Regional features of the influence of inter-fuel competition on energy consumption

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Abstract. The article analyzes the main stages of the formation of inter-fuel competition. A statistical analysis of changes in the fuel and energy balance at the global and regional levels has been performed. The key factors contributing to inter-fuel competition at the present stage of development of energy markets are highlighted.

1. Introduction
A steady trend in the development of global energy in the history of mankind, including the beginning of the XXI century, is the continuous growth of production and consumption of minerals, renewable and alternative energy sources [1]. However, the structure of energy consumption over the past decades has undergone significant changes under the influence of greening and inter-fuel competition [2]. The global benchmark in the development of national energy policy and international cooperation in the energy sector until 2030 is the UN Global Program for Sustainable Development Goals (SDGs) [3]. The UN sustainable development goals are a key part of the global system of targets and indicators, in particular, to increase the consumption of energy produced from renewable sources, the transition to environmentally friendly energy sources and a multiple increase in energy efficiency across the country as a whole [4].

At the same time, the fuel and energy complex is the main element of the global energy supply system, serves as the basis for the formation of state budget revenues of producing countries and resource regions, a guarantor of social stability, a driver of technological and innovative development and economic growth [5].

Inter-fuel competition and regional features in the development strategy of certain types of energy determine the purpose of this study - to test the hypothesis that in Europe countries a high level of inter-fuel competition and consumption of renewable energy sources negatively affect the consumption of hydrocarbons, and in Asia-Pacific countries, on the contrary, there is a low level of inter-fuel competition.
2. Stages of inter-fuel competition
Initially, the simplest types of fuel – wood, peat, etc. – were involved in the economic turnover. Later, as human ideas about the useful properties of natural resources, as well as methods and technologies for their extraction and use, developed, coal became the main source of energy [6, 7]. To date, the bulk of value added in the coal industry is largely determined by the use of coal for the production of electric energy and heat. In the end of the XIX century the so-called era of oil began. Crude oil was practically not used in the economy; it was necessary to carry out the process of its refining [8]. At first, oil was processed into kerosene, which is associated with the proliferation of kerosene lamps in everyday life and urban improvement, starting in the 1850’s. After the invention of the internal combustion engine, oil began to be used more and more to produce motor fuels, which allowed to form added value not only in the sector of extraction and export of raw materials, but also as a result of primary processing [9]. In the late XIX – early XX century the processes of secondary oil refining as a result of thermal or chemical catalytic decomposition of products of primary oil refining with the aim of obtaining raw materials for the subsequent production of aromatic hydrocarbons – benzene and its homologs (toluene, xylene, ethylbenzene, etc.) became widespread. Ensuring a full cycle of oil refining and organizing high-tech and innovative industries for the production of high value-added products will provide the economy with an additional source of sustainable growth [10].

The involvement of natural gas in the world’s economy, as well as oil, began with the domestic sector – after the invention of the gas burner in the middle of the 19th century [11]. In Russia, the gas industry began to take shape from the middle of the 20th century. The added value in the gas industry is created mainly in the energy sector and in the community [12]. Although recently, due to the tendency to decarbonize and green the economy, there has been an increase in gas consumption due to the substitution of coal in the energy sector and petroleum products in the transport sector. Therefore, the transport component is actively added to the traditional sectors of the gas industry (production, energy, and petrochemicals) [13, 14].

3. Data
The research information base was compiled with data from the Statistical Energy Review EP for 2019. Data on the consumption of the main fossil fuels - oil, natural gas and coal, as well as alternative (renewable) energy sources - wind, solar, nuclear and hydropower, are systematized and summarized in a single fuel and energy balance. The data coverage period was almost 50 years - from 1970 to 2018.

An analysis of the data showed that in 2018 the growth rate of primary energy consumption was 2.9%, which is the highest indicator since 2010 (figure 1). It is worth noting that the acceleration in the rate of growth in energy consumption occurs against the background of a slight slowdown in the global economy and in the context of rising energy prices [15].

The total increase in energy consumption in the previous year amounted to 390 million tons of oil equivalent, of which about 43% accounted for natural gas, alternative energy provided more than 25% of the increase. About 75% of primary energy consumption is in industrial production and construction. At the same time, the growth in energy consumption in transport has slowed significantly, which is primarily due to the increase in energy efficiency of transport.

In the regional structure, more than 298 million tons of oil equivalent or 76% of the growth in energy consumption in 2018 was provided by four countries: China, the USA, India and Russia. These same countries account for more than 51% of energy consumption in the world. At the same time, European countries are key consumers of oil and gas supplied from Russia. Therefore, in the study, the authors chose the European market, traditional for Russia, and the fast-growing and promising market of the Asia-Pacific countries as an object of research on inter-fuel competition.
4. Methods
The basis of the model of inter-fuel competition in the work is the opposition of the consumption of fossil and renewable energy sources. In order to determine the competitiveness of renewable energy sources, a multivariate linear regression was constructed, where the dependent variable is the total consumption of oil, gas and coal, and the independent ones are the consumption of solar, wind, geothermal and hydropower. This model will help to identify the existence of negative or positive dependencies of fossil fuel consumption on renewable:

\[ NR = \alpha_0 + \sum_{i=1}^{4} \alpha_i * X_i \]  

where NR – total consumption of oil, gas and coal, X1, X2, X3, X4 – consumption of solar energy, wind energy, cumulative consumption of geothermal energy, biofuels and hydropower, respectively.

It is assumed that in the OECD countries of Europe, the main competitive fossil fuels are wind energy, and in the countries of Eastern Europe - hydropower. The Asia-Pacific region is a world industrial center, and significant economic expenditures are required for economic growth, therefore, the effect of substitution of fossil energy carriers can be weakly expressed.

The next stage after the construction of the model was verified by its consistency and the significance of the obtained coefficients using the Student and Fisher criteria. The null hypothesis, verified by Student's test, is that the factor coefficient is zero. To confirm or refute it is necessary to calculate statistics, and if the level of its significance does not exceed 5%, then the null hypothesis is rejected. Student statistics are determined by the following formulas:

\[ t_{cj} = a_j * S_j^{1/2} \]  

where \( a_j \) – calculated coefficient at the j-th factor, \( S_j \) – unbiased coefficient variance, \( t_{cj} \) - t-statistic having Student's distribution.

The Fisher test checks the consistency of the constructed regression. For this, F-statistics are calculated using the formula:

\[ F_c = R^2 \times (N-n-1) \times [(1-R^2) \times n]^{1/2} \]  

Figure 1. Structure of consumption of energy resources.
where R² – R-squared regression, N – number of observations, n – number of factors. The resulting equation is considered reliable if the significance level of the F-statistics does not exceed 5%. You should also pay attention to the obtained R², the higher it is, the greater the share of the explained variance in the total.

5. Results and discussion
The development of alternative and renewable energy should contribute to the gradual abandonment of traditional fuels – oil, gas and coal. However, the process of replacing fossil fuels is slow, since projects to create an energy complex based on renewable resources require a lot of time to implement, have special requirements for the level of technological and human resources, in most cases they are capital intensive and require government support. In order to assess the competitiveness of renewable energy compared to fossil energy, multivariate linear regressions were constructed for two groups of European countries (members of the OECD and not members of the OECD) and Asia-Pacific countries.

| Table 1. Inter-fuel competition model for OECD countries in Europe. | 2007 | 2010 | 2015 | 2016 | 2017 |
| --- | --- | --- | --- | --- | --- |
| Sunny | + | + | + | + | + |
| Significance level | 0.12 | 0.00 | 0.21 | 0.19 | 0.14 |
| Wind | - | - | + | + | + |
| Significance level | 0.00 | 0.7 | 0.26 | 0.39 | 0.10 |
| Geothermal | + | + | + | + | + |
| Significance level | 0.00 | 0.00 | 0.23 | 0.34 | 0.84 |
| Hydropower | + | + | + | + | + |
| Significance level | 0.4 | 0.05 | 0.98 | 0.86 | 0.73 |

| Table 2. Inter-fuel competition model for non-OECD countries in Europe. | 2007 | 2010 | 2015 | 2016 | 2017 |
| --- | --- | --- | --- | --- | --- |
| Sunny | + | - | - | + | + |
| Significance level | 0.8 | 0.9 | 0.68 | 0.93 | 0.93 |
| Wind | - | - | - | - | - |
| Significance level | 0.9 | 0.11 | 0.45 | 0.43 | 0.93 |
| Geothermal | + | + | - | - | - |
| Significance level | 0.33 | 0.67 | 0.20 | 0.68 | 0.45 |
| Hydropower | + | + | + | + | + |
| Significance level | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |

| Table 3. Inter-fuel competition model for Asia-Pacific countries. | 2007 | 2010 | 2015 | 2016 | 2017 |
| --- | --- | --- | --- | --- | --- |
| Sunny | + | + | + | + | + |
| Significance level | 0.29 | 0.09 | 0.29 | 0.27 | 0.19 |
| Wind | - | + | + | + | + |
| Significance level | 0.31 | 0.05 | 0.02 | 0.00 | 0.00 |
| Geothermal | - | - | + | + | + |
| Significance level | 0.78 | 0.6 | 0.05 | 0.09 | 0.14 |
| Hydropower | + | + | + | - | - |
| Significance level | 0.00 | 0.00 | 0.67 | 0.88 | 0.35 |

The study did not reveal a statistically significant negative dependence of hydrocarbon consumption on renewable energy sources. In the OECD countries of Europe, the influence of wind and geothermal energy on the energy consumption of oil and gas, in another group of European countries – hydropower, and in the Asia-Pacific region – wind. The largest hydroelectric power stations are located in the countries of Eastern Europe, but they were not created to replace hydrocarbons, but to meet the increased energy demand. OECD countries of Europe, although
developing alternative energy, are nevertheless highly dependent on traditional energy resources. This leads to an increase in the consumption of renewable energy sources with a simultaneous increase in the consumption of hydrocarbons. The largest industrial enterprises are located in the Asia-Pacific countries, so alternative fuel only makes up for the need for energy, and it is not enough to completely abandon traditional energy resources.

6. Conclusion
The most stable trend in the transformation of the fuel and energy balance is the displacement of fossil fuels. Two competitive groups have developed – these are fossils (oil, gas, coal) and renewable or alternative (wind, solar, geothermal, nuclear, etc.) energy sources. At the same time, competition between energy carriers is also observed in each of the groups. The main driving forces in the inter-fuel competition at present are the environmental factor, which stimulates the growth of production and consumption of renewable energy sources, as well as the price factor. It should be noted that it is oil prices that largely create the prerequisites for inter-fuel competition. High oil prices necessitate the search for cheaper energy sources, for example, natural gas, the price of which is based on long-term contracts and is not as volatile as oil.

A factor that has lost its relevance in connection with the intensive development of technologies for the search, assessment, development and production of hard-to-recover minerals is a factor of exhaustibility. In connection with the increase in the security of the current level of oil production by reserves, it ceases to be important to replace oil with other energy carriers in anticipation of its exhaustion. This indicator is constantly growing and the world average is 54 years. The countries most endowed with reserves are Venezuela, Libya and Canada, which can maintain production at the current level for 620, 132 and 106 years, respectively. The exhaustion factor has lost its influence on the balance of supply and demand and, as a result, the price situation on fossil energy carriers. The factor of production efficiency becomes more important. Thus, the development of production technologies, for example, shale oil, allows the United States, combined with government support measures, to increase oil production, which has a tremendous impact on the balance of supply and demand, as well as the market price. This was confirmed by the events of the beginning of 2020, when, as a result of intensified production, the United States brought oil prices to historic lows.

Thus, the inter-fuel competition at the present stage has a man-made character, so to speak, and is largely determined not by natural or evolutionary reasons, but by strategic guidelines for the development of individual countries or macro-regions.

Acknowledgments
The study was carried out with the financial support of the Russian Science Foundation in the framework of grant No. 17-78-20218.

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