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Technological Changes as the Development Factor of the Global and Russian Energy Sector

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ABSTRACT

This article aims to study the real and hidden technological changes that will shape the strategic contours of the world energy civilization development, as well as the development of the Russian energy sector. The paper presents the following main conclusions: (i) Global energy development and nation states energy sector development are determined by a set of issues, foremost of which is innovation and technological aspect that determines the local and global changes that are likely to lead to the formation of a new energy civilization; (ii) New energy civilization is established by concepts of "green economy" and "smart energy." In the new energy civilization for a sufficiently long period, the level of primary fossil energy resources consumption will be reduced, and the consumption of energy derived from renewable energy sources will be increased; (iii) The prospect of long-term and distant future now requires a reorientation of national energy sectors from resource-intensive and resource-dependent development type to resource-efficient and resource-tech development type. For the Russian energy sector, which is one of the problematic areas of the national economy, the local and systemic solutions are offered that reduce the level of its energy intensity and improve its energy efficiency.

Keywords: Energy Sector, Green Economy, Consumption
JEL Classifications: O32, Q48, O13, Q28, Q57, Q38

1. INTRODUCTION

In modern conditions, when the volume of production of primary fossil energy sources tends to decrease, but the demand for traditional energy sources is still high enough according to forecast of its growth due to the Asian region (Energy Futures, 2013), the question arises of ensuring the energy security of individual states and world in general. There are several key scientific views of how the world will develop in the energy plan for the near and distant future. For example, individual researchers and scientists (Gasanov, 2009) state that the global energy development will go in the traditional direction of preserving the very significant proportion of traditional fossil energy resources (primarily oil and gas) in the global energy balance and the balance of the individual nation states. Herewith, the local, sectoral, or technological breakthrough solutions can be implemented that will allow us the following:

- Firstly, to increase the efficiency and effectiveness of the primary fossil energy resources extraction while minimizing their wastage during production and processing;
- Secondly, to reduce the level of threats to the planetary ecosystems that are directly related to industrial production and processing of energy resources;
- Third, to replace the aggressive and the most irrational ways of extraction and use of the traditional energy resources, which pose a threat for the life of modern civilization.

Another group of researchers (Goldthau and Witte, 2009; Grenander, 1994) insists that in a nearby term, such technological discoveries are possible that will completely abandon the traditional (primary fossil) energy sources and switch completely to renewable energy sources in addition to those that already exist now (the nuclear power industry, the use of water, wind, solar, geothermal energy as the renewable energy sources, etc.). In particular, the biofuels industrial production technologies are most likely recognized in this respect, as well as the energy resources production technologies directly from the environment with the use of non-fuel power generators. However, the fact should be accepted that the industrial production of biofuels has both its advantages and disadvantages, and the weight of threats (not only social and economic but also environmental) is very significant. Therefore, at this stage, the biofuels have the limited and local application. The use of non-fuel power generators is still in the theoretical development stage and is unlikely to be implemented in the medium and long term, it is the prospect of the distant future.

There is also a view that integrates the first and second approach (Yergin, 2008; Moran and Russell, 2009), and is it that the energy development of the modern world and the individual nation states will follow the path of gradual and not rapid reduction in the consumption of hydrocarbons with a gradual and phased transition to the use of existing and new renewable energy sources. And this gradual transition will be based on the global experience of the energy sector evolving, as well as on overt and covert technological changes that will shape the new energy civilization. The new energy civilization will be established by the concept of "green economy" (Davies and Simonovich, 2009), energy efficiency and energy sustainable society, and "smart energy" (Green Economy, 2011).

It appears that the third integrated approach to the consideration of the prospects of the global energy development is the most appropriate, so in this article, the overt and covert technology trends should be examined that will determine the most important aspects of the modern civilization for long-term operation and preservation of its for distant perspective.

2. METHODOLOGY

In this article, the system analytical methodical approach is used that allows us to identify the main patterns of formation and changes in the energy sector of the global economy, as well as the results of the energy development achieved to the study date. In addition, the analytical approach allows us to investigate the overt and covert technological changes that determined the formation of the modern civilization and its energy sector, and which will determine the long-term trends in the formation of the new energy civilization (the prospect of the distant future). The article also applies to the macroeconomic analysis, which allows us to briefly review the current status and issues of the Russian energy sector development. The global technological changes are identifies as part of the most probable trend of the global development in the medium and long term, as well as the local technological solutions that will ensure the growth of energy efficiency, reduction of energy consumption and energy security in global. The paper pays special attention to the practical methodical aspects of application of the energy development results (mainly in terms of the renewable energy sources) in order to solve the most pressing issues accumulated in the Russian energy sector up to the study date.

3. RESULTS

Since the second half of 20th century, contemporary social, political, economic and technological space is formed and transformed under the influence of two key factors: The final stage of globalization and the transition to the economy of knowledge. In these circumstances, the issues become important of not only changing the face and structure of world economic relations, but also of the global energy sector, as the energy sector fundamentally determines the viability of civilization and the quality of its development. At this stage, there are three key aspects that are likely to determine the technological trends of the energy sector (not only national but also international) in the long term.

And the first aspect can be regarded as a spatial, namely these are the allocation and distribution of the primary fossil energy resources reserves to the territorial and geographical point of view. Currently (and this is an indisputable fact), the major global energy resources (about 2/3) are concentrated in the territory of Russia, the US and China. The European continent possesses small reserves of fossil or primary (traditional) energy resources. Regarding Africa, the concentrated fossils in the form of the primary energy resources reserves can be considered significant. Thus, the energy consumption synthesized from the primary fossil energy resources increased for more than 10 times only in the last 100 years. But according to current forecasts, by the middle of this century, the consumption of primary energy resources in the form of oil and gas will insignificantly reduce by increasing the volume of energy production from the renewable sources (Figures 1 and 2).

Of course, all the countries with reserves of certain types of primary energy resources will seek to not only rationalize their use (reducing energy consumption and increasing energy efficiency), but also to improve the efficiency and effectiveness of their removal from the depths with decreasing the level of losses in production. Thus, it is likely that in the long term, spatial and geographic pattern of world energy sector will be transformed, including the changes in the specificity of the civilization development.

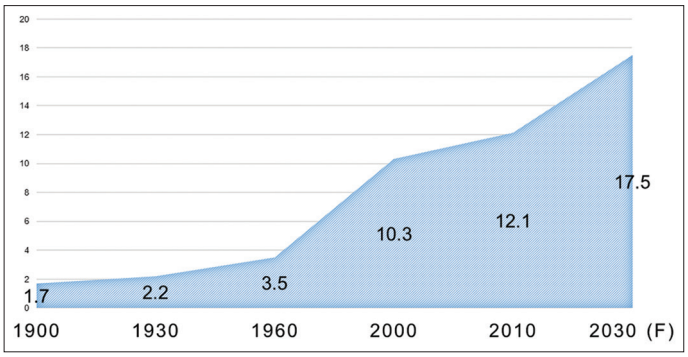
The specificity of the modern civilization evolution is the second important aspect in determining the development of the global energy sector. On the one hand, it can be said that the modern civilization evolution depends directly on the state and dynamics of changes in the energy sector. But on the other hand, the civilization achievements (primarily scientific and technological) largely determine the contour of the global energy map. It can be assumed that influence of the actual energy and proper civilizational trends on each other is *vice versa*.

Over the past 10 years, the global gross domestic product has increased almost two times, and the level of energy consumption in the world has showed an increase of not more than 1/3 (Figure 3).

Available data indicate that the level of energy intensity of the global economy and society at this stage reached their limit values, i.e. a further increase in energy consumption (while maintaining the relative structural stability of the economy and society) will not be characterized by excessive rates.

In other words, the exploitation of energy resources potentiates outstripping growth rates of economic and social benefits. But on the other side, irrational (and in some cases barbaric) production of primary fossil energy resources in previous periods has led to a significant depletion of the reserves. As the resource base has a long cycle of recovery, many countries were initially forced to turn to the use of the renewable (alternative) energy resources. Now, the renewable energy sources are conscious and objective reality (its description in more detail is given below). Here, it also should be depicted that the world development in terms of energy is currently characterized by the desire of many countries and states to reduce volatility.

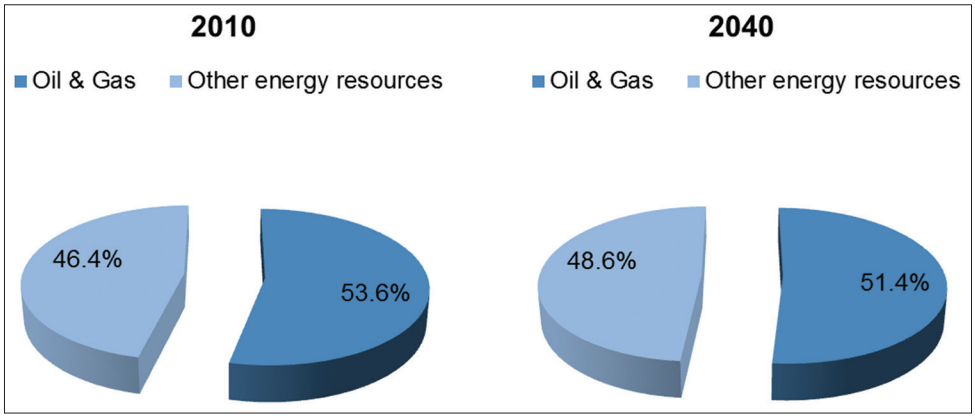
Figure 1: Dynamics of energy consumption in the world, billion tons of oil equivalent



Source: Global Energy Outlook to 2030, 2013

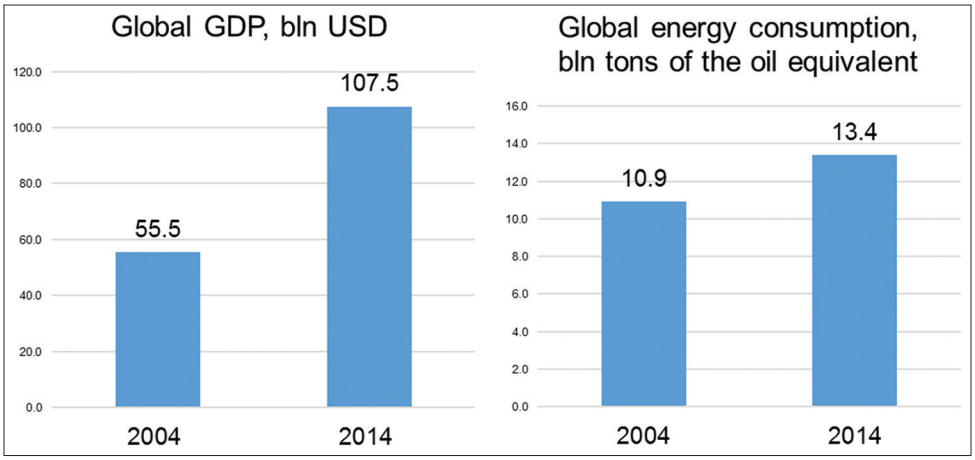
Consequently, innovation and technological aspect is the third important aspect of determining the global energy industry development. The innovation and development of new technology efficient, safe and affordable solutions for the energy supply for needs of modern civilization are no longer the ordinary scientific thesis. On the contrary, the state energy policies are focused on the search for reserves to reduce energy consumption, increase energy efficiency and ensure an adequate level of energy security through optimal scientific and technological developments. It should be understood that the transition from an industrial economy to an innovation economy, due to the change of the phase of the economic cycle and the big V transformation of technological

Figure 2: Specific contribution of oil and gas in the world consumption of energy resources for the future until 2040



Source: Global and Russian Outlook to 2040, 2013

Figure 3: Dynamics of the global gross domestic product growth (according to the PPP) and energy consumption in the world in 2004 and 2014 (World Economy, n.d.; Statistical data and information)



Source: World Economy, n.d.; Statistical data and information

structure in the VI technological structure, must be accompanied by a qualitative change in all spheres and sectors.

Currently, the main focus is made primarily on technologies of the primary fossil energy resources production and operation, as there are some skeptical views and assess regarding the value and feasibility of the renewable energy resources development (Research and Development in the Energy Sector, 2010) (in particular, for instance, in the ratio of the potential economic benefits and environmental risks). But on the other hand, as it has been noted above, many states set the task of finding the optimal balance between imports and domestic production of energy resources, tending to transition to self-sufficiency. This will contribute to finding the solutions to expand the domestic resource base, which in turn creates the preconditions for further regionalization of the global energy sector.

The innovation and technological development stimulates inter-industry competition in the global energy sector, which in turn is a factor of sustainable development of the global social and economic system. In addition, competition in the global energy sector will intensify trends associated with the redistribution of influence spheres of the energy resources exporting countries. Do not forget that the innovation and technological development stimulates competition for control over transitive areas of supply of these resources. In the long term, the innovation and technological development will lead to a so-called dematerialization of the energy market, in other words, there can be a transition from the market of energy carriers to the market for energy services and energy technology market.

This trend puts the country exporting large volumes of energy resources (mainly primary minerals) in a state of dependence.

Therefore, in the medium term both transformation and the simultaneous complexity of structural and dynamic processes in the global energy sector can be expected. In addition, the divergent aspirations of the energy resources importing and exporting countries (the first tend to be self-sufficient, the second are interested in expanding the volume of deliveries) can significantly alter their energy specialization. Hence, the innovation and technological component seems to us the most important for the specifics of the global energy sector development.

The overt and covert technological changes in the energy sector will be determined by geographical and product diversification of the market. Identifying and most faithful interpretation of the overt technological changes in the energy sector makes it possible to build the best strategy to ensure an adequate level of the energy security. Accordingly, the most likely technological changes should be further considered that will affect not only the development of the global and national energy sector, but in general, the evolution of the modern human civilization.

The technological changes (in this case in the energy sector) are natural and dynamic structural transformations due to the scientific and technological progress. In turn, the scientific and technological progress is of uneven evolutionary and revolutionary nature, which leads to discontinuity of certain technical and technological changes in time and space. In other words, the technological changes indicate the presence of current and future projected changes in the structure of the segment, sphere, industry, or the economy as a whole (Glaziev, 2015).

It is quite natural that all the current and upcoming changes in the energy sector are based on the previous technological changes that have specifically determined the transition from one energy resources to the other (from wood and steam to coal, from coal to hydrocarbon, from hydrocarbons to renewable energy of a new quality).

Thus, the technological changes in energy sector are structural transition from use and, accordingly, from the consumption of the same type/kind of energy resource to another with complete or partial substitution of the first one. The technological changes in the energy sector have two conditional stimulus, the first of which is aimed at improving the competitiveness and ensuring the greening of the energy sector (its constituent economic entities). The second is aimed at the formation of the scientific and educational platform, on the one hand ensuring the improvement of the previously developed technologies of energy production, distribution and supply, and on the other hand providing the creation of new technological solutions.

Over the past two thousand years, the modern civilization made a breakthrough in the energy sector, including the research, production and distribution of the energy resources. Modern framework of the energy sector is formed by the following key technologies:

- Technologies for the production and distribution of electricity (condensing power plants, nuclear power plants, hydroelectric power plants);
- Fuel energy technologies (research, production and processing of hydrocarbons, including those derived from unconventional sources of hard mining);
- Fuel resources transportation technologies (piping system for pumping oil, petroleum products and gas);
- New primary fossil energy resources exploration technologies;
- Technologies for the production and distribution of alternative liquid and gas fuels, and other energy resources derived from the renewable energy sources.

But these technologies are already regarded as the technology refer to the Vth and in part to the beginning of the VIth technological structure. In other words, the above-mentioned technologies have a real and obvious determinants that stimulated the technological changes observed during the last century. In the long term until 2050, the development of the following technologies will also determine the overt and obvious technological changes:

- Hydrocarbons production technologies (production and distribution) including obtained from the unconventional resources (shale oil, gas, the Arctic shelf) as well as technologies of coal gasification and deliquation;
- Pervasive gasification and electrification technologies of industrial and commercial activities, as well as the vital functions of society;

- Technologies for the production of liquid biofuels, as well as synthetic biofuels;
- Technologies for the production of energy resources from other renewable resources (non-fuel power generators, monothermic and bithermic installations, nuclear fusion energy, solar energy, geothermal energy, energy of wind, and so on).

Of course, for many countries, the transition from high-carbon to low-carbon energy is the most important, which is not real in the future of the next 25-50 years. In the distant future, the covert technological changes backgrounds are localized that are considered by Russian and foreign scientists to the position of formation of the new energy civilization. The new energy civilization formed on the basis of the concept of "green economy" and ecologically oriented society is an "electric world," which is replaced by autotrophic and energy integration, working on fractal principle (Bushuev and Gromov, 2013; Grenander, 1994; Winzer, 2011).

Many scientists working in the sciences, humanities and accurate research agree with the concept of the new energy civilization in varying degrees. But there are some differences of opinion about the transition of the current global social and economic system to the new civilization conditions. Many scientists (Hawking, 2008; Bushuev and Gromov, 2013; Dudin et al., 2013) argue that the transition to new forms of energy production is possible only through the crisis, which is likely to have a pronounced adverse environmental aspect. The probability of the crisis transition is very high and, therefore, already at present, along with requirements to increase the availability of energy resources, the requirements for energy efficiency are becoming more relevant for private and commercial purposes, as well as reducing the energy intensity of the economy and society.

Despite the presence of the negative environmental and technological point of view, the modern civilization saves a significant chance of transition to a new energy era not through the crisis, but through the sustainable development. And here it should be understood that at the level of nation states, it is important to implement a diversified energy strategies, which are aggregated and directed both to ensuring the public availability of energy, and reduction of energy intensity of national economies and society. These strategic thesis are the most important for Russia, because there is still resource dependence of the economy, there is a deepening the stagnation in the real and financial sectors.

4. DISCUSSION

Issues of the Russian energy sector development are studied from different perspectives. And, despite the fact that the Russian Federation is one of the leaders of the world market providing about 19% of world gas production and about 12% of oil production (Energy Bulletin, 2014), the Russian energy sector is the most vulnerable sector of the national economy.

There are many reasons limiting the ability of the Russian energy sector to sustainably and competitively develop. There are the following reasons: The high dependence on the fossil energy production; undiversified structure of energy production and consumption; high energy intensity of many economic activities and public consumption.

The use of the renewable energy sources is very limited in Russia. Possessing enormous potential of the renewable primary energy sources (wind, solar, water, biomass), Russia practically does not use it. For instance, at the end of 2015, the installed power of the renewable energy sources in Russia was 51.8 GW, while in Germany in the same period, the installed power of the renewable energy was more than 104 GW (Statistical Yearbook of Global Energy).

Deep and long-term conditions of inertial tendencies are apparent; here the main source of the issues lays in the following: The program documents of the Russian energy sector development were weakly sensitive to the realities of the national business model, were based on developments mainly from best practices of foreign countries, which showed considerable innovation breakthrough. It is obvious that under the current situation, the technological basis for the development of the Russian energy sector should be rethought, including that through the use of renewable energy resources.

The author propose to consider the individual technological solutions (Komkov et al., 2014) in the use of the renewable energy sources, which can be implemented to address the problems of high energy consumption and low energy efficiency of the Russian economy and welfare sector. Obviously, the global technological trends clearly demonstrate the upcoming transition from hydrocarbons to the renewable energy sources. Consequently, the local renewable energy solutions are considered to be the most optimal in Russia with its centralized power system and limited capabilities to radically reform the national energy sector in order to improve energy efficiency in the economic and welfare sector. These local processing solutions can be used for obtaining energy from solar, wind, biomass, nuclear fusion, as well as by a combination of various renewable energy sources for synergistic effects.

The agriculture is characterized by high consumption of heat and hot water, while taking into account that the centralized heating and hot water supply is not fully accessible to small farmers, it is advisable to pay attention to solar water heaters. As it is known, the level of conversion of solar energy into thermal energy has a higher efficiency than in the conversion of solar energy into electricity. Therefore, small farms located in the central and southern part of Russia can significantly reduce the costs of hot water through the use of the solar water heaters, which in turn will mean a reduction in the cost of agricultural products.

That solution has its limitations in the north and north-western regions of Russia, as the density of the solar radiation flux required for heating water is 1.5 times lower than in the central and southern latitudes of the country. Impossibility to maintain a large reserve of transformed solar energy for quite a long time is another limitation

on the use of the solar water heaters. The solution is to use solar collectors of spherical volume type. Those collectors are focused on the accumulation and subsequent conversion of solar energy into heat with a significant reduction in heat loss and a significant increase in the level of efficiency of the produced thermal energy. Besides, the spherical solar collectors are cinematically more convenient to use and do not require additional energy costs associated with their use (Overview for the Introduction of Renewable Energy, 2013).

The wind energy can be used in areas where the solar energy volumes are not enough to convert it into thermal or electrical energy. In particular, in the Urals region, the wind turbines were developed with a fundamentally new spiral shape that firstly, considerably simplifies operation and expands the scope of application. And secondly, it allows us to obtain the necessary energy, even at low power and wind speed.

This national technological development is considered the most promising because it provides the ability to completely eliminate the volatility of economic and other entities from the central power supply systems. The advantage of the wind power generators is also in the fact that these installations have zero CO_2 emissions, which, of course, makes them the most promising technological solution. For example, the wind power complex on Sakhalin avoids carbon dioxide emissions into the atmosphere, and also save about 230 of diesel fuel per year.

Despite a restriction on large-scale and systematic use, bioenergy can be considered as local projects. In particular, the bio-fuel plants for agro-industrial facilities have a successful application experience in the Western European countries. Thus, the efficiency of their use is about 96% in the areas that are most distant from the central heat and electricity (when the traditional centralized energy supply systems are used in those areas, the efficiency of networks does not exceed 54%) (Farmer and Trancik, 2012; Chai et al., 2015).

The Russian agro-industrial sector annually collects about 200 million tons of organic waste, which in terms of impact on the ecosystem largely exceeds the likely burden on the use of local autonomous bio-fuel plants (Overview for the Introduction of Renewable Energy, 2013).

Solutions relating to the use of fusion reactors are another very promising trend in the technological aspects. Unlike conventional reactor, the technology of which is based on nuclear fission, the fusion reactors use the controlled synthesis, which does not make heavy radioactive waste, eliminates the physical possibility of an explosion, respectively, radiation hazard of the fusion reactors is minimum or virtually absent. In addition, the fusion reactors are stand-alone solutions that can be implemented in the most remote areas from the centralized energy supply systems, including the Far North, the Arctic.

System technological solutions that clearly can be traced now are mostly relating to the transition to "electric world" and "smart power." And here the real technological changes may be implemented in the following main areas: Electrification of the household and social sector, including the use of alternative resources; electrification of manufacturing and transportation services. At the same time, it is the most likely scenario, in which the integration of power supply systems (electricity, heat and gas) will be performed. This will increase the proportion of the final electric energy consumption up to 25% (currently it is 15-17%), reduce engine fuel usage to 5% (currently it is 8-10%) (Bushuev, 2015). Also, the transition to "smart energy" and "electric world" ensures the development of distributed generation and the development of small generation in the Russian energy sector. This is fully consistent with global trends and the overt and covert technological changes that form the strategic contour of the modern civilization development, its transition to the "green economy" (Chapple, 2008) and "smart power."

5. CONCLUSION

As a result, the aspects discussed in this article make it possible to summarize that:

- The specifics of global energy development is due to the influence of the three key aspects: Spatial, social and economic (including political), innovation and technological;
- The innovation and technological aspect leads to the formation of the overt and covert technological changes that will have a significant impact on the transformation of not only energy, economic, but also geopolitical space;
- So far in the energy sector, the overt and covert backgrounds of the technological changes have formed. These changes will determine the global energy sector restructuring across the cost shaping chain: From exploration and mining (production) to distribution and final consumption of energy resources;
- In the long term over the next 30-50 years, a goal of the complete transition to a low-carbon energy and the economy is rather difficult to be achieved due to the technological and environmental limitations in the system and industrial and scale use of the renewable energy sources;
- In the long term, the formation of the new energy civilization is anticipated. The transition to the new energy civilization will probably take place on the background of the system ecological crisis in finding the new technological solutions ("electric world" → "power autotrophy" → "fractal energy integration)";
- The Russian energy sector is characterized by catch-up type of development, needs reforms, optimization and modernization not only in infrastructure but also in the technological aspect;
- The global patterns and projected changes in the global energy sector do not allow us to hope solely on traditional fuel industries of national energy sector because in the future the low-carbon economy and energy sector will be formed;
- The overt technological changes in the national energy sector can be considered in two key areas: System and local. The local area is a stand-alone technology solutions focused on the use of renewable energies in the individual segments of the economy and the welfare sector. The system solutions are related to the integrated decentralized electrification of the economy and welfare sector;
- The covert technological changes are due to possible use of non-fuel power generators in the distant future, which

are currently considered primarily from the perspective of scientific and theoretical concepts, but fit much longer term of the energy autotrophy and energy integration of the economy and society.

In this article, the aspects relating to calculations of the real social and economic benefits have not been considered that can be obtained through the innovation and technological achievements by both the global and Russian economy. Besides, the environmental risks in the system aspect have not been analyzed, which are associated with the structure of the Russian and global energy balance. The authors expect that the scientific, methodological and practical aspects will be studied in detail in the following papers devoted to the topic of the technological changes in the global energy sector.

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