in the current year divided by the industrial added value, which can be expressed as

$$EMR = EMU/GDP \quad (6)$$

Equation (6) shows that the ratio refers to the total energy consumption per unit of GDP. GDP here is measured in money and not in energy. As the ratio decreases, the base of industrial added value increases, the efficiency of resource utilization becomes high, and the economy will be more developed.

- (2) Net energy yield ratio (EYR) is the ratio of region output energy to region external input energy, where output energy refers to the net output of all kinds of energy generated through labor production in the region minus all kinds of wastes. The calculation formula is as follows:

$$EYR = (EM_o - EM_w)/EMI \quad (7)$$

EYR can measure the production efficiency and economic development of a region. If EYR is high, then the energy of the products produced in this area under a certain energy input is also high. This notion indicates that this area has higher resource utilization efficiency, better economic benefits, and strong competitiveness.

- (3) Energy investment ratio (EIR) is the ratio of energy from economic feedback to that from natural environment input.

$$EIR = EMI/(EMR + EMN) \quad (8)$$

Economic feedback energy mainly refers to the energy, raw materials, labor services, and information purchased in the production process of the region. The latter is the energy of renewable and non-renewable resources provided by the natural system of the region. This index reflects the energy of external resources that the developing unit natural resources need to purchase. In addition, this index can be used to measure the degree of regional economic development and environmental load. If the ratio is high, then the

dependence of economic development on the natural environment is small, and the degree of development is high.

- (4) Energy exchange ratio (EER) refers to the ratio of commodity energy (the energy obtained by the buyer) to the energy of the currency paid by the buyer. When measuring the gain and loss of regional foreign trade, EER is expressed as the ratio of energy obtained while trading to the energy output. Its expression can be described as

$$EER = EMI/EMO \quad (9)$$

This index is used to study the exchange proportion of energy in the process of inflow and outflow. If the index is large, then the region exchanges or obtains more energy through foreign trade per unit of energy output. Thus, the region is more favorable in the process of foreign exchange.

2.2.3. Ecological Efficiency Index

This index describes the impact of eco-economic system on ecological environment, such as resource consumption or waste discharge. Through the evaluation of the environmental load of the system, decision-makers can choose the appropriate mode of production, optimize the industrial structure, and improve the environmental performance. It mainly includes environmental loading ratio and energy waste ratio.

- (1) Environmental loading ratio (ELR) is the ratio of the total input of non-renewable energy to the total input of renewable energy.

$$ELR = (EMI + EMN)/EMR \quad (10)$$

ELR is generally used to measure the impact of regional economic activities and production processes on the environment. This ratio represents the natural pressure of a certain economic level, providing a warning to the economic system. If the index is large, then the degree of energy utilization is high, and the environmental carrying pressure is greater. Therefore, if an area is in a high environmental loading ratio for a long time, then irreparable structural changes or functional loss may occur.

- (2) Energy waste ratio (EWR) refers to the ratio of the energy value of waste generated in the process of regional economic activities to the total energy value of the system, that is,

$$EWR = EMW/EMU \quad (11)$$

where EMW represents the energy value of waste generated in the process of economic activities. This value reflects the level of cleaner production, the degree of industrial symbiosis, and the degree of pollution of unit output to the natural environment of enterprises in a region. If the index is low, then the level of cleaner production of enterprises in the region is high, and the situation of industrial symbiosis is better.

2.2.4. Sustainable Development Index

The energy-based sustainability index (ESI) is often used to measure the level of regional or national sustainable development, which is directly proportional to EYR and inversely proportional to ELR.

$$ESI = EYR/ELR \quad (12)$$

As a form of output, waste is a harmful and negative benefit output, which has a great impact on the natural ecological environment. In this study, EWR is introduced into the revised energy-based sustainability index (ESI'), which considers social and economic, as well as ecological and environmental benefits. The calculation formula is as follows:

$$ESI' = EYR/(ELR \times EWR) \quad (13)$$

ESI' can comprehensively reflect the sustainable development of a regional economy. If the index is large, then the social and economic benefits of the region under the unit environmental pressure and the level of sustainable development in the region are high.

On the basis of the above emergy index, we can construct the emergy evaluation index system of the regional eco-economic system, as is shown in Table 1.

Table 1. Emergy evaluation index system of regional eco-economic system.

Emergy Index	Expression	Remark
Flow index		
Renewable resource emergy	EMR	Renewable emergy from nature, such as solar, wind, and rain energy
Non-renewable resource emergy	EMN	All kinds of non-renewable emergy from nature, such as coal, oil, and natural gas
Economic feedback emergy	EMI	Emergy from outside the economic system, such as products, information, technology, and services
Output emergy	EMO	Products and services exported by the system and various wastes
Total emergy	$EMU = EMR + EMN + EMI$	Sum of various input emergy
Waste emergy	EMW	Wastewater, waste gas, and solid waste formed in the process of production and service
Structural index		
Emergy self-sufficiency ratio (ESR)	$ESR = (EMR + EMN)/EMU$	The supporting capacity of natural environment
Emergy purchasing ratio (EPR)	$EPR = EMI/EMU$	Reflects the degree of dependence on the external environment
Emergy per person (EPP)	$EPP = EMU/P$	Reflects the people's standard of living
Emergy per area	$EPA = EMU/A$	Reflects the land-use efficiency
Functional index		
Emergy money ratio (EMR)	$EMR = EMU/GDP$	Evaluates the development degree of the regional economy
Net emergy yield ratio (EYR)	$EYR = (EMO - EMW)/EMI$	Measures the contribution of system output to the economy
Emergy exchange ratio (EER)	$EER = EMI/EMO$	Evaluates the gains and losses in the external exchange
Emergy investment ratio	$EIR = EMI/(EMR + EMN)$	Measures the degree of economic development and environmental load
Ecological efficiency index		
Environmental loading ratio (ELR)	$ELR = (EMI + EMN)/EMR$	Evaluates the impact of activities on the environment
Emergy waste ratio (EWR)	$EWR = EMW/EMU$	Reflects the pollution degree of the regional economy to the natural environment
Sustainable development index		
Emergy-based sustainability index (ESI)	$ESI = EYR/ELR$	Measures the status and level of sustainable development
Revised emergy-based sustainability index (ESI')	$ESI' = EYR/(ELR \times EWR)$	Comprehensively reflects the level of sustainable development

3. Eco-Economic System Evaluation of Anhui Province

3.1. Background of Anhui Province

Anhui, referred to as "Wan" for short, is located in East China. Its geographical location is between $114^{\circ}54'$ – $119^{\circ}37'$ E and $29^{\circ}41'$ – $34^{\circ}38'$ N. The total area is 140,100 km², accounting for 1.45% of the country. Anhui Province is located in the transition area between the warm temperate zone and subtropical zone. The north of Huaihe River belongs to a warm temperate semi-humid monsoon climate, whereas the south of Huaihe River belongs to the subtropical humid monsoon climate, with four distinct seasons, namely, changeable spring, concentrated summer rain, crisp autumn, and cold winter. Anhui is also located in the middle latitude zone, and with the monsoon transition, precipitation has evident seasonal changes, which is one of the regions with obvious monsoon climate. The annual frost-free period is 200–250 days, and the active accumulated temperature of 10 °C is approximately 4600–5300 °C. The annual average temperature is 14–17 °C, and the annual average precipitation is 773–1670 mm. The terrain is mainly composed of plains, hills, and mountains and crosses the Huaihe River, Yangtze River, and Xin'anjiang river systems. Moreover, the terrain is the hinterland of the Yangtze River Delta, with the Yangtze, which is close to the east in the middle, having the Yangtze River waterway inside, and the coastal economic radiation outside.

Anhui is rich in biological, water, mineral, and other natural resources. This province is China's important base for agricultural products, energy, raw materials, and processing and manufacturing. The automobile, machinery, household appliances, chemical, electronics, agricultural products processing, and other industries occupy an important position in the country. In 2019, the annual GDP of Anhui Province was RMB 3711.4 billion, with an increase of 7.5% over the previous year at comparable prices. Among them, the added value of the primary industry was RMB 291.57 billion, with an increase of 3.2%. The added value of the secondary industry was RMB 1533.79 billion, with an increase of 8%, and the added value of the tertiary industry was RMB 1886.04 billion, with an increase of 7.7%. The per capita GDP reached RMB 58,496, which is equivalent to USD 8480. By the end of 2019, the registered resident population of Anhui was 71.194 million, and the urbanization rate of the registered resident population was 34.65%. The permanent resident population was 63.659 million, and the urbanization rate of the permanent resident population was 55.81%.

In view of the typical regional, economic, and social development of Anhui Province in China, this study collected and analyzed the statistical data of Anhui economic development from 2010 to 2018. Moreover, the study measured and evaluated the sustainable development of the ecological economy in Anhui Province and provides targeted decision-making suggestions for the sustainable and high-quality development of the Anhui economy.

3.2. Data Calculation and Results

By collecting and sorting the data of physical geography, economy, society, and waste discharge of Anhui Province from 2010 to 2018, we selected the appropriate energy conversion rate by consulting the references to calculate the original data. Then, the energy data of input and output materials or energy of the Anhui eco-economic system were obtained. The original data mainly came from the China Statistical Yearbook [45], Anhui Statistical Yearbook [46], government report [47], and Anhui Provincial Department of ecological environment [48]. Tables 2 and 3 show the specific data and energy.

According to the relevant energy data in Table 3, and on the basis of the energy evaluation index system and the calculation method of the eco economic system constructed in the second part, we obtained the index values of the eco economic system in Anhui Province, as shown in Table 4.

3.3. Index Evaluation and Analysis

In accordance with the above energy data analysis results, this study analyzed and evaluated the eco-economic system of Anhui Province from four aspects, namely, structure, function, ecology, and sustainable development index.

(1) Analysis of energy structure index

Combining Table 4 and Figure 3, we found that the total energy of Anhui Province increased from 2010 to 2018, and its growth mainly came from the input of purchasing energy. The total purchased energy increased from 4.01×10^{23} in 2010 to 9.65×10^{23} in 2018, and the total volume increased by 1.41 times. Moreover, EPR increased by 29.4%, and the utilization rate of local energy decreased year by year (from 50.1% to 35.4%), showing that the economic self-sufficiency of Anhui Province is declining. In the process of economic development, the economic model gradually changed from the direct use of natural resources to the purchase of external ones. The development and utilization intensity of natural resources is decreasing, and the energy structure of resources is more reasonable. However, the ESR of Anhui Province is still relatively high. On the basis of the rational use of its own resources, Anhui Province should strengthen the investment in high-tech and advanced equipment, further optimize the energy structure of resources, maximize the advantages of regional resources, improve the efficiency of resource utilization, and achieve the best benefits.

Table 2. Energy data of Anhui Province in 2010–2018.

Collection Object	Original Data									Energy Conversion Rate (Sej/Unit)	References	
	2010	2011	2012	2013	2014	2015	2016	2017	2018			
Renewable resources												
Solar energy (J)	7.85×10^{20}	7.85×10^{20}	7.85×10^{20}	7.85×10^{20}	7.85×10^{20}	7.85×10^{20}	7.85×10^{20}	7.85×10^{20}	7.85×10^{20}	7.85×10^{20}	1.00	[21]
Rainwater chemical energy (J)	9.06×10^{17}	7.37×10^{17}	8.12×10^{17}	7.08×10^{17}	8.85×10^{17}	9.43×10^{17}	1.12×10^{18}	8.69×10^{17}	9.10×10^{17}	9.10×10^{17}	1.54×10^4	[21]
Rainwater potential energy (J)	2.14×10^{17}	1.74×10^{17}	1.92×10^{17}	1.68×10^{17}	2.09×10^{17}	2.23×10^{17}	2.64×10^{17}	2.06×10^{17}	2.15×10^{17}	2.15×10^{17}	8.89×10^3	[21]
Wind energy (J)	1.08×10^{18}	1.08×10^{18}	1.08×10^{18}	1.08×10^{18}	1.08×10^{18}	1.08×10^{18}	1.08×10^{18}	1.08×10^{18}	1.08×10^{18}	1.08×10^{18}	6.63×10^2	[21]
Geothermal energy (J)	2.03×10^{17}	2.03×10^{17}	2.03×10^{17}	2.03×10^{17}	2.03×10^{17}	2.03×10^{17}	2.03×10^{17}	2.03×10^{17}	2.03×10^{17}	2.03×10^{17}	2.90×10^4	[21]
Non-renewable resources												
Loss of topsoil (J)	6.59×10^{16}	6.59×10^{16}	6.59×10^{16}	6.59×10^{16}	6.59×10^{16}	6.59×10^{16}	6.59×10^{16}	6.59×10^{16}	6.59×10^{16}	6.59×10^{16}	7.40×10^4	[26]
Natural gas (J)	2.09×10^{16}	2.52×10^{16}	2.85×10^{16}	3.81×10^{16}	4.22×10^{16}	4.39×10^{16}	5.08×10^{16}	6.51×10^{16}	7.50×10^{16}	7.50×10^{16}	1.70×10^5	[26]
Coal (J)	2.83×10^{18}	3.14×10^{18}	3.27×10^{18}	3.58×10^{18}	3.66×10^{18}	3.58×10^{18}	3.48×10^{18}	3.61×10^{18}	3.57×10^{18}	3.57×10^{18}	9.71×10^4	[26]
Coke (J)	2.56×10^{17}	2.66×10^{17}	2.72×10^{17}	2.86×10^{17}	2.90×10^{17}	2.98×10^{17}	2.81×10^{17}	2.87×10^{17}	3.02×10^{17}	3.02×10^{17}	6.44×10^4	[26]
Electronic (J)	2.78×10^{17}	3.15×10^{17}	3.39×10^{17}	3.62×10^{17}	3.80×10^{17}	3.90×10^{17}	4.08×10^{17}	4.19×10^{17}	4.30×10^{17}	4.30×10^{17}	2.78×10^5	[26]
Diesel oil (J)	1.43×10^{16}	1.45×10^{16}	1.57×10^{16}	1.63×10^{16}	1.54×10^{16}	1.46×10^{16}	1.45×10^{16}	1.37×10^{16}	1.33×10^{16}	1.33×10^{16}	1.07×10^5	[26]
Gasoline (J)	3.18×10^{15}	2.85×10^{15}	3.05×10^{15}	3.03×10^{15}	2.87×10^{15}	2.74×10^{15}	2.62×10^{15}	2.55×10^{15}	2.07×10^{15}	2.07×10^{15}	1.06×10^5	[26]
Input resources												
Total energy consumption (J)	1.97×10^{15}	2.14×10^{15}	2.30×10^{15}	2.45×10^{15}	2.51×10^{15}	2.58×10^{15}	2.65×10^{15}	2.73×10^{15}	2.77×10^{15}	2.77×10^{15}	9.71×10^4	[49]
Output resources												
GDP (CNY)	1.24×10^{12}	1.53×10^{12}	1.72×10^{12}	1.92×10^{12}	2.08×10^{12}	2.20×10^{12}	2.41×10^{12}	2.70×10^{12}	3.00×10^{12}	3.00×10^{12}	8.61×10^{11}	[49]
Total sales of goods (CNY)	1.00×10^{12}	1.29×10^{12}	1.58×10^{12}	8.90×10^{11}	9.43×10^{11}	9.45×10^{11}	1.07×10^{12}	1.15×10^{12}	1.30×10^{12}	1.30×10^{12}	8.61×10^{11}	[49]
Total energy production (J)	2.02×10^{15}	2.15×10^{15}	2.29×10^{15}	2.10×10^{15}	1.97×10^{15}	2.09×10^{15}	1.95×10^{15}	1.91×10^{15}	1.91×10^{15}	1.91×10^{15}	9.71×10^4	[49]
Wastewater (G)	7.10×10^{14}	7.09×10^{14}	6.72×10^{14}	7.10×10^{14}	6.96×10^{14}	7.14×10^{14}	4.96×10^{14}	4.30×10^{14}	4.26×10^{14}	4.26×10^{14}	1.24×10^9	[31]
Waste gas (G)	1.78×10^{14}	3.04×10^{14}	2.96×10^{14}	2.83×10^{14}	2.92×10^{14}	2.92×10^{14}	2.54×10^{14}	3.14×10^{14}	2.91×10^{14}	2.91×10^{14}	1.84×10^8	[31]
Solid waste (G)	9.16×10^{13}	1.15×10^{14}	1.20×10^{14}	1.19×10^{14}	1.20×10^{14}	1.31×10^{14}	1.27×10^{14}	1.20×10^{14}	1.31×10^{14}	1.31×10^{14}	2.52×10^8	[31]

Table 3. Energy data of Anhui Province in 2010–2018.

Collection Object	Energy Data									
	2010	2011	2012	2013	2014	2015	2016	2017	2018	
Renewable resources										
Solar energy	7.85×10^{20}	7.85×10^{20}	7.85×10^{20}	7.85×10^{20}	7.85×10^{20}	7.85×10^{20}	7.85×10^{20}	7.85×10^{20}	7.85×10^{20}	7.85×10^{20}
Rainwater chemical energy	1.40×10^{22}	1.14×10^{22}	1.25×10^{22}	1.09×10^{22}	1.37×10^{22}	1.46×10^{22}	1.72×10^{22}	1.34×10^{22}	1.41×10^{22}	1.41×10^{22}
Rainwater potential energy	1.91×10^{21}	1.55×10^{21}	1.71×10^{21}	1.49×10^{21}	1.86×10^{21}	1.98×10^{21}	2.35×10^{21}	1.83×10^{21}	1.91×10^{21}	1.91×10^{21}
Wind energy	7.16×10^{20}	7.16×10^{20}	7.16×10^{20}	7.16×10^{20}	7.16×10^{20}	7.16×10^{20}	7.16×10^{20}	7.16×10^{20}	7.16×10^{20}	7.16×10^{20}
Geothermal energy	5.89×10^{21}	5.89×10^{21}	5.89×10^{21}	5.89×10^{21}	5.89×10^{21}	5.89×10^{21}	5.89×10^{21}	5.89×10^{21}	5.89×10^{21}	5.89×10^{21}
Non-renewable resources										
Loss of topsoil	4.88×10^{21}	4.88×10^{21}	4.88×10^{21}	4.88×10^{21}	4.88×10^{21}	4.88×10^{21}	4.88×10^{21}	4.88×10^{21}	4.88×10^{21}	4.88×10^{21}
Natural gas	3.55×10^{21}	4.29×10^{21}	4.84×10^{21}	6.47×10^{21}	7.18×10^{21}	7.47×10^{21}	8.64×10^{21}	1.11×10^{22}	1.28×10^{22}	1.28×10^{22}
Coal	2.75×10^{23}	3.05×10^{23}	3.18×10^{23}	3.48×10^{23}	3.55×10^{23}	3.48×10^{23}	3.38×10^{23}	3.51×10^{23}	3.47×10^{23}	3.47×10^{23}
Coke	1.65×10^{22}	1.71×10^{22}	1.75×10^{22}	1.84×10^{22}	1.87×10^{22}	1.92×10^{22}	1.81×10^{22}	1.85×10^{22}	1.94×10^{22}	1.94×10^{22}
Electronic	7.72×10^{22}	8.77×10^{22}	9.43×10^{22}	1.01×10^{23}	1.06×10^{23}	1.08×10^{23}	1.14×10^{23}	1.16×10^{23}	1.19×10^{23}	1.19×10^{23}
Diesel oil	1.53×10^{21}	1.55×10^{21}	1.68×10^{21}	1.74×10^{21}	1.65×10^{21}	1.56×10^{21}	1.55×10^{21}	1.47×10^{21}	1.42×10^{21}	1.42×10^{21}
Gasoline	3.37×10^{20}	3.02×10^{20}	3.23×10^{20}	3.22×10^{20}	3.04×10^{20}	2.91×10^{20}	2.78×10^{20}	2.70×10^{20}	2.19×10^{20}	2.19×10^{20}
Input resources										
Total purchase of goods	4.01×10^{23}	5.33×10^{23}	6.19×10^{23}	6.85×10^{23}	7.29×10^{23}	7.22×10^{23}	8.08×10^{23}	8.76×10^{23}	9.65×10^{23}	9.65×10^{23}
Total energy consumption	1.91×10^{20}	2.08×10^{20}	2.24×10^{20}	2.37×10^{20}	2.44×10^{20}	2.50×10^{20}	2.58×10^{20}	2.65×10^{20}	2.69×10^{20}	2.69×10^{20}
Output resources										
GDP	1.06×10^{24}	1.32×10^{24}	1.48×10^{24}	1.66×10^{24}	1.80×10^{24}	1.89×10^{24}	2.08×10^{24}	2.33×10^{24}	2.58×10^{24}	2.58×10^{24}
Total sales of goods	8.65×10^{23}	1.11×10^{24}	1.36×10^{24}	7.66×10^{23}	8.12×10^{23}	8.14×10^{23}	9.20×10^{23}	9.89×10^{23}	1.12×10^{24}	1.12×10^{24}
Total energy production	1.96×10^{20}	2.09×10^{20}	2.22×10^{20}	2.04×10^{20}	1.91×10^{20}	2.02×10^{20}	1.89×10^{20}	1.86×10^{20}	1.85×10^{20}	1.85×10^{20}
Wastewater	8.80×10^{23}	8.79×10^{23}	8.33×10^{23}	8.80×10^{23}	8.63×10^{23}	8.86×10^{23}	6.15×10^{23}	5.33×10^{23}	5.28×10^{23}	5.28×10^{23}
Waste gas	3.28×10^{22}	5.60×10^{22}	5.45×10^{22}	5.21×10^{22}	5.38×10^{22}	5.37×10^{22}	4.67×10^{22}	5.79×10^{22}	5.36×10^{22}	5.36×10^{22}
Solid waste	2.31×10^{22}	2.89×10^{22}	3.03×10^{22}	3.01×10^{22}	3.02×10^{22}	3.29×10^{22}	3.19×10^{22}	3.02×10^{22}	3.30×10^{22}	3.30×10^{22}

Table 4. Eco-economic system evaluation index data of Anhui Province.

Energy Index	2010	2011	2012	2013	2014	2015	2016	2017	2018
Renewable emery (EMR)	2.33×10^{22}	2.03×10^{22}	2.16×10^{22}	1.98×10^{22}	2.29×10^{22}	2.39×10^{22}	2.70×10^{22}	2.26×10^{22}	2.34×10^{22}
Non-renewable emery (EMN)	3.78×10^{23}	4.21×10^{23}	4.41×10^{23}	4.81×10^{23}	4.93×10^{23}	4.89×10^{23}	4.85×10^{23}	5.03×10^{23}	5.05×10^{23}
Economic feedback emery (EMI)	4.01×10^{23}	5.33×10^{23}	6.19×10^{23}	6.86×10^{23}	7.29×10^{23}	7.23×10^{23}	8.08×10^{23}	8.76×10^{23}	9.65×10^{23}
Output emery (EMO)	1.06×10^{24}	1.32×10^{24}	1.48×10^{24}	1.66×10^{24}	1.80×10^{24}	1.89×10^{24}	2.08×10^{24}	2.33×10^{24}	2.58×10^{24}
Total emery (EMU)	8.03×10^{23}	9.74×10^{23}	1.08×10^{24}	1.19×10^{24}	1.25×10^{24}	1.24×10^{24}	1.32×10^{24}	1.40×10^{24}	1.49×10^{24}
Waste emery	9.36×10^{23}	9.64×10^{23}	9.18×10^{23}	9.62×10^{23}	9.47×10^{23}	9.72×10^{23}	6.94×10^{23}	6.21×10^{23}	6.15×10^{23}
Structural index									
Emery self-sufficiency ratio (ESR)	5.01×10^{-1}	4.53×10^{-1}	4.28×10^{-1}	4.22×10^{-1}	4.15×10^{-1}	4.15×10^{-1}	3.88×10^{-1}	3.75×10^{-1}	3.54×10^{-1}
Emery purchasing ratio (EPR)	4.99×10^{-1}	5.47×10^{-1}	5.72×10^{-1}	5.78×10^{-1}	5.85×10^{-1}	5.85×10^{-1}	6.12×10^{-1}	6.25×10^{-1}	6.46×10^{-1}
Emery per person (EPP)	1.35×10^{16}	1.63×10^{16}	1.81×10^{16}	1.97×10^{16}	2.05×10^{16}	2.01×10^{16}	2.13×10^{16}	2.24×10^{16}	2.36×10^{16}
Emery per area (EPA)	5.73×10^{12}	6.95×10^{12}	7.72×10^{12}	8.47×10^{12}	8.89×10^{12}	8.82×10^{12}	9.42×10^{12}	1.00×10^{13}	1.07×10^{13}
Functional index									
Emery money ratio (EMR)	6.49×10^{11}	6.37×10^{11}	6.28×10^{11}	6.17×10^{11}	5.97×10^{11}	5.62×10^{11}	5.47×10^{11}	5.19×10^{11}	4.98×10^{11}
Net emery yield ratio (EYR)	3.20×10^{-1}	6.64×10^{-1}	9.12×10^{-1}	1.01	1.16	1.28	1.71	1.95	2.04
Emery exchange ratio (EER)	3.77×10^{-1}	4.04×10^{-1}	4.18×10^{-1}	4.14×10^{-1}	4.06×10^{-1}	3.81×10^{-1}	3.89×10^{-1}	3.77×10^{-1}	3.74×10^{-1}
Emery investment ratio	9.98×10^{-1}	1.21	1.34	1.37	1.41	1.41	1.58	1.67	1.83
Ecological efficiency index									
Environmental loading ratio (ELR)	1.63×10^1	2.07×10^1	2.04×10^1	2.42×10^1	2.15×10^1	2.04×10^1	1.80×10^1	2.22×10^1	2.16×10^1
Energy waste ratio (EWR)	8.80×10^{-1}	7.31×10^{-1}	6.19×10^{-1}	5.81×10^{-1}	5.27×10^{-1}	5.13×10^{-1}	3.34×10^{-1}	2.67×10^{-1}	2.38×10^{-1}
Sustainable development index									
Emery-based sustainability index (ESI)	1.97×10^{-2}	3.21×10^{-2}	4.47×10^{-2}	4.17×10^{-2}	5.41×10^{-2}	6.25×10^{-2}	9.52×10^{-2}	8.75×10^{-2}	9.44×10^{-2}
Revised emery-based sustainability index (ESI')	2.24×10^{-2}	4.38×10^{-2}	7.22×10^{-2}	7.18×10^{-2}	1.03×10^{-1}	1.22×10^{-1}	2.85×10^{-1}	3.28×10^{-1}	3.97×10^{-1}

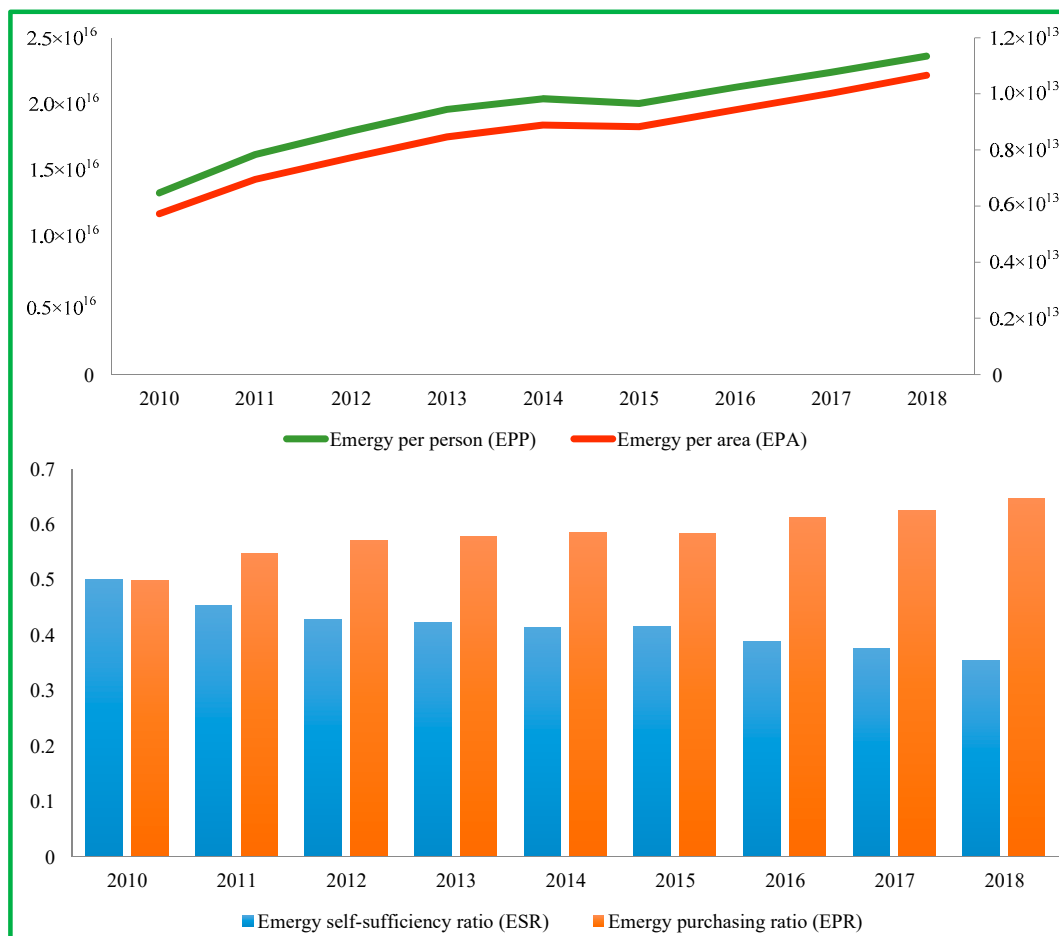


Figure 3. Analysis of energy structure index.

The population of Anhui Province gradually increased from 2010 to 2018 (from 59.57 to 63.24 million), the total energy also increased (from 8.03×10^{23} to 1.49×10^{24}), and the EPP showed an evident upward trend (from 1.35×10^{16} to 2.36×10^{16}). These results show that with the continuous economic development of Anhui Province, people's standard of living has improved significantly. This is closely related to the livelihood work of Anhui Province during the 13th Five Year Plan period. The accumulated investment in livelihood projects in five years reached RMB 526 billion, benefiting 70 million urban and rural people. The people have a more sense of gain, more equal public services, and more harmonious economy and society. However, the growth rate of EPP in Anhui Province was lower than that of GDP per capita. From 2010 to 2018, the growth rate of GDP per capita in Anhui Province was 128.4%, whereas that of EPP was only 74.8%. In the process of future economic development, Anhui Province should continue to improve the ecological and natural environment on the existing basis and increase investment in livelihood projects to improve the quality of life of residents. EPA reflects the development degree of the regional economy, and the EPA of Anhui Province grew steadily (from 5.73×10^{12} to 1.07×10^{13}), which is consistent with the current situation of economic development in Anhui Province.

(2) Analysis of System Function Index

Figure 4 shows that the EMR of Anhui Province declined steadily (from 6.49×10^{11} in 2010 to 4.98×10^{11} in 2018). This event indicates that under the premise of obtaining the same output, the energy cost of Anhui Province is getting lower and lower, which also means that the economy of the region is becoming more and more developed.

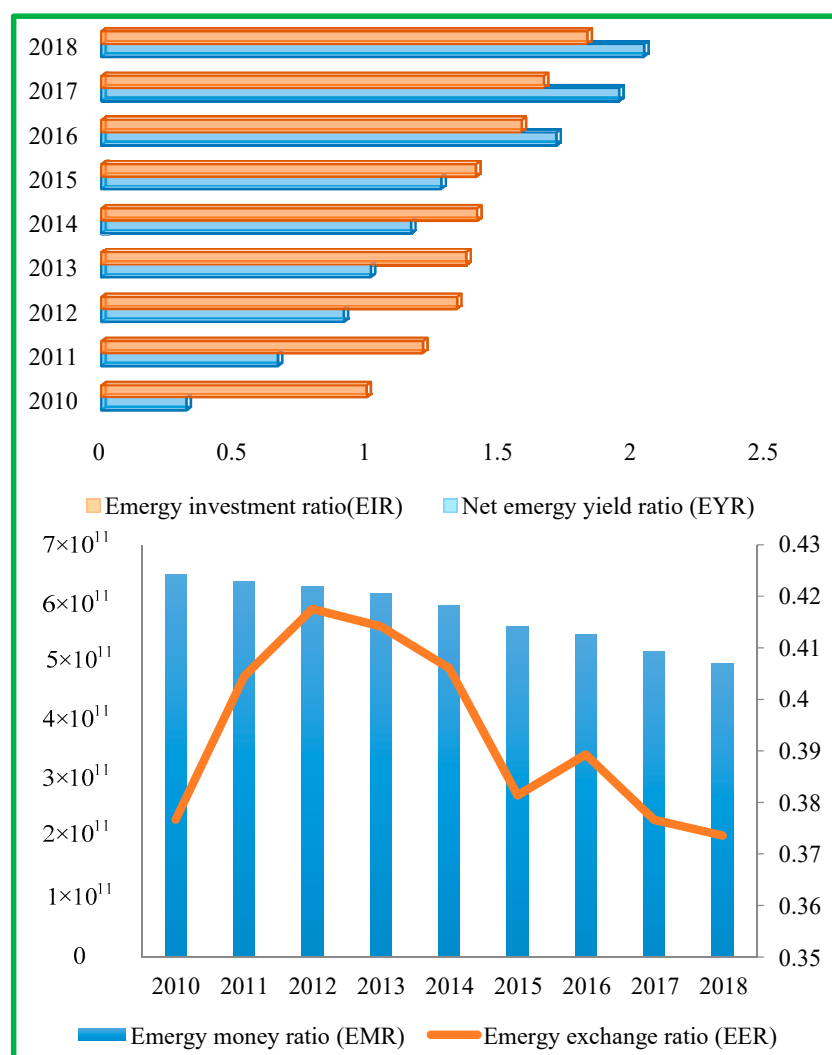


Figure 4. Analysis of system function index.

EIR is used to measure the competitiveness of a region's economic activities and a load of its natural environment on economic activities. If the EIR is high, then the degree of economic development is also high, and dependence on the natural environment is less. The EIR of Anhui Province increased by 83.4% from 2011 to 2018 (from 0.998 to 1.827). This shows that the scale of economic development in Anhui Province is increasing. The regional economic development has gradually changed from relying on the development and utilization of natural resources to purchasing resources from the outside world, and the degree of economic development has increased, while the pressure of the natural environment has decreased.

EER reflects the gains and losses of foreign trade in the process of regional economic development. If the ratio is high, then the position of the region in the process of foreign trade is more favorable. After a short rise in the previous period, the EER of Anhui Province showed a downward trend from 2013, specifically in 2015. From a data point of view, the foreign trade of Anhui Province is in a weak position, and its energy is constantly losing in the process of foreign trade. One of the main reasons is that Anhui Province was formally included in the Yangtze River Delta from the central level in the "Guidance on promoting the development of the Yangtze River economic belt relying on the golden waterway" issued by the State Council in 2014. The Yangtze River Delta region is quite short of energy and raw materials, and more than 90% of its disposable energy needs to be imported. Huaibei, Huainan, Ma'anshan, and Tongling in Anhui Province are

important energy and raw material suppliers. To ensure the supply of raw materials in the Yangtze River Delta, Anhui Province exports more low-value-added products, such as raw materials, and primary processing products in the process of foreign trade. This case helps the economic development of Yangtze River Delta, reflecting the industries of Anhui Province and Yangtze River Delta Jiangsu, Zhejiang, and Shanghai, giving full play to its positive role in the integration of the strong complementarity and strong supporting capacity. On this basis, Anhui Province should eliminate backward production capacity, adopt advanced technology, continue to tap the potential of existing raw material output and primary product processing output, and improve the EER.

EYR reflects the ratio relationship between emergy output and input, and is one of the important indicators for measuring production efficiency. If the ratio is high, then the production efficiency will also be high. Since 2010, the EYR of Anhui Province has maintained a strong upward trend, with a rapid growth rate. Particularly after 2015, the EYR and the production efficiency of Anhui Province has greatly improved. The reason is that Anhui Province is rich in coal resources, particularly in the Huainan and Huaibei areas. The regional economic development mainly relies on coal and oil. After a golden decade of the coal industry from 2002 to 2011, the coal industry was in overall recession from 2012 to 2015 due to overcapacity, sluggish market demand, and the impact of imported coal and new energy; however, the situation improved in 2016. Moreover, after Anhui Province joined the Yangtze River Delta, industries led by wholesale and retail, real estate, and construction have been developing rapidly. The introduction of talents and technology improves the production efficiency of the region and quickly promotes the development of the regional economy.

(3) Analysis of ecological efficiency evaluation index

The EWR in Anhui Province decreased from 8.80×10^{-1} in 2010 to 2.38×10^{-1} in 2018, showing an evident downward trend. This result shows that the waste discharge in the process of economic operation in Anhui Province continues to decrease. In addition, the resource utilization rate and the level of renewable resources have improved. Figure 5 depicts that this index declined more rapidly in 2015 because this year was known as the “policy year” in the field of environmental protection in China. Moreover, a series of favorable policies was introduced intensively—from the formal implementation of the new environmental protection law, which is known as the “most stringent” in history, to the printing and issuing of the “ten water items”; from the release of the “13th five-year plan” proposal, to the introduction of the “overall plan for the reform of ecological civilization system”; from the implementation of “vertical management” in environmental protection and the gradual implementation of relevant policies to the general office of the State Council issuing the “guidance on promoting the construction of sponge city” and others. At the policy level, the state continuously increased its support for environmental protection. Anhui Province took this opportunity to strengthen the supervision and management of waste discharge of enterprises, institutions, and other producers and operators and improve the awareness of energy conservation, emission reduction of enterprises, and recycling of waste. Aside from economic development, additional attention should also be paid to technology and environmental protection.

In recent years, the ELR of Anhui Province has been consistently high, ranging from 16.25 to 24.24. According to Brown and Ulgiati’s suggestion, when ELR is greater than 10, the ratio belongs to a high load [50]. The economic development of Anhui Province is highly dependent on non-renewable resources, and the ecological economic system has been in a high-load state for a long time, bearing increasing environmental pressure. This event has sounded an alarm for the economic development of the region. If the high environmental load does not change, then the ecosystem function of Anhui Province will decline irreversibly. Therefore, to achieve high-quality and sustainable development, Anhui Province needs to change the existing development model, vigorously develop industries such as information technology services, reduce the consumption of non-renewable resources, and put an end to the resource consumption development path.

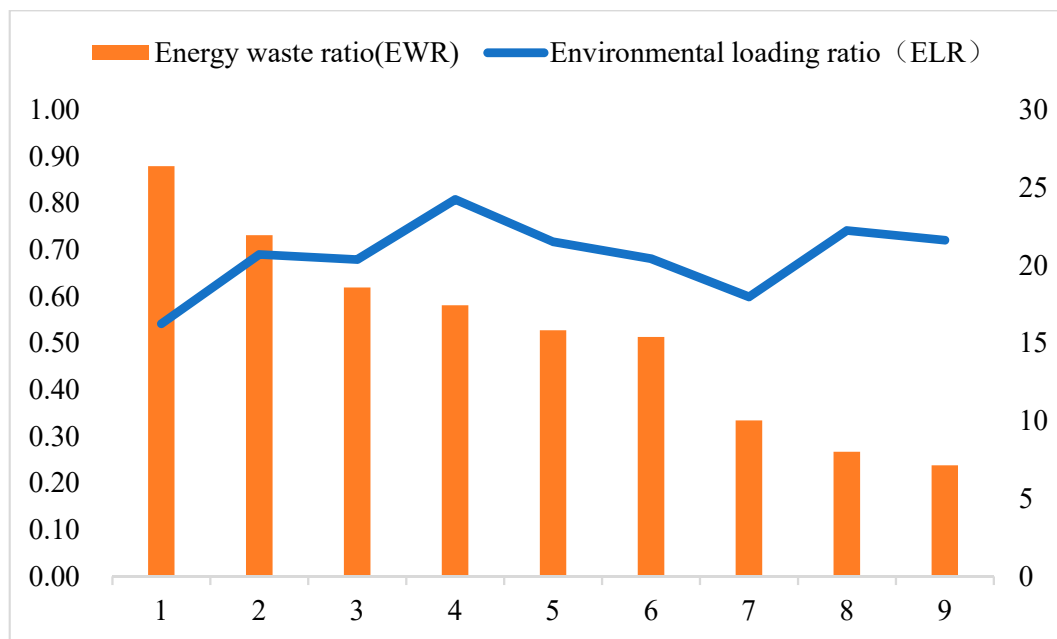


Figure 5. Analysis of ecological efficiency evaluation index.

(4) Analysis of the sustainable development index

From Figure 6, we can see that from 2010 to 2018, the ESI and the ESI' of Anhui Province show the characteristics of small fluctuation but have an overall improvement. ESI is directly proportional to the EYR and inversely proportional to ELR. The EYR of Anhui Province is growing faster, but the ELR has been fluctuating in a stable range, which affects the growth of the ESI. ESI' considers the impact of waste energy on the ESI. With the enhancement of the awareness of energy conservation and emission reduction of production enterprises in Anhui Province, including the increase of waste recycling, the EWR decreased sharply, which weakened the impact of ELR on ESI. ESI' rose slightly from 2010 to 2015 and then entered a rapid rising stage from 2015, which reflects the results of waste emission in Anhui Province. However, regardless of the method adopted, the sustainable development index of Anhui Province is lower than 1. The research shows that if the sustainable development index is less than 1, then the utilization of non-renewable resources is large, and the economic system is in an unsustainable development state [51]. Therefore, in the process of economic development, in addition to reducing waste discharge, Anhui should also reduce the use of non-renewable resources, reduce the ELR as much as possible, and improve the level of sustainable development.

3.4. Management Suggestions

On the basis of the analysis of the above energy evaluation index, we can see that since 2010, the economy of Anhui Province has been developing steadily, the competitiveness has been gradually enhanced, the people's living standard has been higher and higher, and the ecological environment has also been improved to a certain extent. Combined with the economic development of Anhui Province, the following suggestions are proposed to improve the sustainable development ability of Anhui Province.

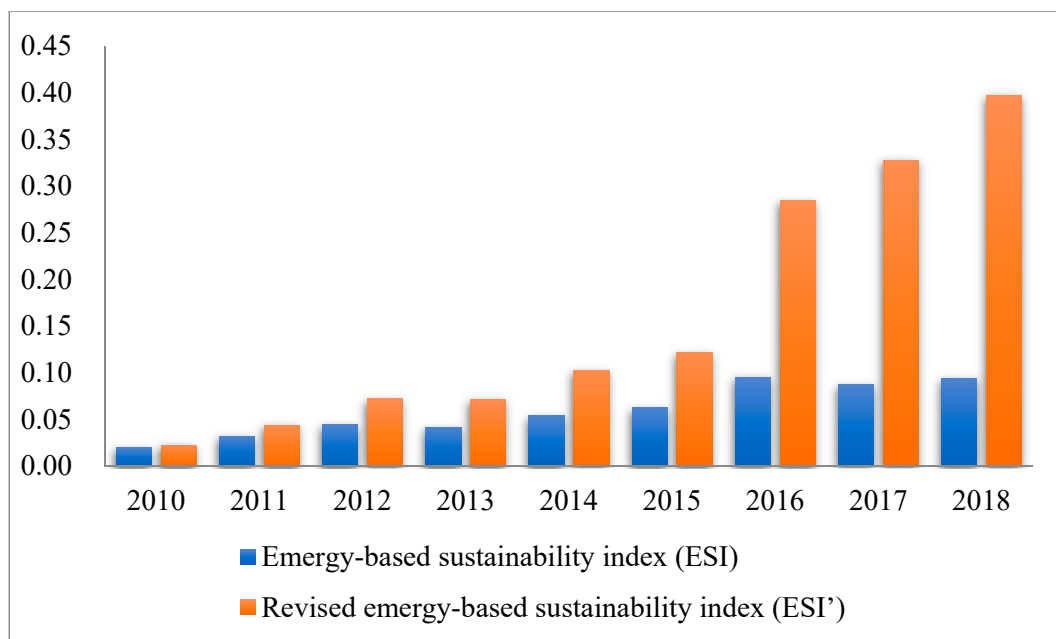


Figure 6. Analysis of the sustainable development index.

(1) Actively promote the optimization and upgrading of energy structure

With the rapid development of the regional economy, the demand for resources will continue to increase. If the regional economic development greatly relies on local resources, then local resources will be overdeveloped, which is not conducive to its long-term sustainable development. Moreover, if the regional economic development relies too much on the purchase of resources, then the regional economy will have a passive position. Anhui Province is rich in energy, but the extensive industrial structure and mode of production increase its demand for energy. In determining the source structure of energy, according to the principle of benefit maximization, we should promote the optimization of energy structure, develop local resources moderately, and increase the purchase of energy on the basis of self-reliance to alleviate the pressure of local resources. Furthermore, we should improve the utilization efficiency of local renewable resources; vigorously promote free energy, such as solar, rainwater, and wind energy; increase the development of new energy, such as geothermal energy; improve the depth of resource utilization; and conduct multi-level transformation of resources.

(2) Optimize industrial structure and change economic growth mode

Anhui Province is rich in resources, such as Huainan–Huaibei areas, Ma’anshan, and Tongling. As a result, the development of the region greatly relies on coal, oil, electricity, and other non-renewable resources. The export commodities are mainly raw materials and primary products, with low added value. The extensive industrial development mode leads to more resource consumption and waste discharge. Therefore, Anhui Province should, on the one hand, adjust the industrial structure; increase the proportion of the tertiary industry; speed up the elimination of industrial enterprises with high resource consumption and waste discharge; encourage the development of high-tech, new energy-saving, and modern service industries with low resource consumption and high added value; and reduce the consumption of non-renewable resources. On the other hand, Anhui Province should focus on introducing advanced technology, equipment, management experience, and all kinds of talents and increasing investment in scientific and technological innovation. This approach will help the region increase the added value of export commodities, improve the grade and technical content of export commodities, and enhance the comprehensive competitiveness of the region.

(3) Reduce waste energy emission and develop circular economy

Waste discharge has a great impact on the ecological environment and regional sustainable development. In the process of economic development, first, we should take a variety of measures to reduce waste discharge. Industrial enterprises can improve the production process, save energy, and reduce emissions and waste discharge in the production process as much as possible. Then, the government should increase the publicity and education of environmental protection legislation and punishment and strengthen environmental protection supervision. Moreover, people should enhance their awareness of resource conservation and environmental awareness and jointly build an environment-friendly ecological economic development model. A circular economy should also be developed to improve the utilization rate of waste resources. For the waste generated in the production process, we should further tap its potential use and turn waste into treasure to achieve a balance in economic growth, social development, and environmental protection.

4. Conclusions

With the in-depth development of economy, the contradiction between resources and environment is further highlighted—the ecological environment is deteriorating seriously, which has a serious impact on the sustainable development of regional economy, and thus the construction of ecological economy is imminent. Sustainable development pays attention to dealing with the contradiction between ecological environment and economic development while maintaining stable and rapid economic growth. Evaluating the sustainability of the regional economy and putting forward targeted improvement measures are conducive to fundamentally changing the mode of economic development and improving the quality and efficiency of economic development.

This paper puts forward a method of regional ecological efficiency evaluation. The main innovation points are as follows. (i) Using energy method to process the input–output data of the regional eco-economic system in a unified dimension directly reflects the mutual energy flow relationship among the elements in the eco-economic system. (ii) The energy evaluation index system of regional ecological economy is established to evaluate the energy structure, function, ecological benefit, and sustainability of regional economy. (iii) Ecological environment and other factors such as waste energy are included in the reference range of energy analysis, which makes up for the deficiency of traditional economic development evaluation method that only considers GDP. (iv) The evaluation index was used to evaluate the sustainable development level of ecological economy in Anhui Province. The results show that the sustainable development index of Anhui Province is lower than 1, and the economic system is in an unsustainable state, which is consistent with the current situation of ecological economic development in Anhui Province.

This study is a good reference for the sustainable development, transformation, and upgrading of the regional economy, providing theoretical and methodological support for the high-quality development of the regional economy as well as effective solutions for policymakers. However, due to the complexity of the eco-economic system and the availability of data, some indicators such as information energy and education energy cannot be reflected, and the construction of indicators is not perfect. In future studies, these energy values can be considered, and we can add a comparative analysis with other regions, which is more conducive to understanding and analyzing the current situation of the sustainable development of the regional economic system. Through the comparative study of the gap with other regions, we can find the existing problems in the sustainable development of the regional economy and propose more effective suggestions for high-quality development.

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