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УСТОЙЧИВОСТЬ ЭНЕРГЕТИЧЕСКОГО РАЗВИТИЯ В КИТАЕ

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Рассматриваются показатели и методика оценки устойчивости развития энергетики. Анализируется устойчивость развития энергетики в Китае. Сравниваются показатели устойчивости развития энергетики в провинциях Китая, а также в Китае и других странах. В Китае устойчивость развития энергетики относительно низкая и между провинциями нет существенных различий. Из-за несбалансированного распределения ресурсов устойчивость развития энергетики зависит от разных факторов. На основе особенностей и степени устойчивости развития энергетики в различных странах и провинциях Китая даются рекомендации по оптимизации развития энергетики.

Ключевые слова: устойчивость развития энергетики; возобновляемая энергетика; энергетическая революция; энергетическая эффективность; энергетическая структура; ресурсный регион; энергетическая безопасность.

SUSTAINABILITY OF ENERGY DEVELOPMENT IN CHINA

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This paper discusses the indicators and method to evaluate the sustainability of energy development and analyse the current situation of sustainability of energy development in China. There are comparison and analysis on sustainability of energy development between China and other countries and among provinces of China. In China, the sustainability of energy development is relatively poor and there are no significant differences among provinces. Due to unbalanced resource distribution, the sustainability of energy development varies with different factors. Based on the characteristics and degrees of sustainability of energy development in various countries and provinces of China, the possible advices are proposed to optimise the energy development.

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Introduction

Energy resource is a general term for substances that can generate various types of energy. Energy refers to various resources that can be directly obtained or obtained through processing and conversion to obtain useful energy. It includes primary energy such as coal, crude oil, natural gas, coalbed methane, water energy, nuclear energy, wind energy, solar energy, geothermal energy, biomass energy, and secondary energy such as electricity, heat, refined oil, and other new and renewable energy.

Energy is the most basic driving force for the development and economic growth of the whole world, and it is the basis for human survival. The issue of energy security has arisen since the Industrial Revolution. With the increasing demand for energy in human society, energy security is gradually closely linked with political and economic security. Prime Minister of France G. Clemenceau once said, «A drop of oil is equal to a drop of blood for our soldiers». It can be seen that the importance of energy security has been generally recognised by the international community at that time.

By the middle of the 21st century, or around 2050, oil resources will be exhausted and prices will rise substantially, according to a common estimate by economists and scientists. If the new energy system has not yet been established at this time, the energy crisis will sweep the world, especially the developed countries that are heavily dependent on oil resources.

In order to avoid the above dilemma, countries around the world are actively developing new renewable energy sources such as solar energy, wind energy, ocean energy (including tidal energy and wave energy), or turning their attention to new fossil energy sources such as seabed combustible ice (hydrated natural gas). At the same time, fuels such as hydrogen and methanol have also received extensive attention as substitutes for gasoline and diesel.

At present, some renewable energy utilisation technologies have made great progress and have formed a certain scale around the world. The utilisation technologies of biomass energy, solar energy, wind energy, hydroelectric power and geothermal energy have been applied.

The International Energy Agency (IEA) conducted a study on international electricity demand from 2000 to 2030, and the study showed that the average annual growth rate of total power generation from renewable energy will be the fastest. IEA research believes that in the next 30 years non-hydro renewable energy power generation will grow faster than any other fuel power generation, with an annual growth rate of nearly 6 %, and its total power generation will increase fivefold between 2000 and 2030.

The proportion of renewable energy in primary energy is generally low. On the one hand, it is related to the importance and policies of different countries. On the other hand, it is related to the high cost of renewable energy technology, especially the high-tech solar energy biomass energy, wind energy, etc. According to a forecast study by the IEA, the cost of generating electricity from renewable energy will drop significantly over the next 30 years, thereby increasing its competitiveness. The cost of renewable energy utilisation is related to many factors, so the result of cost forecast has certain uncertainty. But these forecasts point to a declining trend in the cost of renewable energy technologies.

China is the world's largest energy producer and consumer. The continuous growth of China's energy supply provides important support for economic and social development. The rapid growth of China's energy consumption has also created a broad development space for the world energy market. Currently, China has become an indispensable and important part of the world energy market, and is playing an increasingly important and active role in maintaining global energy security.

Therefore, by studying China's energy factors and comparing China's energy factors with other countries, it can help us better understand the choices different countries make in the face of energy.

Materials and methods

The sustainability of energy development is a comprehensive issue integrating economics, environment, society and politics. In the study of sustainability of energy development, we focus on the operation of energy system.

Based on the indicators and methods in references for assessing the operation of energy system and its sustainability, we identify 12 specific indicators to study and analyse. And all those indicators could be divided into four categories of factor, secure factor, social factor, ecological factor and economical factor. The categories of factor and indicators are shown in the table 1 [1–3].

Table 1

Indicators of sustainability of energy development

Factor	Indicator	Explanation
Secure	Proportion of dominant energy	Difference of 1 and proportion of main energy consumption and total energy consumption
	Proportion of self-owned energy	Share of self-owned energy to total energy consumption
	Ratio of energy export and import	Ratio of export of main exported energy to import of main imported energy
Social	Energy intensity	Difference of 1 and energy consumption per GDP
	Education	Share of educated to total population
	Life expectancy	Ratio of life expectancy to 100
Ecological	Share of CO_2 emission in energy sector	Difference of 1 and proportion of CO_2 emission in energy industry and total CO_2 emission
	Forest coverage	Share of the forest area to the total area
	Share of clean energy	Share of clean energy generation to total energy generation
Economic	Share of the investment in energy	Share of investment in energy industry to total investment
	Share of output in energy sector	Share of value created by the energy industry to GDP
	Employment	Share of employed to total population

Based on the score given by experts to each indicator, the analytic hierarchy process is applied to decide the weight of each indicator. And the index of sustainability of energy system is calculated with the formula

$$I = \sum_{j=1}^{k} z_j \sum_{i=1}^{m} x_{ij} f_{ij},$$

where I is index of sustainability of energy development; k – number of factors; z_j – weight of j factor; m – number of indicators; x_{ij} – weight of i indicator for j factor; f_{ij} – value of i indicator for j factor.

The formula is carried out to reduce values of each indicator to a uniform range:

$$x_{i,\,0-1} = \frac{x_i - x_{\min}}{x_{\max} - x_{\min}},$$

where $x_{i,\,0-1}$ is normalised value of x_i indicator; x_i – reference value of an indicator; $x_{\min}$ – the minimum value of certain indicator among basic data; $x_{\max}$ – the maximum value of certain indicator among basic data.

In this paper, the data for each country are calculated from publicly available data on the internet. Data for each region in China are calculated from raw data for 2019 in China statistical yearbook, China energy statistical yearbook, China statistical yearbook on environment, and China industry statistical yearbook.

Sustainability of energy development in China comparing with other countries

On the basis of the given methodology, the index of sustainability of energy development for the seven countries (USA, Belarus, China, Russia, Japan, UK and Denmark) was calculated (table 2). Sources of information for calculating the index were following: the data of national statistics, United Nations Sustainable Developmnet Group and International Energy Agency[1].

As shown in fig. 1, in 2019, Denmark has the highest level of sustainability of energy development (0.635), and China has the lowest level of sustainability of energy development (0.427) of the whole seven countries, leading in secure, social, ecological and economic factors.

As shown in fig. 2, in 2019, Russia has the highest level of sustainability of energy production (0.879), and Japan has the lowest level of sustainability of energy production (0.231).

[1]World bank open data // The World Bank [Electronic resource]. URL: https://data.worldbank.org (date of access: 26.10.2021) ; Statistics Division // United Nations [Electronic resource]. URL: https://unstats.un.org/sdgs/unsdg (date of access: 10.11.2021) ; Shaping a secure and sustainable energy future for all // The Intern. Energy Agency [Electronic resource]. URL: https://www.iea.org (date of access: 05.11.2021).

Table 2

Initial data and calculation results of the index of sustainability of energy development for the seven countries

Indicator	Country							
	Weight	USA	Belarus	China	Japan	Russia	UK	Denmark
Sustainability of energy production	*0.250*	*0.507*	*0.319*	*0.490*	*0.231*	*0.879*	*0.686*	*0.668*
Proportion of dominant energy	0.273	0.525	0.696	0.597	0.489	0.646	0.578	0.611
Proportion of self-owned energy	0.545	0.661	0.229	0.585	0.179	0.955	0.956	0.905
Ratio of energy export and import	0.182	0.024	0.025	0.046	0.000	1.000	0.039	0.041
Sustainability of energy consumption	*0.250*	*0.921*	*0.842*	*0.628*	*0.932*	*0.793*	*0.939*	*0.950*
Energy intensity	0.545	0.990	0.831	0.427	0.942	0.739	0.990	0.996
Education	0.273	0.878	0.934	0.942	0.976	0.941	0.923	0.954
Life expectancy	0.182	0.780	0.740	0.760	0.840	0.730	0.810	0.810
Sustainability of energy environment	*0.250*	*0.306*	*0.293*	*0.281*	*0.254*	*0.313*	*0.277*	*0.394*
Share of CO_2 emission in energy sector	0.545	0.277	0.385	0.287	0.127	0.226	0.245	0.380
Forest coverage	0.182	0.315	0.431	0.231	0.684	0.498	0.132	0.157
Share of clean energy	0.273	0.359	0.018	0.303	0.221	0.363	0.437	0.579
Sustainability of energy management	*0.250*	*0.257*	*0.334*	*0.308*	*0.416*	*0.311*	*0.350*	*0.526*
Share of the investment in energy	0.545	0.051	0.200	0.102	0.293	0.192	0.262	0.431
Share of output in energy sector	0.273	0.212	0.170	0.279	0.297	0.103	0.121	0.433
Employment	0.182	0.940	0.980	0.970	0.962	0.978	0.956	0.952

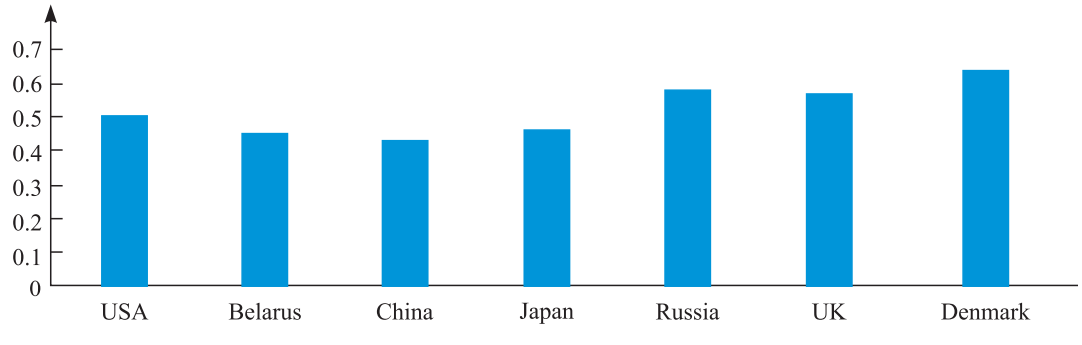

Fig. 1. Index of sustainability of energy development for the seven countries in 2019

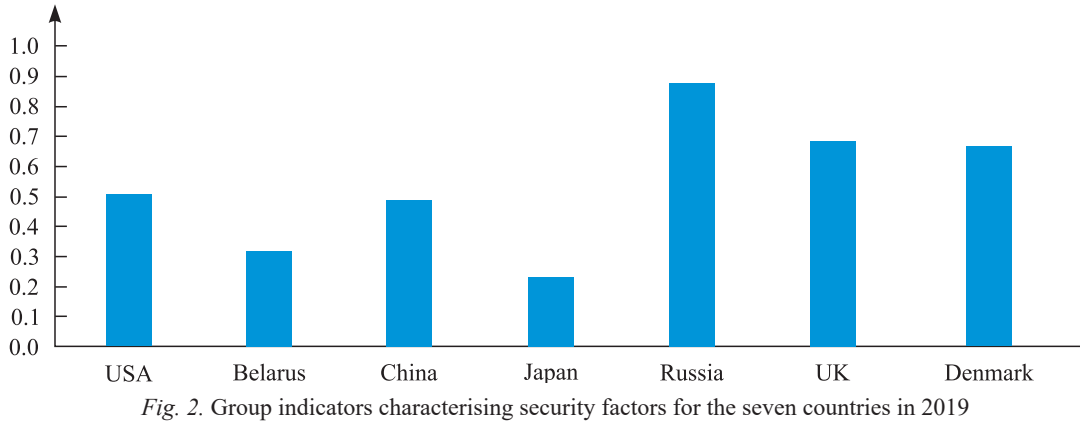

Fig. 2. Group indicators characterising security factors for the seven countries in 2019

As shown in fig. 3, about the social factors, we can conclude that Denmark, UK, USA and Japan are higher than Belarus, Russia and China. According to other indicators, this gap is mainly widened by energy intensity.

As shown in fig. 4, about the ecological factors, we can find that there is no significant difference in the values of the seven countries for this indicator. In terms of numerical value, Denmark is slightly higher than other countries (0.394), which is because Denmark has a great advantage in the proportion of clean energy generation.

As shown in fig. 5, the differences in employment rates between seven countries are not very large, but when it comes to investment in the energy industry, Denmark is undoubtedly the dominant player (0.526), while the USA, which accounts for a smaller proportion, has a lower value (0.257).

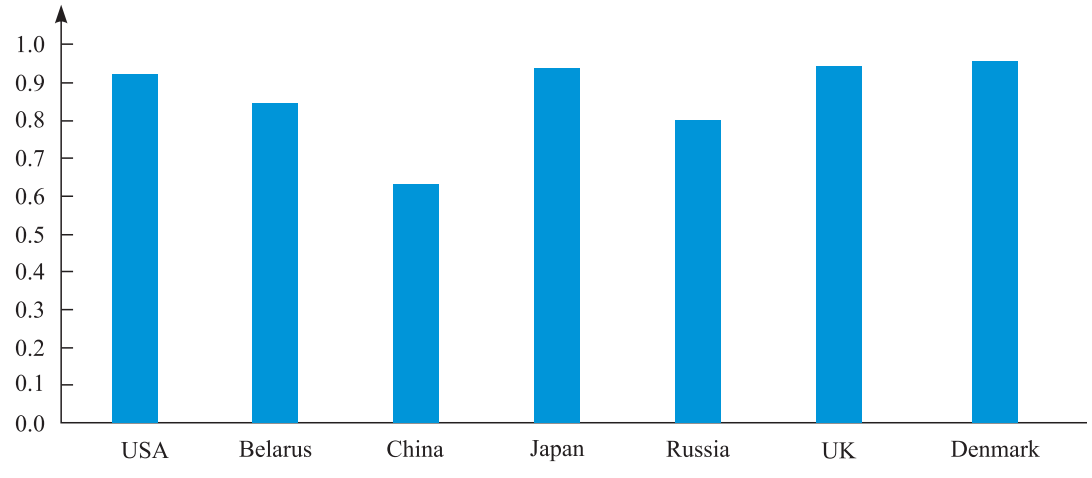

Fig. 3. Group indicators characterising social factors for the seven countries in 2019

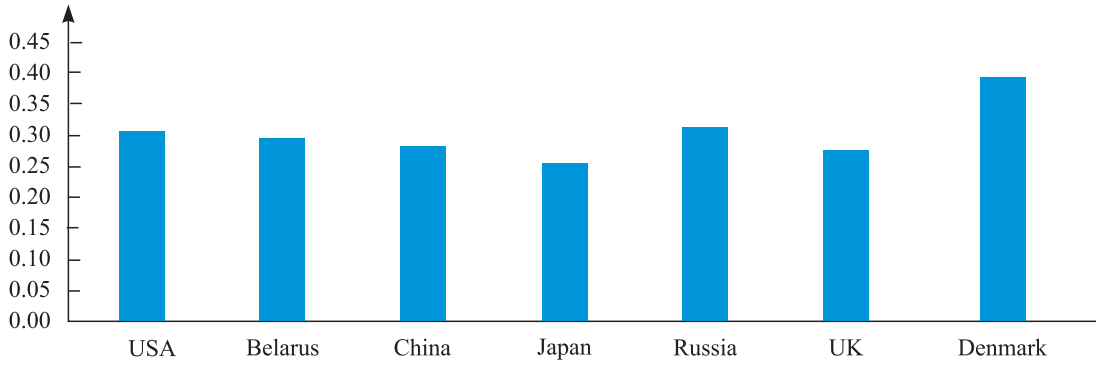

Fig. 4. Group indicators characterising ecological factors for the seven countries in 2019

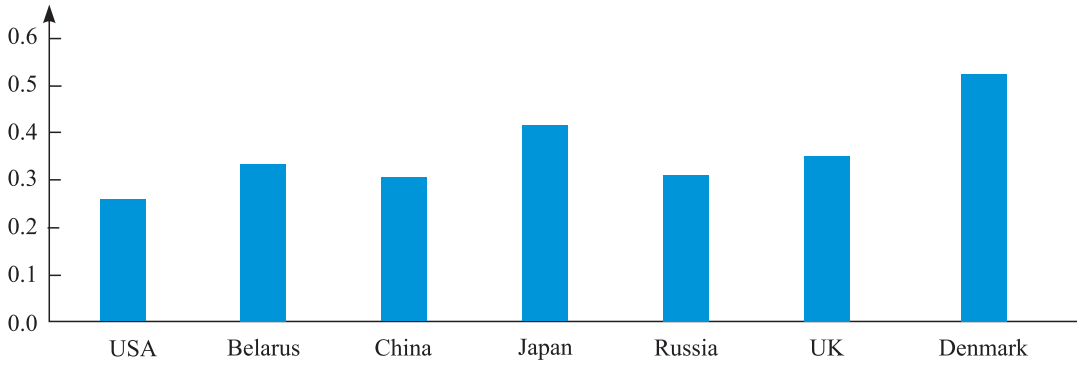

Fig. 5. Group indicators characterising economic factors for the seven countries in 2019

Sustainability of energy development in China

Based on the methodology, we calculate the index of sustainability of energy development for each province in China and classify each province as strong sustainability (rank 1), moderate sustainability (rank 2), or weak sustainability (rank 3) according to the index. The index of sustainability of energy development to each province and the classification are shown in the table 3.

According to the table 3, the sustainability of energy development in various provinces of China is universally poor. And there are no significant differences between provinces.

With the arithmetic progression, the provinces are classified as strong sustainability (rank 1), moderate sustainability (rank 2) or weak sustainability (rank 3). The majority of provinces (19 of them) belong to the category of weak sustainability (rank 3). And there are 4 provinces (Anhui, Chongqing, Gansu and Shanxi) belonging to the category of moderate sustainability (rank 2). Among them, Anhui has a significant advantage in terms of secure factor of sustainability of energy development, Chongqing performs better in terms of social and ecological factors, Guizhou has an advantage in terms of secure and economic factors, and Shanxi has an advantage in terms of secure and economic factors. There are 7 provinces (Beijing, Guizhou, Inner Mongolia, Qinghai, Sichuan, Xinjiang and Yunnan) which have strong sustainability (rank 1). Except for Beijing, all of them have strengths in the aspect of secure factor when it is concerned with sustainability of energy development. It is because that all these provinces have some energy endowment and are the resource-based regions of China. While as the capital of China, Beijing has an outstanding advantage in the aspect of social factor. This is inseparable from the level of social development in this region.

In terms of secure factor, there are significant differences in the index of sustainability of energy development between provinces and regions. The resource-based provinces (Inner Mongolia, Shanxi, Shaanxi and Xinjiang) have significantly higher indexes than other regions. Thanks to their abundant energy reserves, outstanding energy production capacity, and relatively large share of self-owned energy, these provinces have a higher degree of energy security and are less likely to be affected by the energy situation in other regions. However, most of China's provinces lack energy resources and have to rely on energy supplies from other regions to meet their requirement. This kind of dependence makes these provinces potentially at risk in terms of energy, and thus they have a low index of sustainability of energy development in the aspect of secure factor.

In terms of social factor, the level of sustainability of energy development in provinces of China is good. There are no major differences between regions. China is during a period of rapid social development, and initial success were achieved in the social construction. The implementation and enforcement of national policies are generally consistent across regions and have some good results.

In terms of ecological factor, the mean of index of sustainability is good countrywide, but there are obvious differences between regions. Some resource-based provinces (Inner Mongolia, Ningxia, Shanxi, Shaanxi, and Xinjiang) have severely low index of ecological factor. The ecological problems of resource-based provinces have become an issue that cannot be ignored. In China, the use of clean energy is relatively uncommon, and the main energy source is coal, which causes a large amount of CO_2 emissions. This makes ecological issues an important issue in China in energy.

In the terms of economic factor, the overall situation of all provinces is not good, and the differences between regions are not obvious. Some resource-based regions have a slightly higher index of sustainability of energy development in the terms of economic factor, but most of China's regions do not have advantages in resource, and investments in the energy sectors do not bring lucrative output returns, so from an economic perspective, the potential for sustainability of energy development is weak everywhere [4].

According to the above analysis, it can be seen that Chinese provinces are already in a great situation in terms of social factor of sustainability of energy development. As for resource-based provinces, such as Inner Mongolia, Ningxia, Shanxi, Shaanxi, and Xinjiang, the key to improving their energy sustainability is the ecological amelioration. Under the premise of ensuring a stable supply of energy nationwide, the production and emission of carbon dioxide will need to be strictly controlled. The government should invest more in clean energy and increase the use of clean energy at the national level. And for other regions that do not have resource endowments, the country should promote cross-regional energy flow projects to ensure a stable supply of energy in each region and avoid possible energy risks [5].

Conclusion

The findings show that energy security, social, ecological and economic factors play important roles in the sustainable development of the energy industry. The energy industry is one of the leading industrial sectors for the development of the national economy. For a country, the development and utilisation of energy is of great strategic significance in economic development.

The closer the country's index is to 1, the stronger the country's energy sustainability; the closer the country's index is to 0, the worse the country's energy sustainability. Based on the discussion of the research results, we first divide the seven countries into two categories: the index level is at [0.0, 0.5] and the index level is at [0.5, 1.0]. In this way the USA, Belarus, China and Japan are under the first category, while the UK, Russia and Denmark are under the second category.

Table 3

Calculation of the energy development sustainability index of Chinese provinces based on secure, social, ecological and economic factors

Province	Secure factor				Social factor				Ecological factor				Economic factor				Index of sustainability of energy development	Rank
	Proportion of dominant energy	Proportion of self-owned energy	Ratio of energy export and import	*Mean value*	Energy intensity	Education	Life expectancy	*Mean value*	Share of CO_2 emission in energy sector	Forest coverage	Share of clean energy	*Mean value*	Share of the investment in energy	Share of output in energy sector	Employ-ment	*Mean value*		
Anhui	0.737	0.658	0.008	*0.561*	0.963	0.266	0.751	*0.734*	0.687	0.287	0.077	*0.448*	0.019	0.160	0.974	*0.231*	0.493	2
Beijing	0.987	0.197	0.005	*0.378*	0.979	0.596	0.802	*0.842*	0.990	0.438	0.039	*0.630*	0.019	0.346	0.987	*0.285*	0.534	1
Chongqing	0.763	0.233	0.001	*0.335*	0.962	0.314	0.757	*0.748*	0.877	0.431	0.316	*0.643*	0.054	0.112	0.974	*0.237*	0.491	2
Fujian	0.833	0.097	0.011	*0.282*	0.968	0.264	0.758	*0.737*	0.770	0.668	0.453	*0.665*	0.017	0.130	0.965	*0.220*	0.476	3
Gansu	0.798	0.541	0.008	*0.514*	0.910	0.274	0.722	*0.703*	0.687	0.113	0.304	*0.478*	0.052	0.307	0.970	*0.288*	0.496	2
Guangdong	0.891	0.000	0.011	*0.245*	0.968	0.339	0.765	*0.760*	0.771	0.535	0.320	*0.605*	0.073	0.185	0.977	*0.268*	0.470	3
Guangxi	0.799	0.051	0.000	*0.246*	0.947	0.238	0.751	*0.718*	0.768	0.602	0.455	*0.652*	0.033	0.163	0.974	*0.240*	0.464	3
Guizhou	0.580	1.000	0.054	*0.713*	0.938	0.209	0.711	*0.698*	0.712	0.438	0.393	*0.575*	0.011	0.233	0.969	*0.246*	0.558	1
Hainan	0.892	0.000	0.005	*0.244*	0.957	0.295	0.763	*0.741*	0.768	0.574	0.385	*0.628*	0.021	0.133	0.977	*0.225*	0.460	3
Hebei	0.787	0.177	0.011	*0.313*	0.907	0.263	0.750	*0.703*	0.803	0.268	0.155	*0.528*	0.016	0.237	0.969	*0.250*	0.449	3
Henan	0.807	0.546	0.006	*0.519*	0.959	0.270	0.746	*0.732*	0.669	0.241	0.116	*0.440*	0.004	0.157	0.968	*0.221*	0.478	3
Heilong-jiang	0.667	0.381	0.002	*0.390*	0.915	0.303	0.760	*0.720*	0.660	0.438	0.180	*0.489*	0.008	0.321	0.965	*0.268*	0.467	3
Hubei	0.733	0.003	0.000	*0.202*	0.962	0.329	0.749	*0.751*	0.803	0.396	0.503	*0.647*	0.007	0.115	0.976	*0.213*	0.453	3
Hunan	0.627	0.138	0.000	*0.247*	0.960	0.300	0.747	*0.741*	0.855	0.497	0.382	*0.660*	0.014	0.107	0.973	*0.214*	0.466	3
Jilin	0.758	0.144	0.001	*0.285*	0.939	0.338	0.762	*0.743*	0.698	0.415	0.234	*0.520*	0.006	0.197	0.969	*0.233*	0.445	3
Jiangsu	0.896	0.044	0.007	*0.270*	0.967	0.349	0.766	*0.762*	0.758	0.152	0.135	*0.478*	0.009	0.134	0.970	*0.218*	0.432	3

Ending table 3

Province	Secure factor				Social factor				Ecological factor				Economic factor				Index of sustainability of energy development	Rank
	Proportion of dominant energy	Proportion of self-owned energy	Ratio of energy export and import	*Mean value*	Energy intensity	Education	Life expectancy	*Mean value*	Share of CO_2 emission in energy sector	Forest coverage	Share of clean energy	*Mean value*	Share of the investment in energy	Share of output in energy sector	Employ-ment	*Mean value*		
Jiangxi	0.714	0.063	0.001	*0.229*	0.961	0.270	0.743	*0.733*	0.793	0.616	0.200	*0.599*	0.007	0.157	0.971	*0.224*	0.446	3
Liaoning	0.861	0.176	0.004	*0.332*	0.905	0.329	0.764	*0.722*	0.745	0.392	0.288	*0.556*	0.007	0.211	0.958	*0.236*	0.461	3
Inner Mongolia	0.663	1.000	1.000	*0.908*	0.853	0.335	0.744	*0.692*	0.529	0.221	0.161	*0.373*	0.009	0.549	0.963	*0.330*	0.576	1
Ningxia	0.629	0.545	0.003	*0.469*	0.796	0.308	0.734	*0.651*	0.508	0.126	0.182	*0.349*	0.018	0.771	0.963	*0.395*	0.466	3
Qinghai	0.865	0.834	0.003	*0.691*	0.857	0.254	0.700	*0.664*	0.809	0.058	0.879	*0.691*	0.007	0.465	0.978	*0.309*	0.589	1
Shandong	0.829	0.276	0.005	*0.378*	0.942	0.287	0.765	*0.731*	0.645	0.175	0.102	*0.411*	0.049	0.201	0.967	*0.257*	0.444	3
Shanxi	0.759	1.000	0.176	*0.784*	0.877	0.338	0.749	*0.707*	0.248	0.205	0.119	*0.205*	0.010	0.762	0.973	*0.390*	0.522	2
Shaanxi	0.727	1.000	0.550	*0.844*	0.948	0.340	0.747	*0.745*	0.393	0.431	0.152	*0.334*	0.020	0.335	0.968	*0.279*	0.550	3
Shanghai	0.956	0.000	0.002	*0.261*	0.969	0.529	0.803	*0.819*	0.818	0.140	0.030	*0.479*	0.014	0.098	0.964	*0.210*	0.442	3
Sichuan	0.828	0.440	0.006	*0.467*	0.955	0.266	0.748	*0.729*	0.863	0.380	0.870	*0.777*	0.014	0.165	0.967	*0.229*	0.551	1
Tianjin	0.924	0.000	0.004	*0.253*	0.942	0.447	0.789	*0.779*	0.821	0.121	0.036	*0.480*	0.078	0.252	0.965	*0.287*	0.450	3
Xinjiang	0.832	1.000	0.146	*0.799*	0.864	0.297	0.724	*0.684*	0.590	0.049	0.229	*0.393*	0.031	0.394	0.979	*0.303*	0.545	1
Yunnan	0.666	0.733	0.013	*0.584*	0.948	0.219	0.695	*0.703*	0.841	0.550	0.909	*0.806*	0.048	0.177	0.967	*0.251*	0.586	1
Zhejiang	0.904	0.000	0.000	*0.247*	0.964	0.315	0.777	*0.753*	0.697	0.594	0.293	*0.568*	0.065	0.211	0.975	*0.271*	0.460	3
Weight	*0.273*	*0.545*	*0.182*	*0.250*	*0.545*	*0.273*	*0.182*	*0.250*	*0.545*	*0.182*	*0.273*	*0.250*	*0.545*	*0.273*	*0.182*	*0.250*	–	–

Overall, the USA ranks in the middle of the seven countries. We summarise some recommendations that the USA could pursue:

- reduce energy prices, try to develop local energy sources, and reduce foreign oil imports;
- reduce the burden on the energy industry and cancel the «climate action plan» that is harmful to energy;
- continue the shale revolution to rebuild roads, schools, bridges, and utilities with revenue from energy production;
- support clean coal technologies to revive coal industry;
- focus energy policy on protecting the environment and resources.

About Belarus, there are two plan be given: one is to improve energy efficiency, and the other is to develop the use of local fuel power resources, including renewable energy. The measures taken include adopting modern energy efficiency technologies, energy-saving equipment, instruments and materials; improving the working efficiency of power equipment; using technical equipment powered by local fuel power resources (including renewable energy) for energy production, transformation and modernisation. All these plans can improve the productivity of the national economy and enhance national energy security.

Based on China's index calculation results, we can make the following recommendations:

- adjust the industrial structure and promote the optimisation and upgrading of the industrial structure, when planning the consumption and production of energy, follow the laws of the market and fully consider the impact of industrial structure changes on energy consumption;
- increase investment in science and technology to improve energy utilisation, adhere to the policy of giving priority to energy conservation, strive to reduce energy consumption and improve energy efficiency;
- optimise the energy consumption structure and increase the development and utilisation of new energy, increase capital and technical investment in new energy, especially clean and renewable energy;
- strengthen the government's macrocontrol, not only invest in energy conservation and new energy technologies, but also strengthen administrative legislation.

In this regard, Japan can study alternative energy sources and gradually increase the proportion of new energy sources in its energy supply, such as nuclear energy, solar energy, hydro power and ocean thermal energy.

At the same time, Japan can seek close ties with various oil-producing countries, confirm the long-term and stable supply relationship between the two sides while cooperating in development, and conduct «technology transactions» in addition to money transactions.

The energy industry is the most important industrial sector in the Russian economy, an important force driving Russia's economic growth, and it also provides an important way and great potential for Russia to play a role in the international community. Since 1990, Russia's oil exports have risen from 47.7 to 73.6 % of total oil production[2].

Russia is trying to gradually invest in renewable energy by localising equipment and acquiring the necessary capacity. The government is working to create the conditions for renewable energy to be economically competitive in specific regions. After creating the necessary framework and making initial investments in research and development, and after the regulatory grey area and smaller barriers affecting companies developing renewable energy have been removed, the state can relax regulations and allow the industry to develop independently.

The UK can use scientific innovation to prioritise the development of renewable energy including wind, hydro (wave, tidal), biomass and solar energy; improve the efficiency of the energy industry and reduce carbon dioxide emissions by implementing an emissions trading scheme. The reduction and exemption policy encourages the use of high-efficiency energy resources; for the ecological environment, the use of fertilisers should be reduced, forests and vegetation should be protected, and agricultural greenhouse gas emissions should be reduced [6].

According to the results of the index calculation, Denmark's energy development sustainability has the highest score (0.635) among the seven countries, which is due to the Danish government's emphasis on energy development sustainability.

For many Danes, March 22, 2012 was a historic day. On this day, the Danish parliament passed the new energy bill with a huge lead. This bill, which is welcomed by most Danes, stipulates that by 2050, all energy supply in Denmark including electricity, heat, industry and transportation will be supplied by renewable energy provided. We can give the following suggestions [7].

First, Denmark should formulate clear energy development goals and plans. Renewable energy development and sustainable development have always been the main objectives of energy strategies and policies, which are also a distinctive feature of energy development in Denmark.

The second is to establish an energy regulatory department with clear functions and coordinating all parties. In 1976, Denmark established the Energy Agency, which is responsible for the top-level design of energy

[2] *Xie Y.* Status, potential and development trend of Russia's energy exports [Electronic resource]. URL: https://www.doc88.com/p-5751215431999.html?s=rel&id=7 (date of access: 26.10.2021).

development, the overall mobilisation of energy resources, formulating policies in the fields of energy production[3], transportation, sales and energy conservation, and supervising the implementation of policies.

The third is to fund the key research fields of wind energy development. The Danish government should clarify the key research areas for funding according to different stages of wind energy development.

The sustainability of energy development in various provinces of China is universally poor. And there are no significant differences between provinces. The majority of Chinese provinces belongs to the category of weak energy sustainability (rank 3). There are only 4 provinces belonging to the category of moderate energy sustainability (rank 2) and 7 provinces belonging to strong energy sustainability (rank 1). Chinese provinces are already in a great situation in terms of social factor of sustainability of energy development. Because of the abundant energy reserves, resource-based regions have much higher indexes on the secure factor and economic factor of sustainability of energy development. However, these provinces have lower indexes on ecological factor of sustainability of energy development countrywide. As for them, the key to improving their energy sustainability is the ecological amelioration.

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