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OPTIMIZING ENERGY BALANCE OF CHINA: PROBLEMS AND PROSPECTS

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The article analyzes the compliance of the current energy structure of China with the existing requirements of the socio-economic system and the principles of sustainable economy. The problems of the Chinese energy sector, which are increasingly dependent on imported fuels, have been identified. This fact predetermines the need to optimize China's energy balance and energy transform to meet the demand of modern society and the rapid growth of economic demands. It is substantiated that China needs to focus on energy efficiency, energy saving, renewable energy sources and transition to the main source of energy, i.e., natural gas, during formation of China's energy balance. Simulation for prediction of prospective energy balances is proposed; using it should allow to form the Chinese industrial structure of the electricity sector of industry in accordance with its production process, production volumes and resource consumption.

Keywords: evolution of electrical power industry, coordination of interaction, distribution efficiency, energy balance, energy structure

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ОПТИМИЗАЦИЯ ЭНЕРГЕТИЧЕСКОГО БАЛАНСА КИТАЯ: ПРОБЛЕМЫ И ПЕРСПЕКТИВЫ

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Анализируется соответствие современной энергетической структуры Китая сложившимся требования социально-экономической системы и принципам устойчивой экономики. Выявлены проблемы китайской энергетической сферы, которая все больше зависит от импортного топлива, что предопределяет необходимость оптимизации энергетического баланса Китая и преобразования энергии для удовлетворения спроса современного общества и быстрого роста требований со стороны экономических задач. Энергетическая составляющая рассматривается как важный индикатор оценки национальной экономики, а топливно-энергетическим ресурсам уделяется ключевое место в стратегических программах и во внешнеэкономической политике страны. Электроэнергетика, которая обеспечивает деятельность предприятий, различных отраслей, функционирующих на территории страны, безопасность государства и материальные условия жизни населения, является базовой стратегической системой. Влияние состояния электроэнергетического комплекса на экономику трудно переоценить, учитывая большую энергоемкость валового внутреннего продукта и рост спроса на энергоносители, что выводит проблемы эффективного функционирования энергетических предприятий регионов в ряд важнейших. Обосновано, что при формировании энергобаланса Китая необходимо сосредоточиться на энергоэффективности, энергосбережении, возобновляемых источниках энергии и переходе к основному источнику энергии – природному газу. Современная энергетика, являясь основополагаю-

щей отраслью в экономических системах, оказывает серьезное воздействие на развитие стран и их национальную энергобезопасность. Для выявления основных тенденций и подходов для определения влияния энергетического фактора на макроэкономические показатели стран наиболее важным представляется изучение сложившегося положения в энергообеспеченности их и мирового сообщества в целом, направленное на формирование и разработку обновленных способов, приоритетов, подходов и схем управления территориального развития национальной экономики с учетом энергетической составляющей. Происходящие на мировом и национальном уровне преобразования в этом направлении влияют и на организационно-структурную модернизацию производства в топливно-энергетических компаниях, на механизмы управления ими и на перспективы развития. Предложена имитационная модель для прогнозирования перспективных энергетических балансов, использование которой позволит сформировать китайскую промышленную структуру электроэнергетической отрасли в соответствии с ее производственным процессом, объемами производства и потребления ресурсов.

Ключевые слова: развитие электроэнергетики, координация взаимодействия, эффективность распределения, энергобаланс, энергетическая структура

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Introduction China consists of more than 30 provinces and special regions, and some of them are large not only in terms of area and population, but also in terms of production. It is very important to understand the differences between these regions in order to fully analyze the current energy infrastructure of China and optimize its future needs and necessary investments [13].

Currently, the task of developing country's energy balance with maximum detail is top priority in the fuel and energy complex. Based on the energy balance of the country, it is possible to develop or adjust the energy strategy in the field, and most importantly, gain an understanding how to construct an optimal system for forming tariffs [15]. It is necessary to understand exactly how much primary (oil, gas, fuel oil, coal, nuclear fuel) and secondary (heat, electricity, gas) energy resources a country has. Development of energy balance means a system of quantitative indicators of mining (production), conversion and final consumption in its territory for a certain period of time. The formed general energy balance serves as an information base of initial data for calculations of various derived indicators for determining the efficiency of using fuel and energy resources and a tool for controlling its flows at all levels from mining (production) to conversion processes and final consumption.

The absence of regional energy balances not only complicates, but practically eliminates clear tracking of fuel and energy flows along the whole chain of their passage, from mining (production) to final consumption, determining energy efficiency indicators, developing forecast balances to solve strategic directions for development of the fuel and energy complex, making the right decisions when concluding long-term contracts for import, transit and re-export, conducting continuous monitoring of the domestic market's energy resources, etc. [17]. These factors make the task of identifying the problems, opportunities and prospects for optimizing the energy balance of China all the more urgent.

Research methodology. The methodology of forming a general energy balance as a whole or individual balances by type of energy, territorial dependence, or by type of economic activity should be based on international recommendations of energy statistics, taking into account the specifics of the state and regional system of statistical accounting and respondent reporting, regardless of their affiliation. In addition, the energy balance is forecasting, comparing and balancing of supply and demand for all types of primary and secondary energy resources in physical and monetary terms necessary to ensure the life and development of the country.

According to methodological provisions [6, 7, 10, 20], the total energy balance includes the types of fuel and energy extracted or produced from natural

sources, or from conversion; those imported or removed by export; as well as difference in balances at the beginning and end of the current year. Volumes of fuel are provided in natural and arbitrary units calculated in caloric coefficients of coal equivalent. Electricity and heat energy produced by thermal power plants, boiler houses or other equipment that use fossil fuels were recalculated to fuel equivalent according to actual specific fuel consumption for their supply. Nuclear energy, hydro energy, energy of non-traditional sources were recalculated using averaged indicators of actual specific fuel consumption for electricity supply by power plants using organic fuel.

Nowadays in China, development of balances or the main types of energy resources occurs fragmentarily, not systematically and late, that is, the country does not have a clear answer to the question of what coal production volumes are needed. There are periods when coal companies' warehouses are overcrowded, and there are periods when thermal power plants operate «on wheels». So if a real balance that takes into account absolutely all aspects of supporting one or another generation is not developed in the regions of China, this can lead to large-scale disruptions in power systems. We can agree that the energy balance is the main and extremely difficult task, whose solution is connected with developing scenario forecasts of energy balance of the country and regions, which should allow to introduce a mechanism of financial risks [12, 19]. In scenario forecasts and balances, it is wrong to replace, for example, one energy source by another, it is necessary to follow the path of introducing technologies with high conversion rates, and rejecting the old industry approaches.

A very promising tool to solve these tasks is formation of an optimal energy balance at the state level, taking into account geographical features, administrative division, economic and socio-demographic characteristics [2]. The combined energy balance of the country is developed as a set of interrelated scenario forecasts of the processes of formation and distribution of energy resources by economic sectors in accordance with the scale and trends of the country's socio-economic development for the relevant period.

Analysis of methodological approaches to determining the future demand for fuel and energy resources (FER) shows that it is traditional to use optimization models for forecasting the development of the energy system. The same class of models were created in the Soviet Union for planning the development of the energy industry at different hierarchical levels. For the energy system of China, where the energy supply of the country's economy is perhaps the most acute issue of national policy, for a number of objective reasons, virtually no studies of this type have been conducted [3]. In conditions of deregulation in the energy sector, modeling the evolution of the fuel and energy complex (FEC) and its sectoral subsystems becomes much more complicated, especially for countries whose economies are in a state of transition to market regulation. In addition, violation of dynamic data series caused by repeated changes in methodological principles of collecting and processing economic and energy statistics makes entire classes of energy models almost impossible to use. Under such conditions, it is now highly advisable to develop a simulation energy-economic model for China.

The basis of this technique is the inter-branch balance matrix, which includes additional features. In order to eliminate possible disagreements between the indicators during the final operations of the balance division, the mathematical algorithms for its maintenance have been developed:

$$P_{G.C.} + P_{C.S.} = P_{C.E.S.} + P_{F.C.} + P_{loss} + P_{N.P.} + P_{ST.D.}, \quad (1)$$

where $P_{G.C.}$ is the level of energy resources supplied under the «Gross consumption» section; $P_{C.S.}$ is the level of energy resources converted with respect to the «Conversion sector» section; $P_{C.E.S.}$ is the level of energy resources consumed by enterprises of the conversion sector under the «Consumption by energy sector» section; $P_{F.C.}$ is the level of energy resources consumed under the «Final consumption» section; P_{loss} is the level of energy resources lost under the «Losses during transportation and distribution» section; $P_{N.P.}$ is the level of fuel consumed as a raw material for non-energy purposes under the «Consumption for non-energy purposes» section; $P_{ST.D.}$ is the energy levels under the «Statistical deviation» section.

The algorithms for determining the energy resource levels under the «Gross consumption»

section ($P_{G.C.}$) are written in the following form (expressions (2) and (3)):

$$P_{G.C.} = P_{vid.} + P_{imp.} + P_{\exp.} + P_{C.R.}; \quad (2)$$

$$P_{G.C.} = \sum_{j=1}^{n}(\sum_{i=1}^{g} P_{vid}^{i} + \sum_{i=1}^{n} P_{imp.}^{i} - \sum_{i=1}^{n} P_{\exp.}^{i} \mp \sum_{i=1}^{n} P_{C.R..}^{i}), \quad (3)$$

where $P_{vid.}$ is the level of energy resources mined or produced by the country; P_{imp} is the level of imported energy resources; $P_{\exp}$ is the level of exported energy resources; $P_{C.R.}$ is the level of change in the energy resource reserve for the end of the current year; i and j are the indices of energy resource type and section number, respectively.

Results. The resource base of the energy balance is determined by the existing reserve of fuel and energy resources (FER), the level of their geological exploration, the readiness of the existing production potential for extraction (processing) of these resources. The results of the simulation are [3]:

- FER consumption volume determined for the economy of the country and for its main sectors;
- Influence of individual state regulatory mechanisms on the level of energy consumption determined;
- Most rational structure of FER import and export determined;
- FER consumption optimized by the criteria of energy and environmental efficiency of the economy due to improvement of technological structure of production, processing and consumption of energy resources. The decisive factor for ensuring the implementation of a certain structure of the energy system is investment in creation of new production facilities and reconstruction of the existing energy facilities based on innovative models of reproduction of energy potential and introduction of new technologies both in production and in energy consumption.

The basic task of energy balance modeling is to assess the future demand for FER on the basis of initial information to determine the potential possibilities and sources for meeting this need. According to the expected volumes of energy consumption, the demand for key material and financial resources is projected. Forecasting the rate of socio-economic development and structural economic change is the basis for such assessment. For this purpose, it is necessary to identify the quantitative interrelations between energy and economics, which may have a different nature depending on the changes in public life, political and economic environment, scientific and technical base, management methods, world market conditions, environmental conditions [20].

We can agree with researchers who believe that the interdependence between economic development rate, changes in its structure and energy consumption is determined by a complex set of factors [9, 14, 16, 18]. Even for industrialized countries, there is no steady correlation between the rate of economic development and changes in energy consumption, and the quantitative impact of economic growth rates on the size and nature of energy consumption is difficult to identify. Among the factors, a special role is played by the structure of the country's energy capacity, consumer properties of individual energy resources and their interchangeability, the dynamics of energy prices, including in world markets, the nature of the mutual influence between prices and volumes of international energy exchange taking into account technological, economic and other factors.

The calculation of the future demand for energy is carried out using a modified production function, which takes into account the price and income elasticity of energy consumption and the coefficient of autonomous technical progress. The linear relationship between the volumes of final fuel consumption and, for example, the emissions of harmful substances (externalities) can be determined by the relevant conversion factors: the coefficients of environmental characteristics and other factors used for predictive calculations.

To analyze the effectiveness of predictive energy balances in accordance with the scenarios of economic development, a system of indicators should be developed, allowing to assess the coverage of energy consumption in the country. Conceptually, such assessment is developed on the basis that the fuel and energy complex should ensure the planned rates of socio-economic development of the country and comply with the set of key requirements for the environmental load, ensure energy and economic security, take into account the real financial and material support to adequately increase the production potential of the fuel and energy sectors. In particular, the main indicators for optimizing the energy structure, in addition to the energy and electricity intensity of the economy, are:

- Level of self-sufficiency by energy resources;

• Share of the dominant resource in the structure and sources of supply of primary FER;

• Share of final energy consumption in total energy supply;

• Indicators of physical deterioration and renewal of fixed assets of the industry's enterprises.

Analysis of statistical data on the sources of electricity production in China shows that the main share is for coal, which is the least environmentally friendly energy resource (Fig. 1).

Consumption of large amounts of coal led to a number of environmental problems: 85 % of sulfur, 35 % of suspended particles and 75 % of CO_2 in the atmosphere come from fossil fuel combustion. That is, the current structure of energy consumption determines the need to transition to renewable energy resources (RES), such as wind, sun and biomass, which are environmentally friendly. Renewable energy sources have become an important choice for China [4].

Considering production and consumption, the north-eastern, north-western and southern regions have significant excess generating capacity, and this situation of excess capacity will continue over the next decade without interference from regulatory authorities. Northern and central regions may have sufficient production capacity, but additional resources may be required in a scenario with higher growth rates. The eastern region requires new resources. Large differences in reserve capacity between the provinces indicate the need for greater coordination between them for ensuring sufficient generation throughout China [3]. Fig. 2 shows the electricity consumption distribution by regions, uniting nearby provinces whose energy structure is combined.

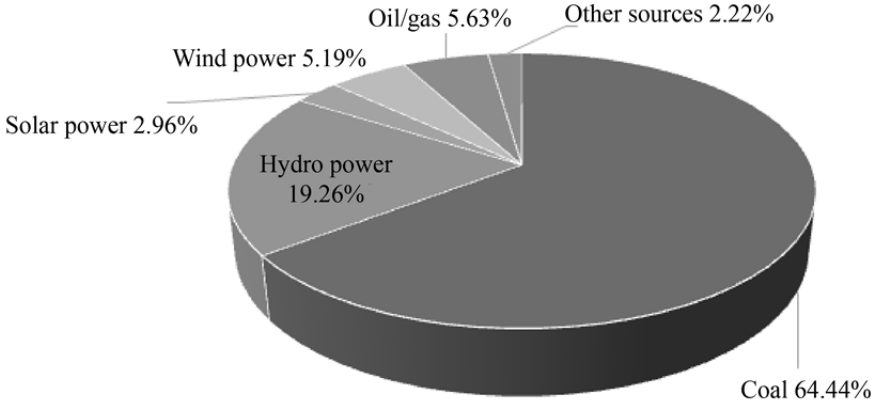

Fig. 1. Installed power capacity by source, 2015 (compiled from [1, 2])

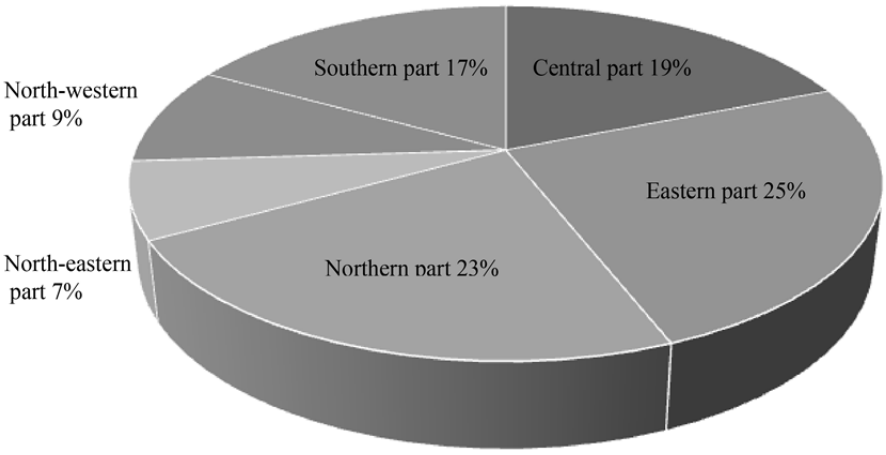

Fig. 2. Shares of regions of China's energy system in total electricity consumption, actual data for 2014, % [1] (compiled from [1, 7, 11])

[1] Key China energy statistics. China Energy Group – 2016. URL: https://china.lbl.gov/sites/default/files/misc/ced-9-2017-final.pdf; National Bureau of Statistics of the People's Republic of China, different years. URL: http://www.stats.gov.cn/english/

As seen from the figure, a large share of consumption falls on the northern and eastern provinces, while energy generation does not correspond to the consumption structure: most of the energy is generated in the northern part (20.8 %), the central part (20.2), and the eastern part (19.7 %), but ultimately, the volume of generated energy is insufficient for consumption (Fig. 1).

Despite this imbalance between supply and demand, research results show that China does not need new thermal power plants, or at least new coal units with a base load. This conclusion underlines the critical importance of improving the investment planning processes in China in order to avoid deterioration of the current problem of overcapacity (which is present in large amount in the country) and to achieve multiple policy goals of creating a reliable, environmentally friendly and cost-effective power system.

Based on the data from Tab. 1, we propose the main goals and objectives for optimizing China's energy balance.

Table 1

Actual data on generation and consumption of electricity

Region	Generation (GW)	Consumption (GW)	Level of correspondence, %
Central part	277.1	1091	25.4
Eastern part	269.8	1381	19.5
Northern part	285.3	1311	21.8
North-eastern part	122.6	397	30.9
North-western part	167.8	520	32.3
Southern part	246.4	932	26.4

Compiled using data from [1, 7, 11]

Table 2

Goals and objectives for optimizing energy balance in China

Goals	Objectives
1. Integrating energy system of provinces throughout the country 2. Improving energy efficiency of energy consumption 3. Balanced and sustainable development of RES 4. Optimization and modernization of energy infrastructure	1. Synchronization of China's energy system with production processes of national economy 2. Improving energy efficiency of energy consumption 3. Development of RES, focusing on increased use of hydro resources, solar energy, biomass and wind energy, use of renewable energy sources for production of centralized heat supply and domestic heating 4. Construction of interconnections in power industry 5. Providing balanced local capacity in production, reservation and balancing; cost-benefit analysis
1. Electricity prices in industrial sector should be the same for all provinces, and for citizens it is necessary to reduce the share of energy costs compared to average income 2. Smooth transition from fossil energy sources to renewable energy sources	1. Improving energy efficiency of energy consumption (energy intensity should not exceed the average in the world) 2. Development of RES, focusing on development of solar energy and wind energy, as well as further use of renewable energy sources for production of centralized heat supply. 3. Use of alternative fuels in transport sector and its electrification. 4. Creating necessary conditions for development of environmentally friendly energy production methods. Development of small and flexible local power-generating plants
1. 80 % of the country's energy requirements come from sources without pollution (zero emissions of greenhouse gases and other air pollutants) 2. 100 % of local electricity production in gross electricity consumption in the country	1. Completing necessary steps for development of environmentally friendly energy production methods 2. Development of efficient and environmentally friendly technologies for production, supply, storage/accumulation and consumption of energy

Compiled using data from [4, 9, 10].

Conclusions. Summarizing the above, it can be concluded that using energy models in the process of planning the development of the energy sector has become a common international practice. Analysis of applied model developments shows that creating a simulation model for predicting energy resources is a standard methodological approach for energy balance modeling. The methodology proposed in this article, based on an intersectoral balance matrix, can become a basis for studying the provincial relations between demand and supply in the power industry. In addition, the obtained results can be used to assess the level of development of electric power industry and effectively describe their dynamically changing coordination relations.

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