

The World Is On The Cusp Of Global Energy Changes

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Abstract — The paper describes the features of the world energy development at the turn of the twentieth and twenty-first centuries with a special focus on the main events, trends and factors of energy transformations in this period. A new energy landscape of the world and the most important challenges, processes and factors that shape this landscape have been analyzed. The inconsistency of a number of trends was especially noted, which, in the author's opinion, indicates an increase in the degree of uncertainty in the development of the world economy as a whole and the world energy in particular. Globalization, geopolitics, and the rapid development of science and technology make their contribution to this growth. The situation is aggravated by the emerging surplus of energy resources, which changes the very basis of the energy philosophy. The new driving forces of the observed and upcoming transformations are examined in detail, in particular the need to respond to the challenges facing humanity due to climate change, and the projected alterations in the energy balance caused by the effects of the 4th industrial revolution. The most important directions and tools for implementing a climate-oriented energy policy, including the formation of low-carbon or carbon-free energy sector of the future, the role of globalization in the future energy development, as well as trends and transformations of global energy markets, are explored. Consideration has been given to new approaches to the long-term forecasting of the

global energy development, that are applied by leading international and national analytical centers, as well as to their assessments of trends in global consumption of energy, oil and other liquid fuels. The current energy situation in Russia is analyzed and conclusions are made about the need to change the priorities of the energy policy of the Russian Federation in the context of the global energy changes.

Key words — world energy, energy transformations, geopolitics, global climate change, energy markets, globalization, geopolitics, energy philosophy, energy surplus, low-carbon energy, long-term forecasting, Russia.

I. INTRODUCTION

The world energy sector, being the most important part of the global economy, is evolving under the influence of various factors, most of which are interdependent and interrelated, which increases the degree of uncertainty of their cumulative effect. A special role in this process belongs to the basic, fundamental factors that have long-term influence. It is worthwhile to note some of them, first of all[5: Chapter 7, 6: Chapter 4]:

- The international division of labor, including the increasing complexity of economic relations between national economies and their growing interdependence, international specialization and cooperation of production, as well as the industrialization of developing countries;
- The internationalization and economic integration of economic life (production and capital), including the intensification of inter-country exchange (overflow) of labor, capital, technology, means of production, and information;
- The uneven economic development of individual countries and the cyclical development of the world economy;
- The technological progress and the latest technological

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PROBLEMS AND SYSTEMS CHALLENGES OF THE UPPER LEVEL:

- Globalization and increased global competition;
 - Global energy security;
 - Energy efficiency;
 - Expected new wave of technological change and 4th Industrial Revolution;
 - Global climate change;
 - The need to transition to a sustainable economy and energy;
 - Human capital as a major factor in economic development;
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- Rise in demand for energy;
 - Emergence of new largest consumers and energy importers, etc.
- 
- Increased differentiation between energy-producing and energy-consuming regions.

IMPORTANT OBJECTIVE REASONS FOR NEW PROBLEMS AND CHALLENGES

- *Cyclical development of the world economy;*
- *Uneven development of major countries and regions;*
- *New technological changes that enhance the role of innovation in socio-economic development and reduce the influence of many traditional growth factors;*
- *Transition of developed countries to the post-industrial type of development;*
- *Development of the global energy landscape, etc.*

Fig.1. Challenges facing today's energy sector and their most important objective reasons.

advances, including the informatization of national and world economies and the full digitalization of production and domestic life;

- The trans-nationalization, i.e. the activities of transnational corporations and transnational banks;
- The strengthening of the role of international economic and financial organizations (IMF, World Bank, World Trade Organization, UNO, etc.) in the regulation of world economic processes;
- The increased participation (increased interference) of the state in the economy, etc.

These factors also include the need to jointly cope with the most important global issues. Such sector-specific fundamental factors of energy development as demand-supply, price, technical-technological, resource security, etc. are of no less significance for the energy sector.

A special feature of the modern stage in the development of the economic systems in most countries of the world is their high degree of internal instability against the background of developing processes of fluctuations in the external economic environment (variations in commodity prices, high volatility in the international financial market – leaps in interest rates and exchange rates, changes in the

customs policy of foreign partners and others). In addition, these processes are also influenced by such factors as the discovery of new sources of energy resources, global warming, demographic processes, sharp increase in social inequality, social revolutions and armed conflicts.

In the new geopolitical realities that have developed in the world in recent years, the so-called geopolitical factors have begun to determine the vector of energy relations between countries in almost all areas. Under their influence, a new architecture of the world economy and international relations is formed, a return to the policy of balance of power begins, and numerous barriers arise in the way of international energy cooperation. At the same time, the immense importance of energy resources in world politics causes an aggravation of hidden and open confrontation between the leading powers for control over them and over energy markets.

II. A NEW ENERGY LANDSCAPE OF THE WORLD

We have had to say and write repeatedly that growing changes occur in the global economy; that serious challenges face modern humanity, in particular in the energy sector, and it is necessary to answer the bell; that the world is on the verge of a global systems crisis, on the verge

Main trends shaping the future of global energy

- **Balancing between globalization and regionalization, the threat of energy shortage and the onset of the global energy surplus;**
- **Change in technological paradigm in the fuel and energy production and consumption;**
- **The end of the hydrocarbon era and the development of an innovative carbon-free energy sector, etc.**

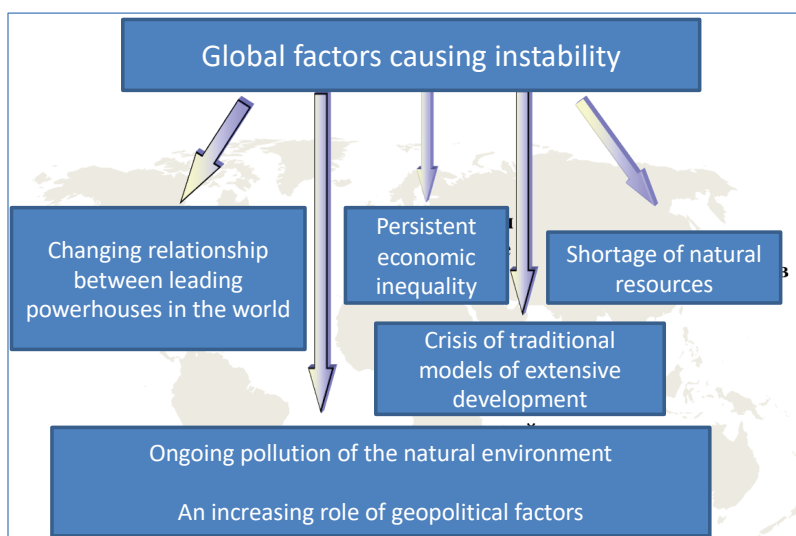


Fig.2. The world on the cusp of global energy changes.

of global changes and replacement of both technological and civilizational patterns (if one can say so, the world has reached “a breakpoint”) [1,3,7-9, etc.].

Moreover, a unique matrix of these challenges (Fig. 1), as well as trends and factors generating the instability (Fig.2) was developed in a general form.

Numerous studies conducted by domestic and foreign experts in recent years [11-16, etc.] convincingly confirm and develop the following our conclusions made several years ago [1,4,17-19]:

- The world is currently on the verge of a systems crisis, covering the economy, energy and politics; on the verge of a change in the basic paradigms of its development and global energy changes, including international relations ; This was recently evidenced in the interview with the French political analyst Thierry de Montbrial. For 40 years, he has headed one of the leading world centers of international research – French Institute of International Relations [20]. In his interview, Mr. Montbrial notes that we are in transition when everything is too unstable, and instead of a new world order, there is a disorder, in which individual characteristic features become obvious.
- Modern energy sector has faced a number of serious

challenges that are simultaneously geopolitical, resource, macroeconomic, environmental, technological and social (Fig. 1);

- Global changes, significant qualitative changes are beginning, unfolding and already occurring in the development of the global energy sector;
- A fundamentally new energy landscape of the world is beginning to take shape. Its most important features are the transformation of the United States from the leading consumer of hydrocarbons into their largest producer and a future significant exporter, and the evolution of China into the largest oil consumer.

At the same time, there also remain global factors generating instability, such as the changing relationship between the powerhouses of the world; persistent economic inequality; the shortage of natural resources in the background of their wasteful expenditure; the progressive pollution of the natural environment, especially with production waste; the crisis of traditional models of extensive development (Fig. 2).

The energy landscape of the world however is not frozen. It is changing all the time both in time and in space. New trends, factors and driving forces of the observed and upcoming transformations are emerging and gaining

**The questions arise:
What is behind these processes, trends and
challenges? And how will they end?**

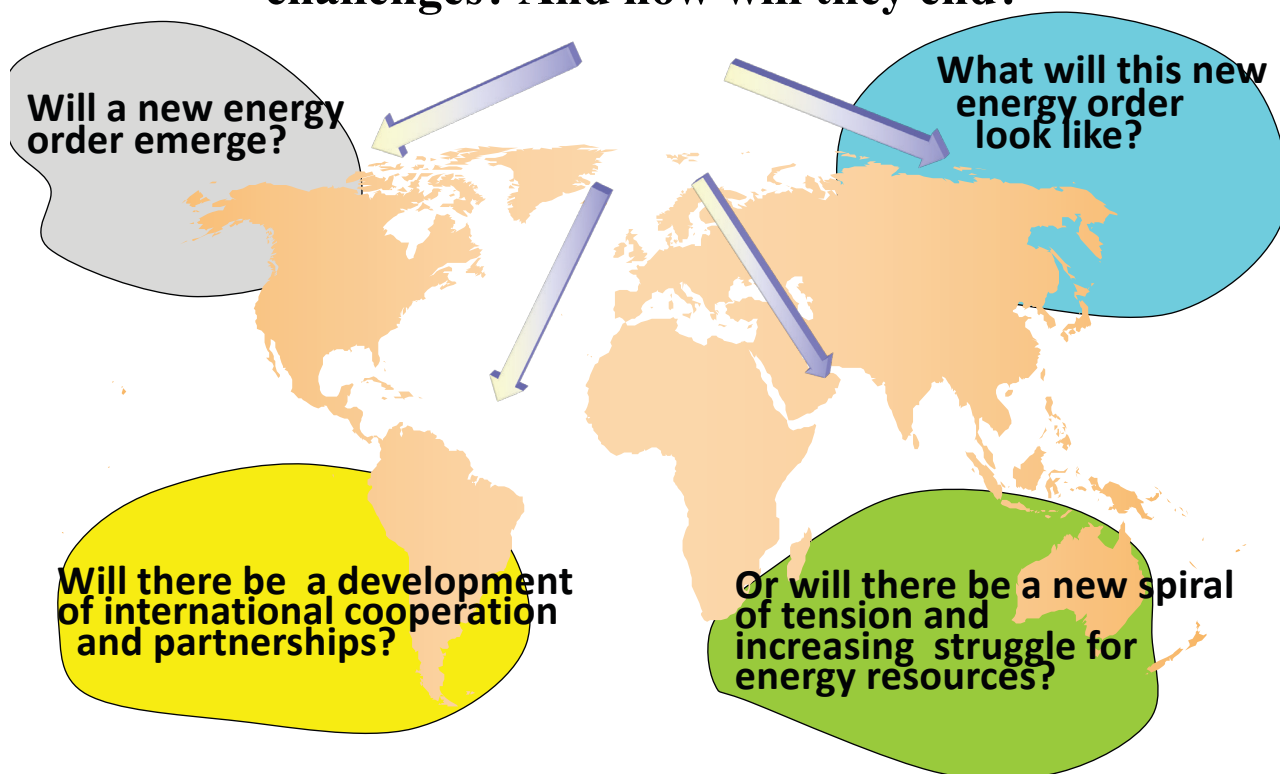


Fig.4. What will the world's energy landscape look like?

momentum. In recent years, the main ones have included the need to respond to the challenges facing humanity in connection with climate change, and the projected changes in the energy mix caused by the effects of the 4th industrial revolution.

Accordingly, the future of the global energy industry, as well as the future of the entire world economy, will be largely determined by such trends as:

- Balancing between globalization and regionalization, the threat of energy shortage and the onset of a global surplus of energy resources;
- Change in the technological structures both in the production of fuel and energy, and in their consumption;
- The end of the hydrocarbon era and the development of innovative carbon-free energy, etc. (Fig. 2).
- One of the most important factors determining a totally new energy landscape is a fundamental change in the energy sector due to the adoption of new technological solutions and radical technological advances in all areas, which primarily implies (Fig. 3):
- New technologies for oil and gas exploration and production (and hence the shale revolution in the United States, and the large-scale development of Canadian oil

sands);

- Reduction in the cost of renewable energy production and protection of the environment. As a result, the need for fossil fuel is reduced;
- Growth of liquefied natural gas (LNG) production and volumes of its transportation. The natural gas market is becoming mobile and interregional;
- Improvement in the energy saving technologies, which refutes the forecasts of a constant growth of energy consumption, etc. Source: [21,22]

Factors determining a fundamentally new energy landscape:

- The USA turns from a leading consumer of hydrocarbons into their largest producer and, in the future, a significant exporter;
- China becomes the largest oil consumer;
- Fundamental changes occur in the energy sector due to the adoption of new technological solutions, radical technological advances in all areas:
 1. new technologies for oil and gas exploration and production (and hence the shale revolution in the United States, and the large-scale development of Canadian oil sands);

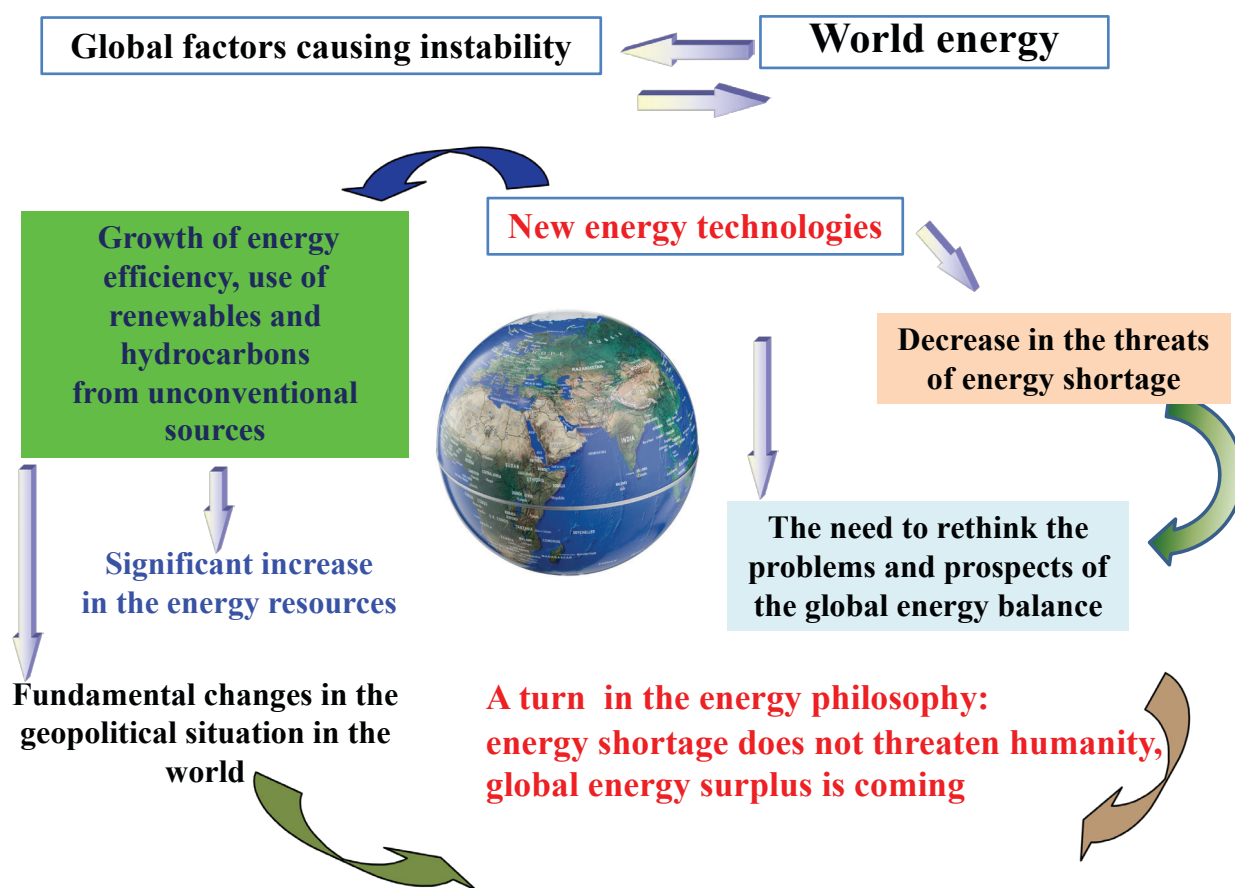


Fig.5. Some implications of global energy changes.

2. reduction in the cost of production of renewable energy sources and environmental concerns. As a result, the need for fossil fuels is reduced;
3. growth of LNG production and its transportation volumes. The natural gas market becomes mobile and interregional;
4. improvement in energy saving technologies, which refutes the forecasts of a constant growth of energy consumption, etc.

Source: [5,21]

In the coming decades, we expect the emergence of fundamentally new technologies, for example, the technologies that capture, utilize and store carbon dioxide (carbon, capture utilization and storage technology - CCUS), as well as the technologies that provide energy storage on an industrial scale (Energy storage technologies) [23,24].

Foreign economic risks, trends and factors will also have a great impact on the future world development [5: Chapter 7]:

- the exacerbation of a number of problems with which the existing international institutions cope so far unsatisfactorily. These include, first of all, the threat of aggravation of the global financial and economic

crisis; persistent and even increasing imbalances and disproportions in the world trade, in the capital flow, in the restructuring of the world economy and the world financial system;

- The growing uncertainty of world development, caused, among other things, by the increased number of countries that determine the formation of world economic dynamics. New powerhouses have a growing impact on all world economic trends, change the configuration of world trade, monetary sphere, capital flows and labor resources;
- The increase in the rate of change of a number of key world economic trends, due to the intensification of innovation activities;
- Various economic sanctions, which are increasingly more often becoming a tool in world politics.

The emergence of these external economic risks, trends and factors introduces additional uncertainties into the already complex energy landscape of the world. Naturally, more and more questions arise: what is behind these processes, trends and challenges? Will there be development of international cooperation and partnership or strengthening of the struggle for energy? Will a new

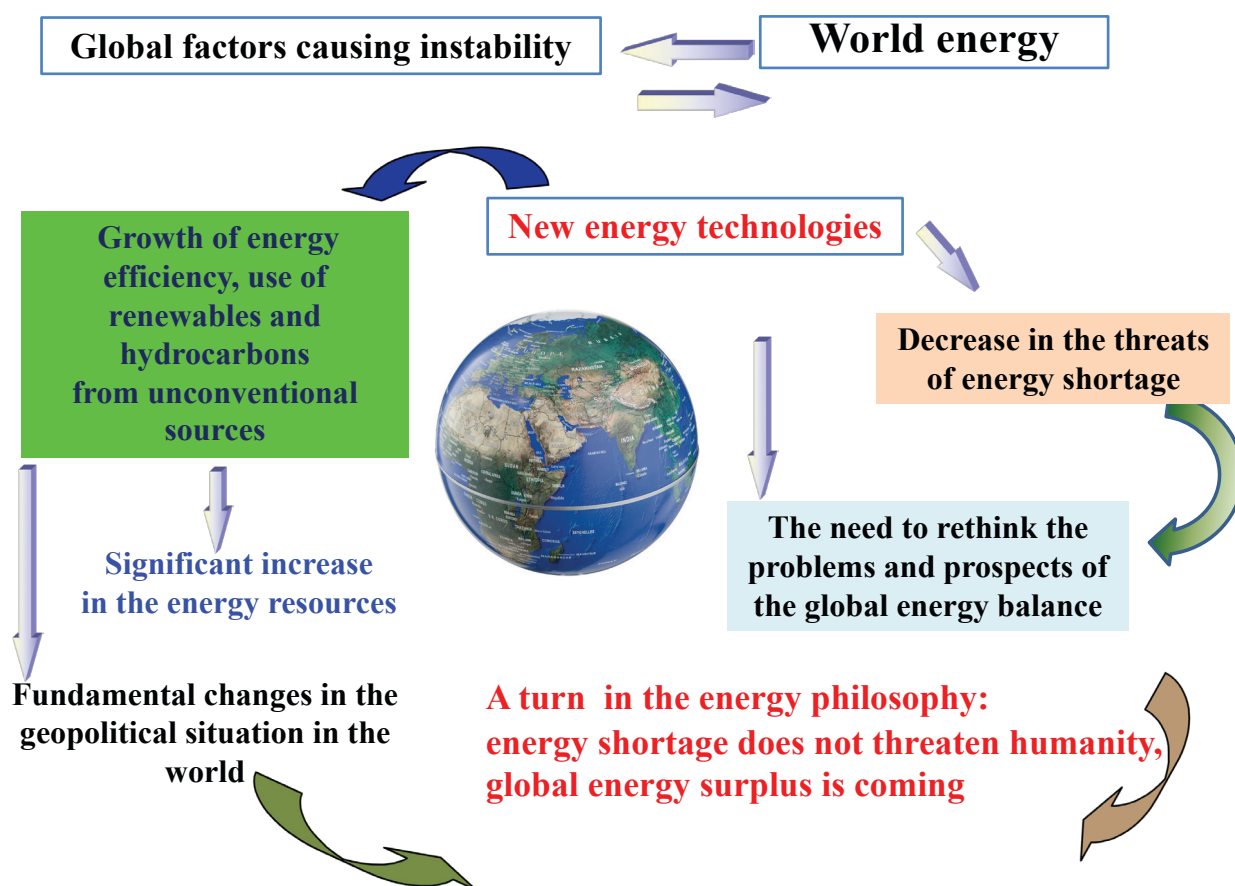


Fig.5. Some implications of global energy changes.

energy order be established? What will this new order be like? Will it draw a line under the struggle for energy resources or, on the contrary, will strengthen it, and move to a military dimension? (Fig. 4). It seems that only time will give answers to these questions.

III. A NEW ENERGY PHILOSOPHY AND FACTORS THAT DETERMINE IT

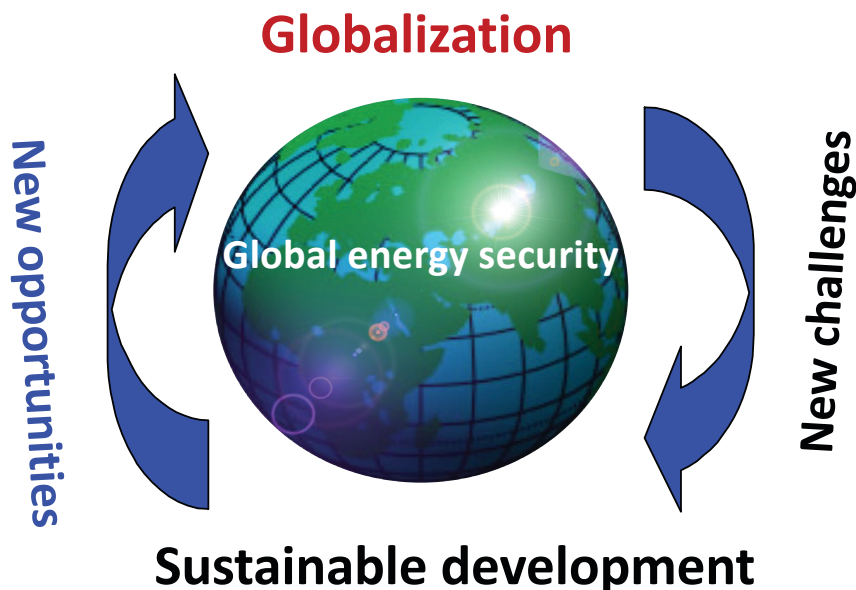
A peculiar result of the impact of the entire set of the above-considered factors and processes on the world energy sector was the change in the energy philosophy itself.

As is known, this philosophy has been long based on the problem of energy shortage, which was formulated (and substantiated based on that level of knowledge) in the middle of the last century by the Rome Club. Since then, mankind has evolved “under the sword of Damocles” of energy shortage, a possible lack of energy for its development. This threat determined not only the general economic and energy policies of the leading countries, but also practical measures by governments and businesses [5: Chapter 7]. At the same time, the oil peak theory (Hubbert peak theory), put forward by the American geophysicist King M. Hubbert in 1956, gained popularity among oil industry workers, according to which the world’s maximum

possible oil production will be achieved in the coming decades, followed by the decline of its production [26].

At the beginning of this century, the situation began to change. The development of science and technology has opened up the possibility of commercially efficient use on a large scale of not only renewable energy sources, but also practically unlimited amounts of unconventional hydrocarbon resources. Moreover, the fundamental science - the theory of polygenesis (a variety of ways of oil formation) and the biosphere theory of oil and gas formation - not only significantly expands the search for new hydrocarbon fields, but also suggests that hydrocarbons, including oil, are also a renewable energy source [27,28].

At the same time, as experts state, oil has already passed its peak as fuel. The 19th century was the century of coal, the 20th century was the century of oil, the 21st century (or rather, its first half) will be the century of diversification of energy resources (oil, gas, coal and renewable, including biomass, energy sources). In the 21st century, other energy carriers will increasingly compete with oil, and not only when used as a boiler and furnace fuel in the power industry where the oil positions are currently quite modest, but also as a motor fuel, where oil still dominates. In particular, the



“Sustainable energy development” = the establishment and operation of an energy system that meets the growing needs of socio-economic development of the world community on the basis of equitable, economically acceptable access to energy resources without irreparable damage to the environment and without infringement of the interests of future generations

Fig. 6. Sustainable energy development in the coordinates of globalization and energy security.

rapidly declining costs of electricity production based on renewable energy sources allow them to win one of their main consumers, the motor transport, from hydrocarbons through electricity.

The technological advances and accomplishments not only have demonstrated that the energy famine does not threaten the world, but also have given rise to the “Peak demand for oil” theory among oilmen and power engineers. These achievements also strongly push for the need to rethink not only the problems of and prospects for the global energy balance, but also the energy philosophy itself, and allowed us to formulate a hypothesis about the coming era of global energy surplus (Fig.5). Source: [25, 29]. The hypothesis about the coming global surplus of energy resources was put forward by the author in 2009-2010 in his speeches at the annual forums of the “Club of Nice – Energy and geopolitics” [7,8,17].

In addition, the possibility of efficient use of renewable energy and non-conventional hydrocarbons not only increases the total energy resources, but also radically changes the geopolitical situation in the world, in particular - the balance of power and the division of states into exporting and importing countries [5: Chapter 7].

The theory of “peak demand for oil” (the most appropriate amount of its consumption) is closely linked with the humanity’s awareness of how important and serious the problem of the so-called global climate change is. Experts have yet to thoroughly investigate this

phenomenon, its causes and trends. Until now, scientists have not been able to say with 100% confidence what causes the current climate change. From their perspective, the causes of global warming include changes in solar activity and changes in the angle of the rotation axis of the Earth and its orbit, unknown interactions between the Sun and the planets of the Solar System, the ocean, volcanic activity, and human activity. It is highly likely that the current global warming is the result of many factors.

Nevertheless, the scientific understanding of the global warming causes has become more definite over time, and now experts believe that there is a 90% probability that most of the temperature change in the last century has been caused by an increase in the concentration of greenhouse gases due to human activity (i.e. due to man-made factor) [30].

Thus comes the conclusion that it is necessary to switch to low-carbon or carbon-free energy (and the economy). The climate agreement reached in Paris on December 12, 2015 during the 21st conference held under the United Nations Framework Convention on Climate Change (COP21) gave additional impetus to the discussion about the role of oil and gas and the global energy balance of the future.

Another reason for the increased attention to the issues of low-carbon or carbon-free energy of the future is the theory that the exhaustion of energy resources by 2030-2035 due to the last wave of rapid industrial growth and,

accordingly, the energy consumption growth, may lead to stabilization of consumption of natural resources and the industrial economy as a whole. This means that in the long term, the demand for raw materials and traditional energy sources will grow slower, then stagnate, and then will completely decline [5,31]. In the next decade, in particular, the developed countries will switch to the formation of a new technological platform of economic systems based on the use of the latest advances in biotechnology, computer science and nanotechnology, which can significantly reduce their needs for primary energy resources. However, there are exactly opposite estimates of the future energy consumption. For example, experts from one of the new think tanks of the Republic of Korea, the Future Consensus Institute, believe that the 4th industrial revolution can become a serious challenge for energy security, because the process of innovations and development of technologies that meet its requirements are accompanied by extremely high energy consumption [22,23].

The natural basis for the increased attention to the problems of low-carbon or carbon-free energy of the future is the development of science and technology noted above, which has expanded the boundaries of our understanding of the capabilities of energy and energy supply of humanity, especially the capabilities of using renewable energy sources.

The transition to low-carbon and carbon-free energy will certainly not happen immediately, and for a long time carbon and non-carbon energy facilities will operate simultaneously. One of the possible scenarios for the start of such a transition to the low-carbon world is shown in the 2016 forecast by the BP Group [34]. During this transition period, the role of natural gas as the most environmentally acceptable type of hydrocarbon resources should increase. However, for natural gas to play this role, its prices should be at least no higher than the prices of alternative energy sources (given the costs throughout the whole chain from production to final consumption, including measures related to the use of environmentally friendly, "green" technologies).

Undoubtedly, during this transition period (at least in the period up to 2035–2040), oil will retain its role in shaping the global energy balance as one of the main energy resources. This however will take place, as already noted above, against the background of the expected systems crisis, which will cover the economy, energy, and politics, including international relations, in conditions of the high uncertainty in almost every component that makes up the overall energy picture of the future. The studies on the key uncertainties that can affect the development of global energy markets until 2040 are presented in the BP Energy Outlook 2019 published on 14.02.2019. According to BP, the greatest uncertainty in this period is related to a greater amount of energy necessary to provide further growth of global economy and welfare and to the need to rapidly transition to low-carbon future. These scenarios

emphasize the dual problem facing the world [35].

The fundamental factors of development of the world economy and energy in recent decades have impacted on the emergence of such a unique phenomenon as the globalization of the world economy, which, in turn, has become one of the most important driving forces for further economic development [5: Chapter 7]. It is worth noting however that although the concept of "globalization" has been lately one of the most frequently encountered terms in the economic literature, in the economic theory there is still no unambiguous view on this phenomenon defined by this term. Thus, there is no universal definition for the term "globalization". Moreover, according to Professor V.S.Pankov, head of the Chair of International economic relations of the Higher School of Economics, in the scientific and social-political literature devoted to the world economy issues, the term of globalization is used massively, chaotically and often in an ugly fashion.

The role of globalization in the future energy development is dual, since it exerts both direct and indirect influence on the development of world energy, encompassing not only energy markets and energy resources, but also such energy-related activities and forms as [1.8]:

- The globalization of energy technology and equipment markets based on international specialization and cooperation;
- The formation of a unified global system of energy information, knowledge and know-how based on the unification of national information systems and liberalization of access to national information resources on energy;
- The approximation and unification of national energy legislation, regulations, technical regulations, etc., including those related to environmental protection during energy activities;
- The establishment of international energy organizations and associations and the strengthening of their role.

Globalization brings new challenges to humanity and at the same time provides it with new opportunities to solve the most complex problems. The former engender increased competition for the right of access to energy resources, increasing threats to global energy security and global economic chaos. The latter lead to the concentration of the world's intellectual and financial resources, the creation of new technologies for the production and use of energy resources, awareness of the need to care about the environment and to fundamentally change the global financial sphere; promote the development of international energy cooperation and reduce the threats to global energy security and of global economic chaos.

The factors associated with globalization, according to specialists from IMEMO RAS and the Atlantic Council (USA) [37], will also affect the growth of price uncertainty in world energy markets. These are:

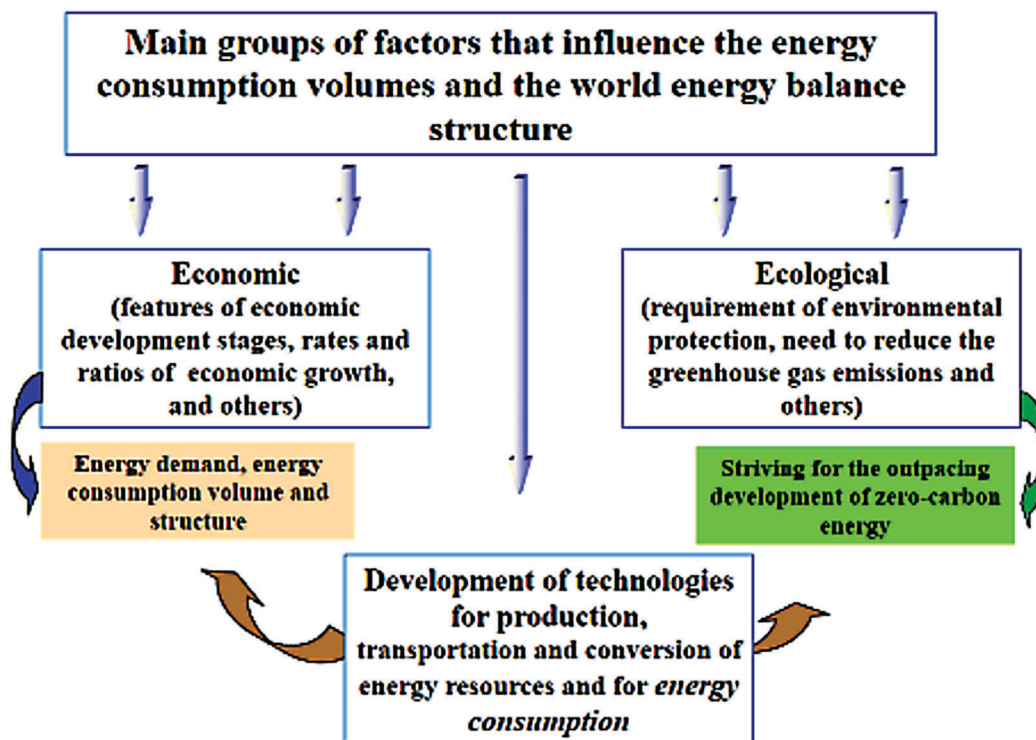


Fig. 7. Some basic energy-economy relationships.

- The transition to a multi-level, polycentric regulatory system capable to keep and stabilize a large-scale global financial system developing much faster than the real economy;
- The development of free trade zones, common markets and currency unions;
- The diversification of technologies and sources of energy, as well as increased energy efficiency in the developing world.

At the same time, globalization activates a number of other, primarily economic factors, such as: economic growth rates, ownership structure, models and instruments for raising capital, accumulation rates, investment, debt burden, relations between public and private finances, internal and external sources for funding the economic growth, macroprudential supervision and reduction of systemic risks, etc. The effect of globalization on the energy development prospects is presented in more detail, for example in [5: Chapter 7]. However, currently, the impact of globalization on the world energy development (as well as on the global economy) can be estimated only on a qualitative level. As was justly pointed out by the authors of the paper "War and peace of the 21st century. The international stability and balance of a new type" prepared in the framework of the international discussion club "Valdai", everybody understands that the fundamental changes are coming but nobody can comprehend them or at least draw the outlines of the future" [38].

In the light of globalization, energy security, understood, above all, as a reliable and uninterrupted supply of

consumers with fuel and energy in the required amounts, required quality and at economically acceptable prices, has acquired a new, global dimension and has become one of the most relevant components of the global security considered in the context of sustainable development of the economy and humanity as a whole. The issues of sustainable development deserve special consideration. Therefore, here we will only note that the term "sustainable development" appeared in the UNO documents in the middle of the 1980s, and its widespread use started after the United National Conference on Environment and Development held in Rio de Janeiro in 1992.

Thus, the concept of "sustainable energy development" has appeared (Fig. 6). Source: [29]. In Russia, the concept of "sustainable energy development" was introduced at the turn of the 20th and 21st centuries owing to the work of a large group of specialists under the leadership of the President of the International Fuel and Energy Association on the public-state program "Put Russian energy industry on the road to sustainable development through joint efforts of the government and civil society"[39]. Somewhat later, this concept was supplemented and developed by specialists from the Melentiev Energy Systems Institute SB RAS and the Institute of Energy Strategy, that by sustainable energy development began to understand "the establishment and operation of an energy system capable to provide the growing needs of the socio-economic development of the world community on the basis of equitable, economically acceptable access to energy resources without irreparable damage to the environment and without infringement of

rights of future generations” [40]. In later studies, the improvement of this concept continued. Thus, according to [4], the concept of “sustainable energy development” means an approach to energy development, which consists in prioritizing the efficient, safe and balanced development of an energy industry over constant quantitative growth in order to achieve a balance of requirements for further economic progress, improvement of the quality of life of people, respect for the interests of present and future generations, the preservation and effective use of the capabilities of the natural environment and energy potential.

Energy security is simultaneously the most important part of the entire energy policy and the national security of the leading states, and one of the main systems challenges faced by the modern energy sector. Thus, energy security acts as a technical, an economic, a political and a philosophical category. The energy security system is designed to ensure the reliability of energy supply in the common interests of the world economy, in the interests of all countries, both energy consumers and producers. Hence the understanding that this system should be transparent, based on international law and responsible policy regarding supply and demand.

Along with this, the dangerous trend of politicizing energy markets is gaining momentum in order to use them as a tool of geopolitics. World energy markets are constantly under strong influence of non-economic factors, which increases the conflict potential and the distrust of market participants to each other, makes them look for alternative, often very expensive solutions to problems. Attractive in theory, the principle of diversification of energy sources and routes of supply, which underlies many energy strategies, in real life provokes increased geopolitical rivalry between countries. In energy diplomacy, it becomes a practice to single out entire regions of critical importance in terms of international energy security.

Of paramount importance for neutralizing the threats to energy security are the technological progress, innovative technologies and technical solutions. These are, first of all, the involvement of heavy, shale and matrix oil; coal bed methane; shale gas and gas hydrates; synthetic liquid fuels; and renewable energy sources in the fuel and energy balance. These are long-distance energy transportation (including via a cryogenic cable) and sea transportation of natural gas in a hydrated (solid) state. Such lines of the technological progress, providing promising energy supply to humanity are at the same time the most important factors directly affecting the global energy security.

In the last decade, the technologies associated with the development of new and unconventional energy sources have made it possible to efficiently use local energy resources, minimizing the transportation component in their price, and refuse from long-distance (and therefore expensive) energy resources. The development and emergence of new technologies will occur constantly.

However, new technologies are developing in cycles, according to their laws and regularities, which makes it difficult to predict the results of this process.

The globalization of scientific and production relations and the transfer of knowledge and technology enabled many oil and gas importing countries to have at their disposal technologies for extraction of unconventional hydrocarbons, renewable energy technologies and to commence their own developments in these areas, focused on energy self-sufficiency and energy security [41: 375].

IV. NEW APPROACHES TO LONG-TERM FORECASTING OF ENERGY FUTURE

Long-term forecasting of the world energy development is an important component part of its operation. However, the considered factors that determine the world economy future, challenges facing humanity, risks and trends considerably hinder this process. In the recent decades, hundreds of national and international teams and tens of thousands of experts in various countries — both exporters of energy resources and their consumers — have been engaged in such long-term forecasting. The events of recent date have increased the degree of uncertainty of future energy development (Fig. 7) and shaped the demand for new approaches to forecasting our common energy future. Globalization, geopolitics and onrush of the science and technologies all contribute to the uncertainty increase. The situation is aggravated by the emerging surplus of energy resources.

This uncertainty encourages the leading international and national analytical centers to build a set of different scenarios covering, in essence, practically all possible options of situation development. At the same time, it allows them to claim that their forecasts, in general, are neither forecasts nor predictions of what can happen. This is merely a study of the pathways for potential development of the world, provided certain conditions are met, and the activities that can lead to such development of events. This is just the basis for speculations about the global energy future [43].

As a result, the estimates and trends of the global demand for energy and consumption of oil and other types of liquid fuel in the long-term forecasts of the world energy development that have been made by these centers recently are very often exactly opposite.

For example, in the basic scenario of the latest forecast by IEA (World Energy Outlook – WEO-2018) — Scenarios of the new policy — growth of the world demand for energy resources, including oil, slows down, but does not reach its maximum until 2040 [43].

In 2040, the demand for oil, without liquid biofuel, equals 106.3 million bbl/d, which is by 11.5 million bbl more than in 2017. If liquid biofuel is considered, the oil demand increases to 110.9 million bbl/d, or 27.6% of the global energy consumption equal to 17 715 million toe. On the contrary, in the Scenario of sustainable development

new for IEA, which provides an integrated strategy for implementation of the key energy-related items of the UN agenda in the area of sustainable development, including the energy access, the air quality and the climatic goals, the maximum oil demand (97 million bbl/d) is reached by 2020 (the maximum total energy consumption by 2030 is 13 820 million toe). By 2040, the world oil consumption in this Scenario decreases to 69.9 million bbl/d (including liquid biofuel – to 77.2 million bbl/d or to 23% of the world primary energy consumption). In the Scenario of the current policies which is based on maintaining the status quo, the current state policy of the leading world countries, the global demand for oil and other liquid fuel types in 2040 is 124.1 million bbl/d or 29% of the world energy consumption equal to 19 328 million toe [43].

The continuing rapid growth of the world oil consumption in the period up to 2040 is forecasted by the US Energy Information Administration as well. In its latest IEO-2018, by 2040 the global oil demand will be about 229 quadrillion BTU (above 131 million bbl/d or 31% of the total world energy consumption) [44].

The estimates of the Secretariat of OPEC (World Oil Outlook 2018) are close to the estimates of the basic Scenario, the latest forecast by IEA. They also believe that in the future the growth rates of the world oil demand will slow and in 2040 they will make up 111.7 million bbl/d or 27.8% of the world primary energy consumption [45].

The forecast of BP Energy Outlook 2019 published on February 15, 2019 [35] considers a set of scenarios: the basic scenario (Evolving Transition Scenario) and the alternative scenarios (Rapid Transition, More energy, Less carbon, Less globalization, Single-use plastics ban, Greater reforms and others). Accordingly, depending on the scenario, the oil demand in this forecast is estimated for 2040 to be from 80 million bbl/d (23% of the global energy consumption) in the Fast Transition Scenario up to 108 million bbl/d (27.2%) in the basic Evolving transition scenario, and up to 130 million bbl/d in the More energy scenario.

Possibility of higher transition rates to low-and zero-carbon energy is analyzed in some prognostic studies by the analytical centers focusing on sustainable development, unconditional fulfillment of targets of the Paris agreement on climate and renewable energy sources.

For example, the prognostic study “Energy Transition Outlook 2018. A global and regional forecast to 2050” presented by the company DNV GL on September 10, 2018 in London notes that the progress in the area of energy efficiency and usage of renewable energy sources (RES) allows anticipating great changes in both the volumes of global primary energy demand and its structure [46]. In particular, the total primary energy consumption will reach its peak (15 809 million toe) in 2032, and its final consumption – in 2035 (11 224 million toe). By 2050, these volumes will decrease to 13 994 and 10 746 million toe, respectively. In addition, the peak oil demand (4

033 million toe or 91.2 million bbl/d) will be reached as early as 2023, then oil consumption will start to decline and make up in 2050 only 2 052 million toe (46.4 million bbl/d). Hence, the oil share in the global consumption of primary energy resources will equal only 15%. In 2050, the share of oil, coal and natural gas will be only half the energy consumed by humanity.

However, even such changes, as acknowledged by the authors of this study, will be insufficient to achieve the targets of the Paris agreement: a combination of higher energy efficiency, more extensive use of RES and more extensive use of carbon capture and storage technologies will be required.

Even more considerable decline in oil consumption is justified in the studies by the International Renewable Energy Agency (IRENA). For example, in the study “Perspectives for the Energy Transition: Investment needs for a low-carbon energy system (IEA and IRENA, 2017)” in the scenario aimed at achievement of the targets of the Paris climate agreement (66% 2°C Scenario), the RES share in the global energy consumption in 2050 is estimated at 47%, and the total volume of fossil fuel use will be only half the 2014 level. Despite the greatest reduction in coal consumption, the oil demand will also decrease almost by 60%, to 760 million toe (to 40 million bbl/d). This scenario can be implemented, as is noted by its authors, “by the unprecedented buildout of all low-carbon technologies in all countries” [47].

IRENA sets even more ambitious targets in the work published in 2018 “Global Energy Transformation: A roadmap to 2050. IRENA 2018”: to increase the RES share in the total consumption of primary energy resources by 2050 to 66% (including their share in electricity generation – to 85%) with parallel decrease of energy consumption to the level lower than that in 2015. Hence, the oil consumption volumes also decrease (approximately to 24 million bbl/d) [48].

Thus, the scatter in estimates of future oil demand in the world, as well as energy consumption as a whole, is quite wide. Based on different scenarios, in the considered prognostic studies for 2040-2050 it varies from 24 to 131 million bbl/d, and from 13.1 to 22.3 billion toe, respectively.

Nevertheless, despite the uncertainty of quantitative estimates of future energy resources production and consumption in the world, the considered forecasts allow identifying some patterns in the future world energy development. The most important of them are:

- A considerable increase in the energy efficiency and development of advanced energy consumption technologies that slow down the growing demand for energy carriers. The developed countries will switch to the development of a new technological platform of economic systems which is based on employment of cutting-edge achievements in the sphere of biotechnologies, computer science and nanotechnologies, which can substantially decrease

their demands for primary energy resources.

- Improvement in the competitiveness of renewable energy sources, an increase in their use in absolute terms and in the structure of the total energy consumption.
- Outpacing development of electric power industry. Development of distributed (decentralized) generation and energy storages, smartization of energy sector and energy consumption as a whole (“smart well”, “smart home”, “smart city”, etc.).
- Technological evolution of thermal power industry with a steady increase in its efficiency and environmental compatibility.
- Maintenance of the achieved proportion (or even its slight growth) of nuclear energy (about 6-7%) in the world production of primary energy resources.
- Stricter energy policy on the climate change and its consequences, stimulation of developing the environmentally clean and environmental protection technologies.
- Improvement and transformation of functioning and regulation of the world energy markets, including the change in contract terms and evolution of exchange market regulation that strengthens the consumer positions; the change in the internal mechanisms that determine price formation in the world energy markets.
- Increase in the international competition in the world energy markets, first of all – in the European gas market, appearance of new energy exporters.

V. ON THE PRIORITIES OF RUSSIA’S ENERGY POLICY IN THE CONTEXT OF GLOBAL ENERGY CHANGES

The energy sector is the most important component part of the economy of the contemporary Russia as it is based on abundant natural resources and intellectual potential of our people and makes a great contribution to the national security and socio-economic development of the country.

Russia has abundant resources that can satisfy the country’s needs and provide a rational fuel export at least until the middle of the 21st century. Russia also occupies leading positions in the world energy, especially in the oil and gas sector. Correspondingly, as we stated almost five years ago, despite the fact that the country possesses a huge energy (including hydrocarbon) potential and is of paramount importance for providing the global energy security, Russia must be ready for the considered qualitative changes in the global energy system, the world is going to face, as long as all the indicated and not indicated challenges will directly influence future socio-economic development of the country, prospects for its energy sector, especially its oil/gas industry [49].

Awareness of this fact is particularly important because the Russian energy sector faces a complex set of internal problems, such as [50]:

- Low competitiveness and a resource-export model of

the Russian economic development;

- Low rates of economic growth that considerably slow the growth of the internal demand for fuel and energy, and weaken the investment activity in the energy sector;
- Technological gap between some segments of the Russian energy sector and the advanced level of their development with excessive dependence on the import of some types of equipment, materials and services;
- Low modernization rates of infrastructure and production assets, high dependence on the external economic situation;
- Limited capabilities for attraction of accessible long-term financial resources.

Correspondingly, the Russian energy sector requires not only re-equipment and upgrade, but rather fundamental technological reconstruction aimed at increasing the flexibility and growth of the economic efficiency in the long-term future.

The recent events have shown that Russia’s economy, with all its openness and integration into the world around, must be self-sufficient and rely, first of all, on own resources, own and adapted technologies. The energy sector possesses a significant potential for creating the demand for domestic knowledge-intensive and innovative products. However, the innovation-oriented development pathway of Russia’s energy sector has been shaped highly weakly yet.

Moreover, as noted in [49], the performed analysis has showed that at present different subindustries of the oil/gas industry experience, though to a different extent, shortage of both up-to-date technologies and really breakthrough innovative strategies for the long-term development. Therefore, the future of the Russian oil/gas industry, the competitiveness of its products in the world market will largely depend on the extent to which the domestic science and the Russian companies will succeed in design of new, especially breakthrough, revolutionary technologies along the whole “chain” from exploration to consumption of hydrocarbons. Primarily this concerns the technologies of effective development of hydrocarbon resources in the arctic shelf and resources of unconventional oil and gas sources, totally new technologies for long-distance transportation of natural gas, advanced conversion of hydrocarbons.

We should be fully aware that Russia and its oil/gas industry are not threatened by the “shale revolution” itself, but rather by the lack of technologies, reluctance to see the need to design advanced technologies, and the lag that can decrease competitiveness of the Russian economy and increase its vulnerability in the context of the escalating geopolitical rivalry. Therefore, both the “shale revolution” and the imposed sanctions should become an additional incentive for extension of import substitution, positive shifts towards local production of equipment for the energy sector, restoration of the innovation process and

refusal to follow the resource-import model of the Russian economy development in favor of the shift to the resource-innovative socially-oriented economic development. For details on the necessity and possibility for the Russian economy transition to the resource-innovative pathway of development see [2,3].

The oil/gas industry of Russia still possesses the world richest mineral resources, developed infrastructure, skilled engineers, considerable innovation potential, and, what is equally important, is characterized by the scaled, quick and effective return on financial assets. At the same time, the oil/gas industry faces a situation dangerous for the national economy. The threat is caused by the rapid depletion of the “active” reserves of readily recoverable oil. By 2022, the production of this oil is expected to decrease by 45-50 million t. The share of hard-to-recover oil reserves is growing, the productive capacity of oil reservoirs is decreasing, the oil and gas resources at a depth of up to 3000 m have been depleted to a great extent, development of the gigantic fields with the unique oil and gas reserves, whose exploitation started in the 1960-70s, is terminated [51].

Let us repeat once again, since over the last years this situation has practically not changed, design of domestic technologies and adaptation of foreign ones should be recognized as the highest priority of the Russian energy policy pertaining to the oil/gas industry development in the emerging conditions. This mainly concerns the technologies that ensure considerable decrease in production costs in the whole “chain”: oil/gas production, processing, transportation and distribution. In the external markets without cheap hydrocarbons, Russia will lose its competitive advantages as an oil/gas exporter. In the internal market, under the natural-climatic and geographical conditions of the country’s economy, without cheap hydrocarbons (in particular, without cheap gas – a source of energy and feedstock for gas chemistry) Russia’s competitiveness prospects are slim. The loss of competitiveness, in turn, can give rise to a prolonged economic recession and a large-scale political crisis in Russia [52].

VI. CONCLUSIONS

The studies presented in the paper allow the following conclusions to be drawn (or the conclusions of our previous research to be confirmed).

1. At the turn of the 20th and 21st centuries the human civilization faced a set of new, interrelated and interdependent problems and challenges that concern not only the entire economic activity of humanity, including the energy sphere, but its social and political aspects. Under highly uncertain conditions of their impact, a new energy landscape, whose outlines at present are rather blurred, is emerging. The objective of our further studies is to assess the extent of this uncertainty, identify critical important processes, factors, challenges and limitations that influence the prospective development of the Russian energy sector in the context of the global economy and energy.
2. A specific resulting effect of the totality of the considered factors and processes on the world energy sector was the change in the energy philosophy itself that was long based on the energy shortage problem. The technological progress and advances gained at the beginning of the current century have shown that the energy shortage does not threaten the planet, and have made it possible to generate a hypothesis on the coming era of the global energy resources surplus. Correspondingly, the time, when availability of natural resources enabled their owner to dictate their terms, has gone, and even if there is a hope for its return, it will not happen soon. Therefore, the people making decisions affecting the interests and lives of millions of people should not only understand this, but also act on the basis of this understanding.
3. Changes in the world energy situation are taking place virtually continuously. However, the critical impact on the situation is made by the changes that have long-term effects and fundamentally alter our vision of the energy sector in the coming decades. This is, above all, the problem of global climate change and the related need to transition to low- or zero-carbon energy, the necessity of its sustainable development, and a new interpretation of the energy security problem. This is the world economy globalization, whose role in the future energy development is dual, since it influences the world energy development directly and indirectly including both the energy markets and energy resources, and the scope of directions and forms of energy-related activities. This is, at last, the technological factor that is the core driver of the forthcoming changes in the world energy balance and its structure.
4. Specific features of the future global economy and the structure of the prospective world energy balance will depend on the accessibility and efficiency of the technologies for production of conventional and unconventional oil/gas resources, utilization of renewable energy sources, growth of energy efficiency, formation of the innovative economy on the basis of the low-energy, nano-, bio-, information, cognitive and other similar technologies. And the world energy landscape in the mid-21st century, and surely, the future of the main energy resources exporters, including Russia, will depend on the technologies, which will enter the market faster – new technologies for production of new energy resources, technologies aimed at effective transportation of conventional energy resources over long distances or technologies aimed at a considerable increase in the

energy efficiency.

5. The timely understanding of the role of one fuel and energy type or another in forming the future global energy balance requires a thorough analysis of capabilities of each energy source - in terms of available resources (volumes), and the economic (primarily, cost) indicators, and the environmental compatibility.
6. There are a lot of opinions, forecasts and studies concerning the development pathways of the global energy sector and its most important components. By virtue of the high degree of uncertainty of practically each of these components of the future energy picture, none of them can be neglected. The way out for Russia and the companies planning to actively participate in the international energy markets is to steadily monitor all new trends and forecasts, sift them, in in order to understand what underlies these forecasts. Furthermore, they should pursue their flexible policy remembering the necessity of comprehensive reduction in costs of their export projects.
7. Future of the Russian oil/gas industry, competitiveness of its products in the world market will largely depend on the extent to which the domestic science and the Russian companies will succeed in designing new, especially breakthrough, revolutionary technologies in the whole "chain" from hydrocarbons exploration to consumption.
8. To solve the indicated problems and provide transition of the Russian economy to the resource-innovative development it is necessary to create effective conditions for attraction of financial resources to implement the innovation projects. This can be achieved through the tax exemptions and soft loans by inclusion of the innovation expenses in the production cost with the multiplying factor, creation of beneficial conditions for both concentration of financial resources in the target science-and-technology areas and projects, and for design and development of integrated technologies. These measures are even more necessary in the situation, when the key problem of the current national science and technology system is its chronic underfunding.

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