

# Changing global economy and energy up to 2050: Scenarios of possible events

V.V. Bushuyev, A.M. Mastepanov, N.K. Kurichev

**The analysis of energy development shows that crises occurring in 40-year intervals lead to a change in the trajectory of world energy development. The rate of growth declines, the energy mix changes and the "quality" of energy use increases. Based on analysis of retrospective dynamics three scenarios for the future of world energy are constructed - inertial, stagnating and innovative.**

**Keywords:** energy development scenarios, cycle in development, hyperbolic growth

## 1. INTRODUCTION

World energy sector is an integral part of global civilization. Therefore, in the long term dynamics of global development must be seen within a single energy-environmental-economic approach (the three "E"). The main contradictions of global development (demographic, resource, financial, technological, environmental) are resolved by deep crises, changing the paradigm of development economics, society, and energy.

Currently, world energy sector is on the critical point. Further inertial development becomes impossible. Increased environmental restrictions, rising costs of fuel energy and the reshaping of demand during the transition from a industrial to postindustrial development, cause a crisis of an sector energy. These factors require the creation of a new type of energy sector. Similarly, the crisis of the world economy requires the transition to a new phase of development. Therefore, there is a high probability to expect that in the medium term (2020) will begin, and in 2050 there will happen profound changes in technology and organization global energy sector.

Analysis of future world energy sector is especially important for Russia, because its economy is still heavily dependent on global energy markets. In western studies the specific features of Russian energy sector are usually poorly recorded. Russia's role on global energy

markets requires independent forecasts, which could be an alternative to International Energy Agency. IEA analysis usually represent the interests of developed countries and consumers of energy resources only and is built within the inertial approach.

In contrast to IEA, we propose to use non-inertial approach. The scenarios are not formed as a junction between the key trends, but as a way of "packaging" related trends. Energy is considered as a complex dynamic system of contradictions, that allows to predict not only the quantitative trends, but also qualitative changes in its organization.

## 2. WORLD ECONOMY AND ENERGY DYNAMICS

### *2.1. Long-term trends in economic and energy development*

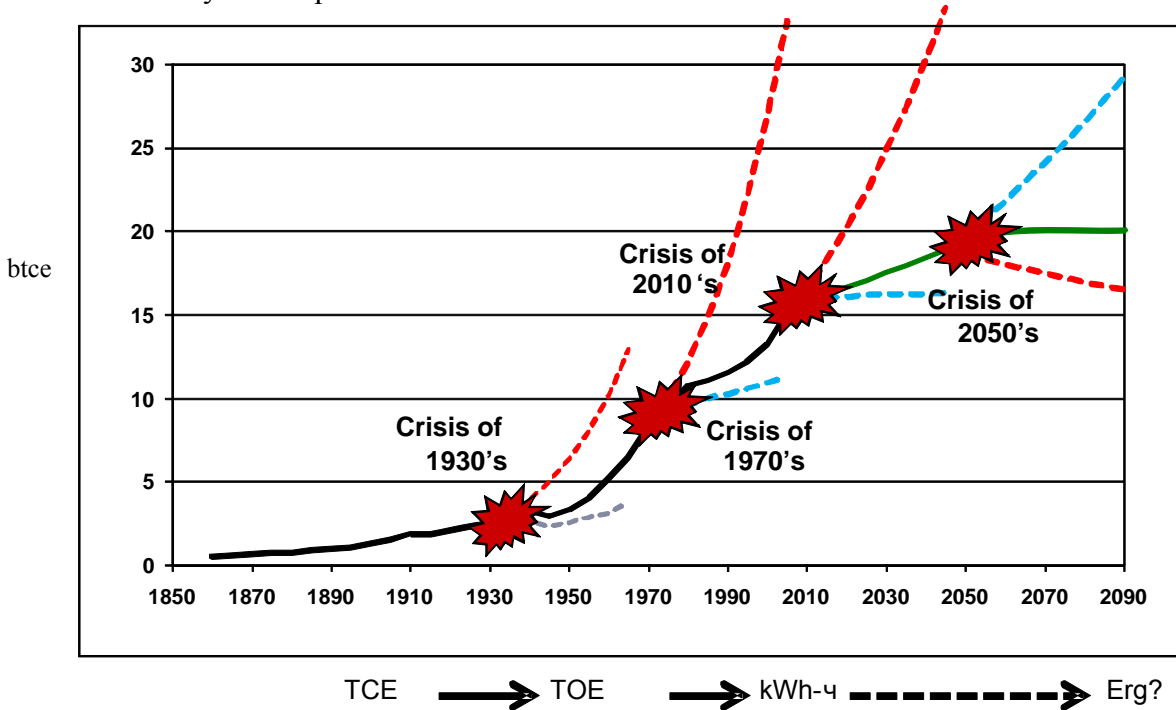
The global economy and energy sector in the long term will be determined by a combination of three principles - static, cyclical and dynamic. In the period until 2050, the inertia of economic and energy development will be in operation (static principle). In addition to the inertia will act cyclic nature of the global energy and economic development (cyclic principle). In 2025-2030 we expect acute complex crisis of society and the economy, which can be solved changing the paradigm of social development (the dynamic principle).

Over the last 100 years there have been three similar crisis accompanied with change of development paradigm - crisis of the early 1930's., crisis of the early 1970's. and the crisis of late 2000's.

Crisis of the early 1930's had led to drastically increased government influence on the economy in the U.S., Germany and the USSR. This process coincided with accelerated industrialization and rapid growth in demand for electricity and petroleum motor fuels.

The crisis of the early 1970's was related with U.S. and Western Europe the transition to post-industrial development. The promotion of private enterprise, liberalization and monetization of the world economy caused a shift from Keynesian to the monetary regulation. At the same time, the development of nuclear energy accelerates, the demand for gas as a fuel for commercial and residential sector rises. The crisis of late 2000's was due to the crisis "virtual economy" and speculative world mar-

ket of virtual assets (including oil futures market). A need for another change of development paradigm emerges. This required strengthening the role of the state, the shift of hydrocarbon resources under the control of national oil companies (instead of the dominance of transnational companies), regional self-sufficiency and national energy security, energy saving and renewable energy development.



Note: The black line - the actual energy consumption in 1860-2010, the green line - a preliminary forecast of energy consumption in 2010-2090, dotted lines - an alternative trajectory of world energy development, red line - the High scenario, Blue Line the Low scenario.

Fig. 1. The dynamics of world energy consumption in 1860-2090

The crises caused a change in dynamics of world energy sector. It went out of a steady trajectory of exponential growth of the pre-crisis period (1945-1970, 1980-2005). During the crisis, the rate of world energy consumption growth could fall below zero. After the crisis, formed a new stable trajectory of exponential growth (Fig. 1). During the crisis happened a choice between alternative trajectories of world energy development - 1) the former growth trajectory (High Scenario), 2) the new growth trajectory and 3) decoupling of energy and economic growth (Low Scenario).

In fact, the first and third trajectories always faced with the formidable constraints, so a compromise second trajectory was implemented. After the crisis the growth of world energy consumption continued, but with a lower rate (growth rate increased only at an early industrial phase).

The point is not simply a change in the dominant energy source, but changes in its quality (value), which entailed moving to a new system of energy units. After the crisis of the early 1930's energy started to be measured in tons of oil equivalent (instead of tons of coal equivalent), and now - in kilowatt-hours as units of

the most valuable final energy source. In the future, the energy of both physical and other kinds of useful work should be measured in the new, more versatile units - for example, in ergs. Although among all the units are conversion factors, they are based on the least skilled forms of energy - thermal and mechanical. In the future, energy would be measured by its quality, which depends not only on the power, but also on the shape of the energy flow.

Based on the retrospective dynamics, we suppose in 2050's. the next crisis in the world economy and energy sector. The crisis will be associated with the exhaustion of the potential of the industrial development and the transition to energy-informational sustainable development in the "nature-society-human" system. As in previous crises, this crisis will be accompanied by a choice between alternative energy development paths. Future crises may lead to very profound changes, including shift from the fuel energy.

The crises caused a change in dynamics of world energy sector. It went out of a steady trajectory of exponential growth of the pre-crisis period (1945-1970, 1980-2005). During the crisis, the rate of world energy consumption growth could fall below zero. After the crisis, formed a new stable trajectory of exponential growth (Fig. 1). During the crisis happened a choice between alternative trajectories of world energy development - 1) the former growth trajectory (High Scenario), 2) the new growth trajectory and 3) decoupling of energy and economic growth (Low Scenario).

In fact, the first and third trajectories always faced with the formidable constraints, so a compromise second trajectory was implemented. After the crisis the growth of world energy consumption continued, but with a lower rate (growth rate increased only at an early industrial phase).

The point is not simply a change in the dominant energy source, but changes in its quality (value), which entailed moving to a new system of energy units. After the crisis of the early 1930's energy started to be measured in tons of oil equivalent (instead of tons of coal equivalent), and now - in kilowatt-hours as units of the most valuable final energy source. In the

future, the energy of both physical and other kinds of useful work should be measured in the new, more versatile units - for example, in ergs. Although among all the units are conversion factors, they are based on the least skilled forms of energy - thermal and mechanical. In the future, energy would be measured by its quality, which depends not only on the power, but also on the shape of the energy flow.

Based on the retrospective dynamics, we suppose in 2050's. the next crisis in the world economy and energy sector. The crisis will be associated with the exhaustion of the potential of the industrial development and the transition to energy-informational sustainable development in the "nature-society-human" system. As in previous crises, this crisis will be accompanied by a choice between alternative energy development paths. Future crises may lead to very profound changes, including shift from the fuel energy.

## 2.2. Global energy scenarios

The crisis of late 2000's. had a profound impact on the dynamics of the global energy sector. Depending on how the crisis of the late 2000's will be solved in 2010-2012, we can consider the following scenarios of world energy development:

- 1) Inertial Scenario,
- 2) Stagnating Scenario,
- 3) Innovative Scenario.

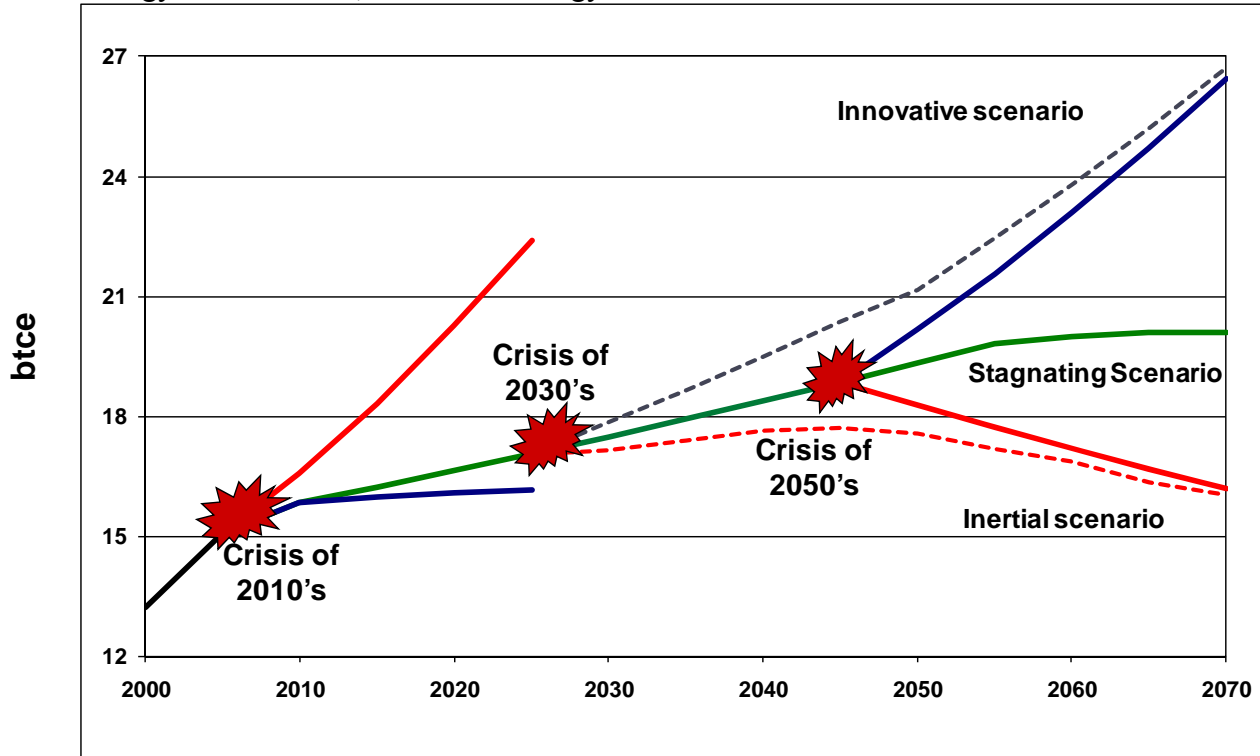
Scenarios are characterized by specific way to solve the global development contradictions, by the scope of global and regional demand for energy for final energy services and of primary energy production.

Scenarios involve two distinct phases: 2010 - 2030 and 2030 - 2050/ In 2010 - 2030 remains considerable inertia of the current state of world energy. The role of the state will increase compared with the period of liberalization of 1970-2010 years.

This trend is already evident today in the resource nationalism and move away from the problems of global energy security in favor of regional energy security. One example is the dominance of national oil companies in major energy producing countries, the development

of production of shale gas and heavy oil in North America, artificial acceleration in development of renewable energy in Europe because of not only economic, but ecological and geopolitical reasons. Since 2030 the inertia is exhausted. A period of stagnation, latent or apparent energy crisis comes, and then energy

sector changes drastically. Scenarios involve training to the world energy crisis of 2050's, accumulation of reasons for apparent crisis in 2050 through latent crisis of 2030's. Forecasted trends in world energy consumption in different scenarios are presented in Figure 2.



Note: The black line - the actual energy consumption in 1860-2010, the green line - a preliminary forecast of energy consumption in 2010-2090, dotted lines - alternative trajectory of development of world energy, red line - inertial scenario, the blue line - innovative scenario.

**Fig. 2.** Scenarios of world energy consumption up to 2070

### 2.3. Inertial scenario

*Inertial scenario* assumes that current trajectory of the world energy sector continues until 2030. The trajectory is unstable because of economic, social, environmental, political reasons. The growing demand for hydrocarbon fuels will lead to the exhaustion of cheap stocks, a sharp increase in investment needs for development of unconventional energy resources.

Energy will constrain the socio-economic development leading either to the suspension of economic development, or to break-up of environmental restriction. Passive energy policy would lead to disaster, which would mean either a physical lack of affordable oil and gas resources, or environmental unacceptability of

coal and nuclear power, or technological inaccessibility of large scale renewable energy.

The key trends in Inertial scenario would be:

- The fall of energy self-sufficiency in key regions (especially China and India) and the redistribution of the international energy trade in favor of Asia.

- In addition to traditional energy suppliers (the Middle East and Russia) and traditional consumers (developed countries) a new group of developing Asian countries appeared.

- Serious transformation of global energy transport infrastructure.

- Increasing competition between international and national oil companies.

- Extreme volatility of energy markets because of to financial and geopolitical risks.

- Energy markets and investment regulation will increase and go on an international level.
- Leading countries implement the strategies to control supply (OPEC, China), demand (Europe) and transit (USA) to ensure national energy security.
- Probable crisis of the world economy and energy after 2030 could lead to the disintegration of the world energy market in some regions, a sharp reduction in oil and gas consumption, the necessity of relying on local resources, especially coal, and the renaissance of nuclear energy.

#### 2.4. Stagnating scenario

*Stagnating scenario* involves adjusting the contemporary development trends in 2010-2030 using legal and political mechanisms. Active energy saving measures will alleviate the problems of climate change and the growth of energy demand, mitigate the imbalances and contradictions in the development of world energy sector. But investment and innovative energy development will be limited. Energy factor will be the brake not only purely industrial, but also post-industrial development. As a consequence, after 2030, this scenario leads to a decrease in the rate of development, stagnation of the global energy and a gradual loss of stability.

Key trends in the stagnating scenario would be:

- Complication of technological chains in the energy sector due to the rapid development of new fuels (biofuels of various types, at the end of the period - hydrogen), other secondary sources of energy, renewable energy.
- The slow growth in international hydrocarbons trade.
- The competition between fuel energy companies and energy, energy service companies.
- The shift away from stock price and the conversion in the energy service market.
- Inter-industry competition and the loss of super-profits in the energy sector.
- Increased importance of environmental and regulatory factors in the energy market.
- Artificial system of prices in the energy sector.

- The use of climate policy at the global level as an important instrument of interstate competition by the U.S. and the EU.
- Reducing the role of the energy-exporting countries.
- Probable conflict between developed and developing countries on climate policy.
- Deceleration energy and economic development in the long term.

#### 2.5. Innovative scenario

*Innovative scenario* involves changing contemporary trends of energy development already in 2010-2030. through an innovative energy development in energy production, and in its final consumption.

A breakthrough might be the creation of powerful and cheap battery power, which will lead to transition to electric cars. The process will lead to an increase in electricity demand and reduction in oil demand. At the same time increase the relevance of finding new ways of non-fuel (direct) generation of electricity. An important role can play the creation of fast reactor and closed nuclear fuel cycle. It should be emphasized that not exhausted reserves of oil but falling demand will lead to cuts in the oil business in the world.

By 2030, oil will cease to be "black gold", the equivalent of power and economic wealth of countries. Inevitably increase in the demand for electricity will require the development of gas generation, nuclear energy and the creation of innovative "Electric World".

Key trends in the Innovate scenarios would be:

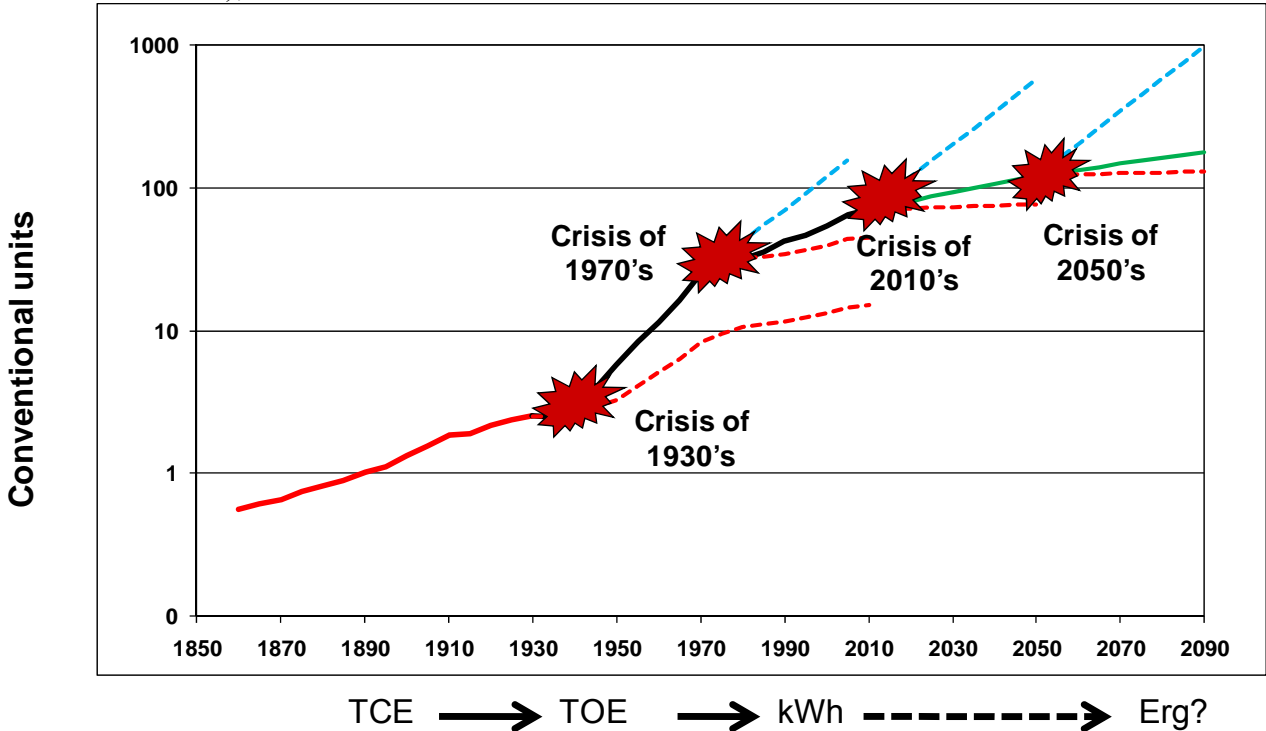
- High investment activity.
- gradual transformation of the energy market in the technology market.
- Contradictions between the states with innovative energy sector and with dominating fuel energy.
- Growing share of electricity in final energy consumption ("Electric World").

A number of major technological projects.

- Rapid innovative development, namely:
    - Development of distributed generation.
- The transition of industrial enterprises to production of energy for own needs, and for other consumers;

- Smart grids. Integration of energy and information networks, energy consumption management end-use sector;
- Energy efficiency, including in the household sector (houses with low and zero energy consumption);
- Powerful and cheap batteries;
- Technologies of electricity transportation and storage (transmission of electricity over long distances using a microwave, half-wave transmission);

- Autonomous and mobile energy sources.
  - Addressing climate change issue by the new energy technologies.
- The main result of technological changes by 2050 will be a shift from quantitative to qualitative assessments of energy.



Note: The black line - the actual energy consumption in 1860-2010, the green line - a preliminary forecast of energy consumption in 2010-2090, dotted lines - alternative trajectory of development of world energy, red line - inertial scenario, the blue line - innovative scenario.

**Fig. 3.** Scenarios of world energy development up to 2050: qualitative changes

### 3. CONCLUSION

The differences between the scenarios of the global economy and energy development are very profound. World energy sector expect significant changes in technology, organization, economic and political role, methods of regulation, the direction of development.

Key corporative changes will be to reduce the role and profitability of the oil business, the growth of the role of atomic energy business, increased competition of international and national oil companies, development of energy service companies. Profit formation will shift

from natural resources exploitation to the creation of new energy technologies.

The dynamics of global primary energy consumption does not adequately reflect the dynamics of global energy and qualitative differences between the scenarios. The development of world energy associated with qualitative shifts from less valuable types of energy to the more valuable. Thus, after 1930 there was a switch from coal to oil power (and consequently to the tons of oil equivalent), in the 1970' - to the electric power industry and to the kilowatt-hours. By 2050 is expected a shift. to some new units of energy (conditionally - "ergs").

The dynamics of world energy consumption may be calculated by the dynamics of priority energy source (in 1850-1930 - by coal consumption, in 1930-1970. - by oil consumption, in 1970-2010 - by electricity consumption) . In this case, growth rate will be much higher, reflecting the real situation. The "effective" energy (real energy available), taking into account the transition to a more valuable (qualified) types of energy, has increased during the XX century about 100 times during the growth of primary energy consumption by 10 times . The results of calculations including the forecast are presented in Fig. 3.

Thus, the differences in "effective" energy consumption between the scenarios are much greater than in the consumption of primary energy. Inertial and stagnating scenario leads to an irreversible disturbance of the stability of global development, although at different speeds. These scenarios suggest stagnating "effective" energy use. Innovative scenario, by contrast, involves a rapid increase of "effective" energy use (useful work done on the base of energy consumption) through the transition to a more skilled forms of energy.

Qualitative changes that will occur in each of these scenarios require Russia to develop adequate strategies for action. Under any of the three scenarios, Russia's role as the largest exporter of energy is insufficient to ensure the national interests and important positions in international relations. In the innovative scenario the reason is diminishing role of the hydrocarbon energy and increasing the value of technological leadership. In the innovative scenario the reason is geopolitical instability and threats to the sovereignty. In the stagnating scenario the reason is global climate policy. The strategy of Russia's actions should not only include a passive adaptation shaped by trends of world energy. Russia should actively shape the agenda of global energy development, including innovative forecasting and providing intellectual leadership of Russia to examine the issue of world energy development.

#### 4. ЛИТЕРАТУРА

- [1] Glazyev S.Y. Theory of long-term techno-economic development. M.: Vldar, 1993.
- [2] Toffler A. The Third Wave. M.: AST, 1999. - 784 c.
- [3] Bell D. The coming post-industrial society organizations. Experience in social forecasting. M.: Academia, 2004.
- [4] Castells M. The information age: economy, Mika, society and culture. Moscow: HSE, 2000..
- [5] Pereslegin SB New maps of the future. M., ACT, 2009 - 701 pp.
- [6] World Energy Assessment: Energy and Challenge of Sustainability. - New York: United Nations Development Programme, Bureau for Development Policy, 2000.
- [7] The prospects of energy technologies. In support of the Plan of Action of the Group of Eight. Scenarios and Strategies to 2050 OECD / IEA. - M.: 2007, 586 pp. – <http://www.wwf.ru>.

#### 5. BIOGRAPHIES



2030.

**Bushuev Vitaly Vasilyevich** - General Director of the Institute of Energy Strategy, Moscow, Russia, Doctor of Technical Sciences, Professor. Graduated in 1961, Kuibyshev Industrial Institute for Electrical Engineer. Head of the working group on the Energy Strategy of Russia up to 2020 and



Economy of Moscow State University.

**Mastepanov Alexei Mikhailovich** - Deputy Head of the Department of perspective development, science and ecology of Gazprom Ltd. (since 2003), Doctor of Economic Sciences, professor of international oil and gas business in Oil and Gas Gubkin Institute. Graduated from the Faculty of



**Kurichev Nikolay Konstantinovich** graduated from the Faculty of Geography Moscow State University in 2009. Senior expert of the Institute of energy strategy.