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## Article

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## Formation of energy policy in Europe, taking into account trends in the global market

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### Abstract

The article highlights the main trends in the development of world energy. The method of forecasting energy consumption is presented, taking into account the level and dynamics of energy consumption in general, as well as the use of individual energy resources with differentiation by countries and regions. In the present study, when forming the energy forecast, the key indicators determining the global energy demand are the dynamics of the energy intensity of GDP and per capita energy consumption. It is shown that in the total volume of world consumption of primary energy resources, oil will continue to occupy a leading position. Among fossil fuels, the demand for natural gas will increase most intensively. The share of coal in the structure of consumption of primary energy carriers will decrease, which is associated with the replacement of coal with natural gas in order to reduce carbon dioxide emissions. The greatest growth rates of demand among non-fossil fuels will be observed in renewable energy sources. The main growth in atomic energy consumption will be in the developing countries of the Asia-Pacific Region.

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### 1. Introduction

Approaches to modeling and forecasting world energy can vary significantly. Significantly different and systematization of such approaches. Jebaraj and Iniyan (2006) chose to compile a review of specific energy models [1]. In general, the authors aggregate all the considered approaches into several main groups — energy demand and supply models (Energy supply–demand models), forecasting models (Forecasting models), optimization models (Optimization models), models based on neural networks (Energy models based on). Neural networks, environmental models based on CO<sub>2</sub> emission reduction (Emission reduction models).

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Bazmi and Zahedi (2011) focus on the energy sector and optimization models, in particular, related to the production, distribution of energy, its consumption in multi-scale energy systems [2]. Pfenninger et al. (2014) present an analysis of existing energy consumption models within different model families [3].

The authors distinguish three main groups of models: (1) optimization models, (2) simulation models, (3) qualitative and aggregated models. There are other types of models, but these four are key to energy policy.

To build a forecast of energy consumption, trend models are often used in the literature. There is a significant amount of work devoted to analyzing trends in both energy consumption in general and specific indicators. One approach to predicting energy consumption is to analyze the dynamics of growth and the level of economic development, as well as the development of technology [4]. Harel and Baguant investigated the dynamics of the ratio of trends in energy consumption and GDP and the corresponding elasticity coefficients that can be used to predict energy consumption [5]. Ang and Zhang (2000) conduct energy consumption modeling using various growth curve models [6]. To predict US oil supply, mathematical models of growth curves have been developed [7]. Based on the saturation curves, extrapolation of the corresponding energy intensity values has been proposed to use modified logistic functions to forecast the demand for crude oil and natural gas this method is proposed by Hammond and Mackay (1993) [8].

Proper analysis of sustainable trends in the extraction and consumption of energy resources in European countries is necessary for the formation of an effective system of state regulation of the fuel and energy complex. An analysis of the development of the energy system in the world is particularly relevant for countries targeting the import of raw materials, which should closely monitor the energy market and forecast its fluctuations and trends. In this regard, the goal of scientific work is the study of structural changes in the energy consumption system of the world, as well as European countries. To achieve this goal in the work were solved the following tasks:

1. Review of existing approaches to predict energy consumption.
2. Analysis of sustainable trends in the extraction and consumption of energy resources in European countries.
3. Building a forecast of energy consumption up to 2040, taking into account differentiation according to the macroregions of the world and types of energy.

## 2. Methodology

To assess the levels of specific energy consumption over the coming decades, a dynamic analysis of the time series of energy consumption by countries and regions from 1970–2017 is carried out. Based on statistical information of the world's largest economic and energy organizations (United Nations Organization, Organization for Economic Cooperation and Development, International Energy Agency, Energy Information Administration, International Bank, International Monetary Fund, etc.) and companies (British Petroleum, Exxon Mobil, Royal Dutch Shell, etc.) a database of countries is created, which is necessary for building an energy consumption forecast.

When building a model of energy consumption, special attention is paid to the consideration of specific energy consumption as per unit of population (per capita energy consumption)

$$E_N = \frac{E}{N}, \quad (1)$$

and per unit of GDP (energy intensity of the economy)

$$Ef = \frac{E}{BB\Pi} \quad (2)$$

where  $E$  — energy consumption,  $N$  — population.

When building prospective energy consumption levels, an important step is the formation of reliable projections of population size and gross domestic product. This is stated in the works of the authors Carayannis et al. (2017), Cherepovitsyn (2018), Sharf et al. (2014a), (2014b) [9–12]. The work is systematized and grouped forecasts into the appropriate structure, made in other research organizations and centers.

Next is the approximation and functional description of the energy intensity levels of the economy  $Ef$  and per capita energy consumption  $E_N$  in time.

Taking into account the conducted dynamic analysis of the energy intensity of GDP around the world, a trend has been revealed to reduce the energy intensity of the economy, which is described by exponential dependence:

$$Ef = \beta * e^{-\gamma t}, \quad (3)$$

where  $\beta$  is the coefficient determining the level of energy intensity of the economy of the initial year,  $\gamma$  — the coefficient of intensity of the economy's energy intensity reduction (The index of energy intensity reduction (IEIR)),  $t$  — the current year.

In the last decade with small current fluctuations, the level of energy consumption per capita is described by linear dependence:

$$E_N = \frac{E}{N} = \varphi + \mu * t, \quad (4)$$

where  $\varphi$  — the amount of per capita energy consumption of the initial year,  $\mu$  — the coefficient of the intensity of change in per capita energy consumption.

Since trend models do not always provide reliable estimates, especially for developing countries, the adjustment of forecast values is carried out taking into account the construction of a multifactor model.

Next is the construction of a multifactor spatial model and analysis of the influence of various groups of factors and individual indicators on the specific level of energy consumption.

Among the various groups of factors influencing the level of specific energy intensity in the framework of the stage under consideration, a multifactorial regression model of the influence of controlling factors is being built (economic structure, level of development of energy-saving technologies, climatic conditions, resource endowment, energy prices, environmental constraints, fuel and energy balance structure):

$$Ef = f \left( St, Teh, \frac{R}{N}, C, Eco, StE \right), \quad (5)$$

$St$  — economic structure,  $Teh$  — level of development of energy-saving technologies,  $R$  — hydrocarbon reserves,  $N$  — population,  $C$  — relative prices,  $Eco$  — environmental restrictions,  $StE$  — structure of thermopile. To determine the energy intensity levels of GDP in developing countries and regions, the multivariate model sets the value to which the energy intensity of developing countries will strive for a group of control indicators. The same applies to developing countries and regions that have not had a steady decline in specific energy consumption per unit of GDP. The result is an adjustment of the trend model, taking into account the multivariate analysis.

For all considered groups of countries, an energy consumption forecast for each year is given, based on the energy intensity of the economy.

Also in this block is given the forecast of energy consumption, based on the level of per capita energy consumption. Taking into account the analysis of the influence of factors on the level of per capita energy consumption in developed countries and the functional dependence of specific energy consumption, a forecast is made of the change in per capita energy consumption over time.

As a result, a forecast of energy consumption per capita is given for all the considered groups of countries, from which, taking into account the existing population scenarios, the level of energy consumption is predicted for each year around the world. Taking into account the above approaches, a combined version of the energy consumption forecast for each macro-region and each energy carrier is formed. The fulfillment of the condition of equality of energy consumption values obtained through the energy intensity of the economy and through the level of per capita energy consumption is checked:

$$E = E_f * BBII = E_N * N. \quad (6)$$

### 3. Results and discussion

On the basis of the proposed methodological approach, it was revealed that during the forecast period, consumption of all types of energy carriers is expected to increase. The total energy consumption by 2040 will grow to more than 17670 million tons of oil equivalent. At the same time, the highest rates in the world will increase the consumption of renewable energy sources (more than 5 times from 2017 to 2040), the slowest increase will be oil consumption (slightly more than 1.1 times from 2017 to 2040) and coal (slightly less than 1.1 times from 2017 to 2040) (See Fig. 1).

By 2040, in the structure of primary energy consumption in the world, the share of oil will decrease to 28% (from 34%), coal — to 22% (from 28%), which is connected with the substitution of these energy carriers for other types of energy in order to reduce carbon dioxide emissions. In addition, atomic energy will be reduced to 4%. For all other energy sources, there will be an increase in the share in world energy consumption (See Fig. 2).

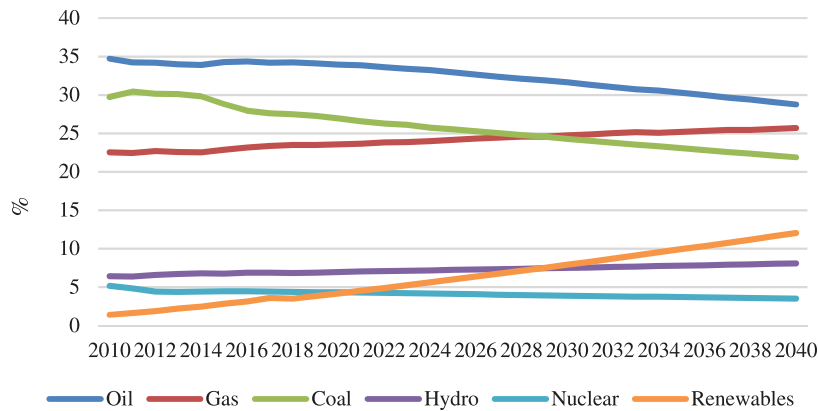


Fig. 1. Structure of primary consumption in the world by type of energy.

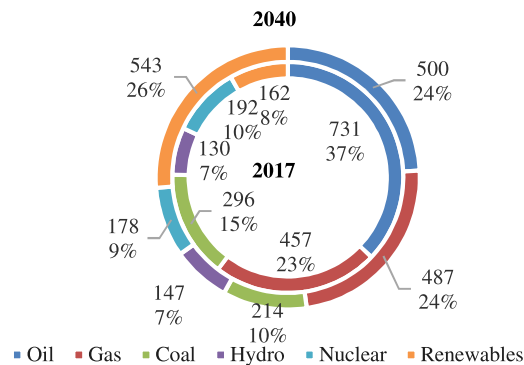


Fig. 2. The volume and structure of primary energy consumption in European countries in 2017 and 2040, %.

The development of gas technologies (shale gas, deep-sea deposits of hydrocarbons), transportation (LNG, offshore pipelines), expansion of the resource base (Central Asia, USA, shelves of the Arctic seas), rapid development of new (APR) and traditional markets (Europe), tightening environmental factors associated with limiting CO<sub>2</sub> emissions [13–15].

The growth of global energy consumption is due to rising prosperity and rising living standards in emerging market economies. The largest increase in energy consumption in the world will be achieved at the expense of the APR countries: China and India. At the same time, as China transitions to a more sustainable model of economic growth, there will be a decrease in energy consumption growth rates. With population growth and labor productivity, there is an annual increase in energy consumption in African countries.

In the structure of primary energy consumption in Europe, by 2040, it is planned to reduce the share of oil from 37% (2017) to 24%, and the share of coal from 15.1% (2017) to 10.3%, mainly due to growth of renewable energy.

The active transition of European countries to renewable energy sources (RES) is due to the availability of energy resources that do not have a negative impact on the environment, human health and contribute to resource conservation. As the share of renewable energy grows, the use of renewable energy sources becomes more and more economically competitive, and sometimes cheaper than the consumption of other types of energy.

#### 4. Conclusion

The main trend in world energy development is the growth of energy production and consumption for all energy carriers without exception. As civilization develops, there is a significant diversification and expansion of the range of energy sources consumed, uneven distribution of the main centers of energy production and consumption, uneven energy consumption in developed and developing countries. Taking into account the proposed methodological

approach, it is shown that the growth of production and consumption of fossil energy sources will continue. At the same time, hydrocarbon production will grow at a slower pace than the production of alternative and renewable energy. Thus, when forming a balanced energy policy in Europe, it is necessary to take into account sustainable trends in the global energy market.

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