Innovative-technological vector of development of world energy in XXI century

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***Summary* – The paper contains the results of author's research of world technological development and it's impact on global energy and economy. The stages of technological development are systematized and their impact on the direction of world energy development in 21st century is determined.**

***Key words* – world financial crisis, stages of technological development, patent application dynamcs, innovation, innovation support measures, il prices.**

Russian Federation has large specific weight in world's energy reserves (more than 27%) Therefore, economic development of Russia during crisis and post-crisis time will largely depend on direction the world energy development in 21st century will take.

What are the reasons for world crisis. It's often called financial, investment, economic. But perhaps there are more fundamental reasons behind these covers? In order to find the answer we studied world dynamics of patent applications per million of population in long term (approx.130-140 years). After aggregation of statistical data of three primary patent offices (American, European and Japanese) we produced the graph (fig.1) that we named "Stages of technological development".

According to this graph, each 25-30 years of increase of specific pattern applications is followed by 25 year of decrease. Such periodicity has simple explanation –scientific and technological knowledge accumulated during the increase is materializing into new technologies during the times of decrease of patenting activity. Actually, during decrease phase world's technological renovation occurs, the world acquires new technological face.

How many such technological stages there were in 20th century? Only two – 1928-1945 and 1970-1991 periods.

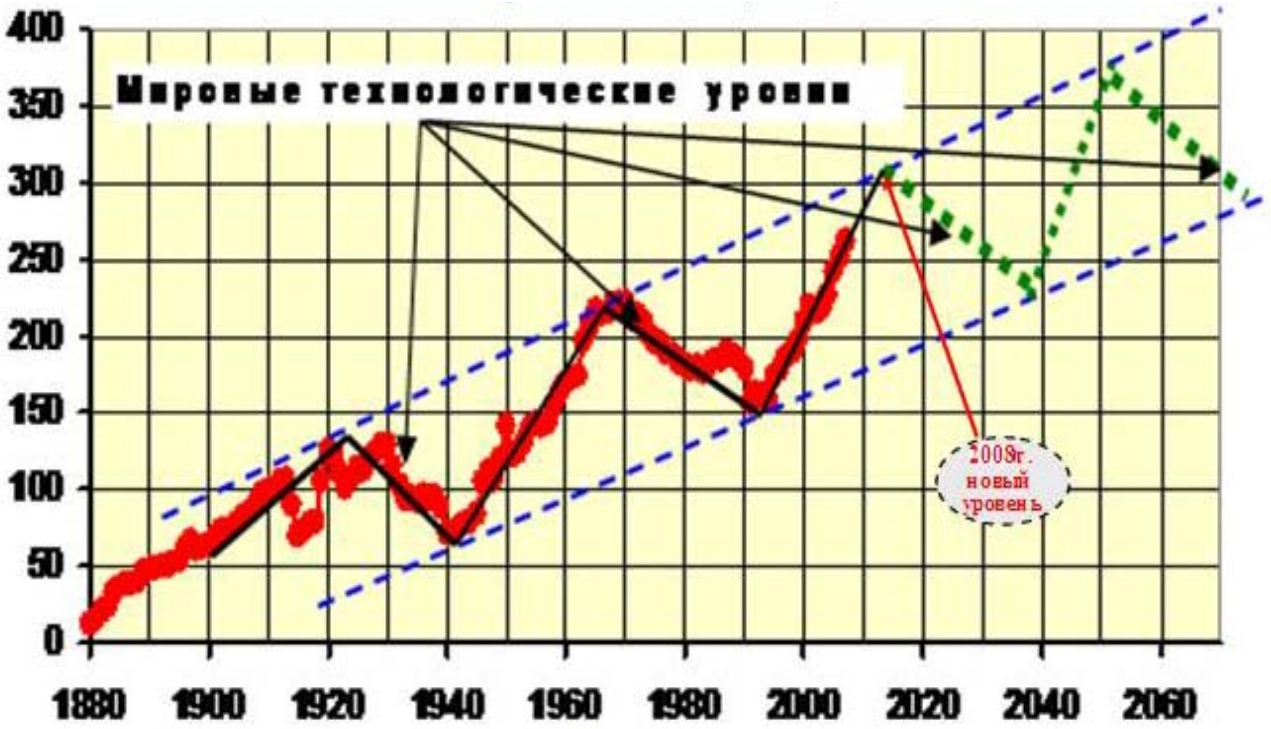

Fig. 1. The forecast of demands for patents for 1 million person. The world only, pieces.

Third technological stage, or first technological stage of 21st century stars at 2010-2011and will last until 2035. Actually, the world already passed the "point of no return", and world economy is already running on the track of technological renovation. On this stage, it's not the sheer volume of consumed resources, but their efficient management becomes the dominant factor of the world's development. Next technological stage will begin at 2050and will last until 2075.

What technological transformation await word economy at this stage? In order to understand the scale of future transformations, it is enough to compare the technologies that emerged during first and second stages. Let us mention only basic technological achievements that appeared during second stage and were not present during first. These are: television, rocketry, nuclear energy, computers, Internet, cell phones, Moon landing etc. If we look at fuel and energy sector, we shall se major technological breakthrough in coal industry – from rock drill and coal cutter to complex automation of firs mining and coal-face works. In oil and gas sector – from simple oil drills to automated floating platforms. This scale of technological transformation should be multiplied during the next stage .

This stage will be characterized by considerable increase in productivity of labor. Just during the transition between first and second stages the productivity of labor increased by factor if 7 for industry on average, 11 times for heavy industry, 5 times – for fuel and energy sector, 15 times for chemical and petrochemical industry.

Apparently, given the scale of expected economy of labor, the next stage of 2008-2025 will be based on robotization of technological processes and development of intellectual systems.

Thus, world economyentered period of technological renovation. The marking sign of this renovation is the world financial crisis.

During the analysis of the staged of world's technological development it is possible to see following political pattern – each new stage is marked by crisis of the global scale at it's beginning and is ended by redivision of the world map. Thus, the beginning of the 1920-45 stage is marked by Great Depression, and it's end is followed by post-WWII territorial changes. Technological stage of 1970-1995 began with world energy crisis and ended with collapse of socialist block and emergence of new countries in Europe and Asia.

The beginning of the third stage is marked by world financial crisis. According to this model, there is the risk of new world map revision in 2030 -ies.

It is necessary to understand – where is Russia in all these large-scale technological, economical and political transformations?

In order to answer this question let us compare patent application activities in various countries of the world. According the data shown on fig.6., despite the crisis, USA, Japan and South Korea continue to build up their scientific and technological potential which is evidenced by steady increase of patent applications in these countries. The most suitable word to describe increase of patent applications in China will be "explosive". And what is going on in Russia?

In order to answer this question let us compare patent application activities in various countries of the world. According the data shown on fig.2., despite the crisis, USA, apan and South Korea continue to build up their scientific and technological potential which is evidenced by steady increase of patent applications in these countries. The most suitable word to describe increase of patent applications in China will be "explosive". And what is going on in Russia?

During 1970-80 Russia had parity in patent applications with USA and Japan, and only in 1980-ies number of patent applications began to fall, reaching it's bottom by the end of the century. What is most vexing, Russia failed to climb out of this bottom during "fat fleshed years" of 2000-2008, when there was real possibility to use financial resources acquired by Russian fuel and energy sector during high oil prices period. Now Russia has to overcome technological gap while enduring deficit of investments. But it is absolutely necessary to close that gap, especially when one takes into account the ominous pattern of world map revision at the end of each stage. This risk is further increased by the fact that next stage will

change not only technologies, but also their geographic origins. While first stage was purely European (fig.3), second was largely

Fig. 2. Dynamics of patent demands on the countries of the world, pieces.

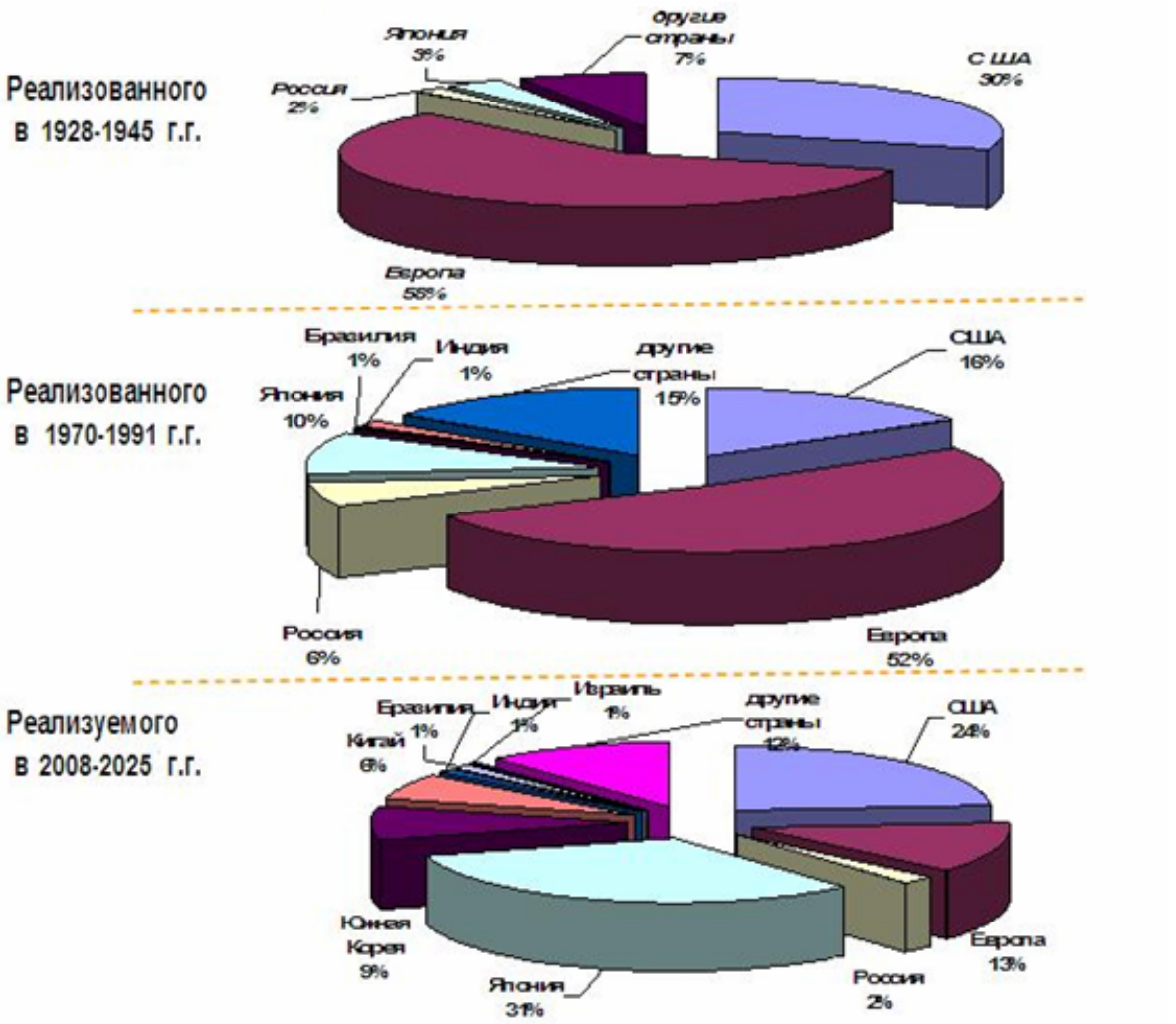

Fig. 3. Shares of the countries in formation of world technological level.

European with some American contribution, the coming 2010-2035 stage will be Asian-American. Asian countries that already have advantage of large workforce resource will also get strong technological resource.

It should be noted that financial instruments are important for Russia to overcome the crisis, but unlike USA, Japan and other developed countries they are not of first priority. The most important for Russia is overcoming crisis of technological potential. It is obvious that patents and new technologies are produced as result of R&D. What is Russia's situation here? Alas, in Russia R&D expenditure per researcher is 8 times lower than in leading countries.

Analysis of R&D financing sources gives following results: while the state still tries to fulfill it's commitments, and gap here is "only" 2-3 times compared with leading countries, Russian business invests in R&D 12-13 times less than it's foreign counterparts.

Apparently, Russian business does not interested in investments in R&D. At the same time, Chinese business invest 4 times more in R&D than Russian, which also explains intensity of patenting activity in China.

Russian business lacks motivation for investments in R&D. *What is to be done, then*

It seems expedient to realize three postulates:

- first - it is necessary at any cost, including economic coercion, create demand for innovation in Russian business;
- second – financing of innovations should be done strictly through real sector of economy; it is absolutely useless to provide the financing for that purposes to the banks, as for banks, unlike for real sector, it is immaterial what projects will provide profit.
- third – each rube provided by the state should be linked to innovation.

On the assumption of these postulates, it is necessary to implement *following measures*:

1. Develop constantly updatable list of innovative technologies and patents that will be supported by the state;
2. Develop the mechanism, through which companies will get tax reductions, state guarantees, investments in any form (loans or leasing) in order to support their financing of projects involving technologies and patents from that list;
3. It is possible to form state-supported industry-level innovation and leasing companies that will work as venture funds;
4. Pass legislation that will give researchers and developers the intellectual property rights for the results of their R&D activities even if they were financed by federal budget;
5. In innovation infrastructure sphere it is necessary create unified information system, that will be used by researchers and developers to present their intellectual property (at any stage of development, from idea to working example) to the business. There is such a system already working in power industry – B2B procurement system "B2B-Energo" with it's Innovation market portal "B2B-intechno" that allows to provide information about innovative analogues to the purchasers of "traditional" products.

What are the parameters within which world economy will develop during third technological stage?

In order to answer this question we performed wave-form analysis on patent application intensity and compared the activity cycles with oil and other final consumption products prices. The analysis shows that patenting dynamics cycles coincide with oil price change cycles (fig.4)

When specific patent applications are on the rise, oil prices are rising as well, and when patenting activities decrease, so do the oil prices. The reasons are clear: during the stage of specific patent applications decrease new technologies are being developed that neutralize upwards dynamics of oil prices.

Also, while these cycles coincide, they are shifted in time for approximately 5 years.

This is also explainable: appearance of technological patents precedes their materiali-

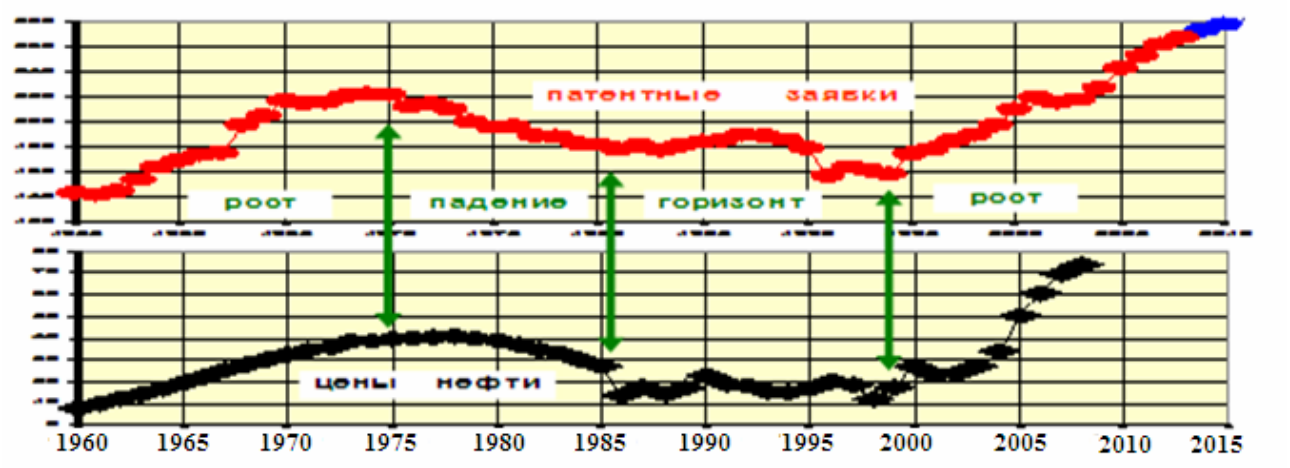

Fig. 4. Comparison of dynamics of patent demands for 1 million person of a world's population (pieces) and the oil world price ($ / barrel).

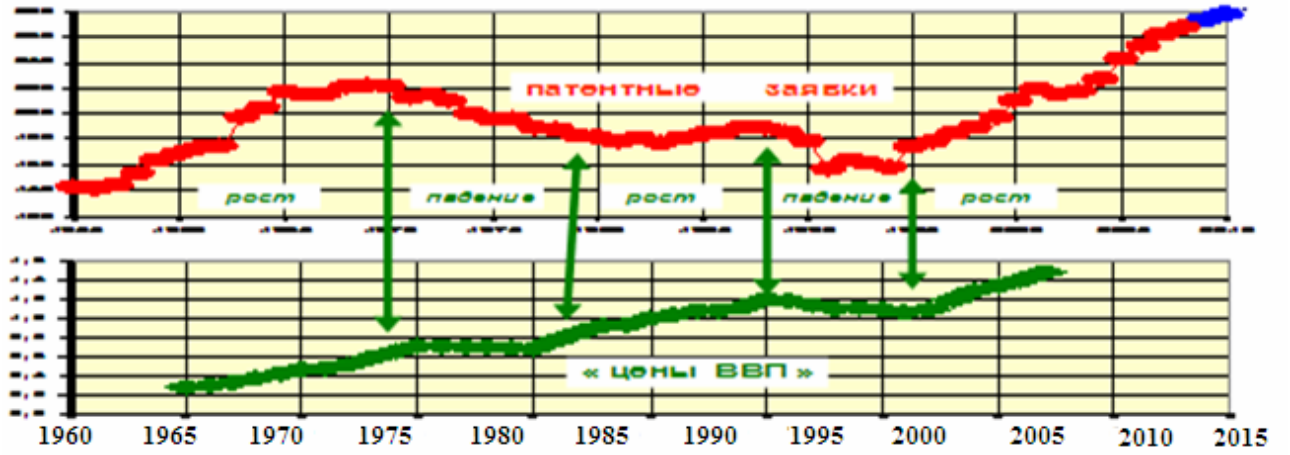

Fig. 5. Comparison of dynamics of patent demands for 1 million person of a world's population (pieces) and "the prices of a total internal product" (relative units).

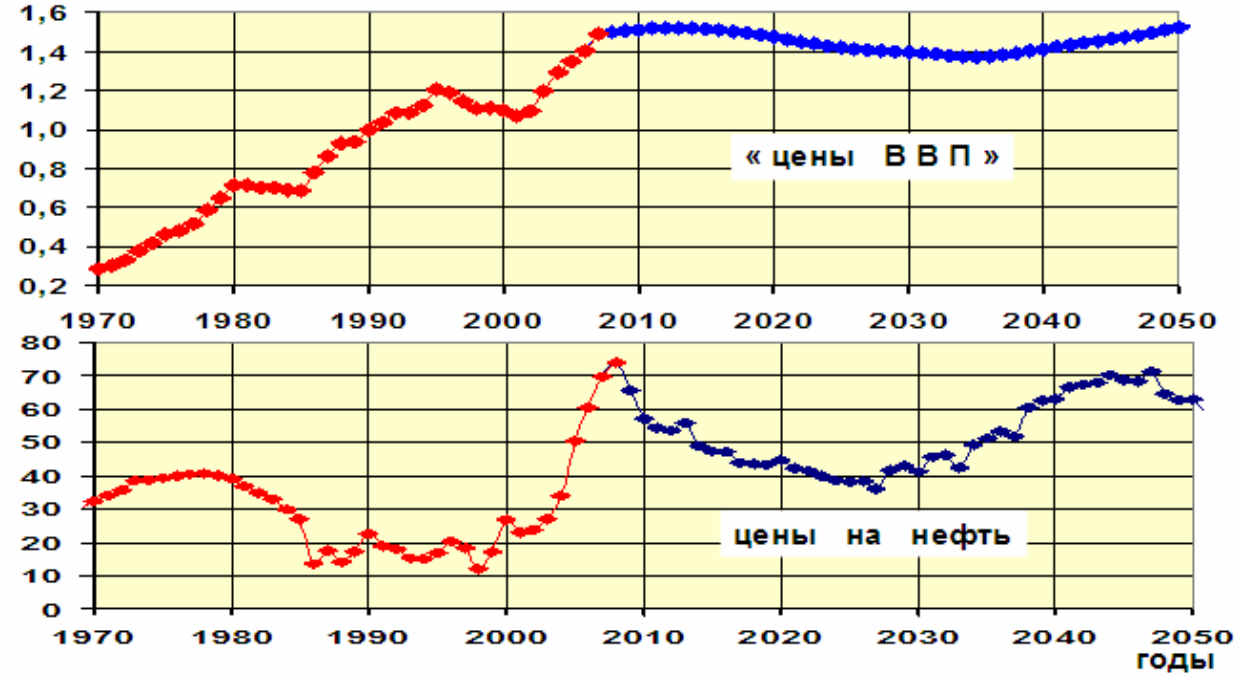

Fig.6. Comparison of look-ahead values of "the prices of a total internal product" (relative units) and the world prices for oil ($ / barrel).

zetion into new technologies that are being introduced into practice. Approximately the same coincidence of cycles and the same time shift exists with specific patent applications and prices for final consumption products.

In future calculations we shall use nominal to real GDP ratio as these prices indicator. According to this model, this ratio – "GDP prices" also have time shift with specific patent applications, but the gap is somewhat wider – approximately 7 years (fig.5).

This analysis allows us to predict prices for oil and final consumption products. The calculation results indicate that oil price will post likely enter systemic decreasing corridor. The oil prices will continue to decline until 2014-2015, where it will reach flat line of 40-50 $ per barrel, that will last approximately until 2035. (fig.6).

The same systemic decrease will also characterize prices for final consumption products – the will decrease until approximately 2025, and then will reach flat line until 2035.

In period until 2035 (during the forming of new technological stage) for the first time in many years, the world economy in general will change its price vector from increasing to decreasing (fig.6).

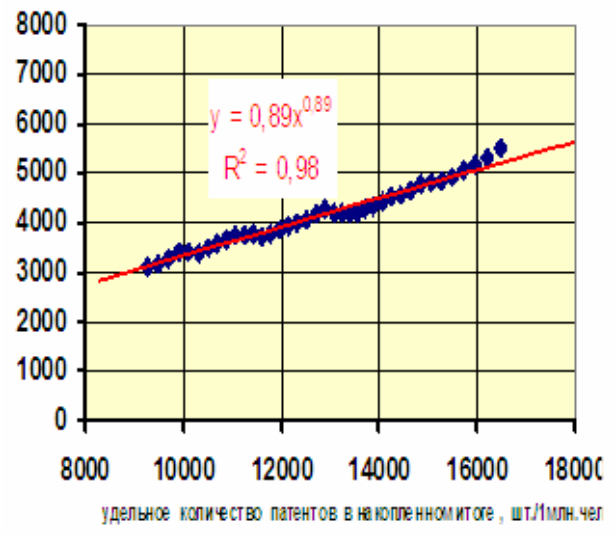

Fig. 7. Dependence per capita GDP the world in the real prices (dollar/person) from specific quantity of patents in the result saved up since 1880 (pieces/1 one million person).

It indicates that world economy is entering demand-dominated stage of it's development, which will lead to it's more efficient consumption, which in turn will be also based on implementation of more advanced technologies.

During the research the dependency between per capita GDP and accumulated (from 1880) average patent applications was found (fig.7) As it is seen from presented data, this dependency has functional character – the volume of accumulated scientific and technological information determines per capita GDP, which is one of primary indicators of social and economic development.

In previous research many authors evaluated scientific and technological progress by average annual per capita GDP growth rate. The viability of such evaluation is proved by this calculated relationship. According to research results, for a long time during 20th century per capita GDP (in indexed form) coincided with volume of accumulated scientific and technological knowledge (in indexed form). But starting from 2010 the volume of accumulated knowledge will separate itself from per capita GDP and will not follow it (fig.8). Actually, in 2010 economy of 20th century will end.

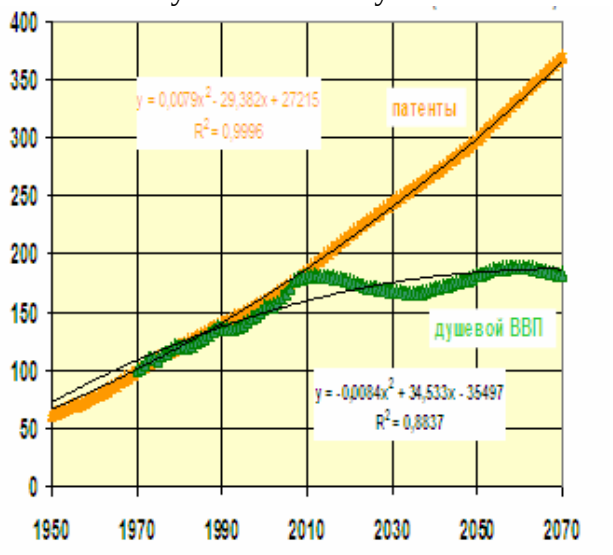

Fig. 8. Retrospective and look-ahead values of indexes per capita GDP the world in the real prices and specific quantity of patents in the result saved up since 1880 (1970 = 100 %).

In 21st century technological progress will be no longer related to growth of per capita GDP. The information value will get into limelight. Information, knowledge will become primary instruments of social development. Apparently, per capita GDP maximization will cease to serve as main criteria of policies' efficiency. The sum of world GDP and per capita accumulated information (knowledge) should serve as such criteria. It shows that developed countries took postindustrial path of development and started to form information society.

The defining factor of such society will be objective information and level of IT development. Therefore, economic activity of postindustrial stage of the civilization, as opposed to agrarian and industrial stages, will primarily consist of storage, transmission and creation of information.

Automated information processing systems that encompass economy, science, art and culture will become one of the most important element of the society. Information will become primary form of property and primary productive force of society. Traditional productive forces will be succeeded by information, first of all by cultural, spiritual values and creative potential.

In this connection, use of traditional methods of forecasting and forming social and economic development programs in attempt to evaluate parameters of future economy is problematic. It is necessary to develop of new methods and models that will help to analyze and understand information creation and processing activities of human beings. Does world power industry confirm these regularities found in world economy? In order to answer that question, the long-term (more than 200 years scale) dynamics of world energy consumption was studied. According to analysis of this dynamics, the tendency of doubling of energy consumption each 40-50 ears was revealed. In that connection the new question arises: will that regularity be continued in 21st century, or there are some factors that will prevent that? (fig.9).

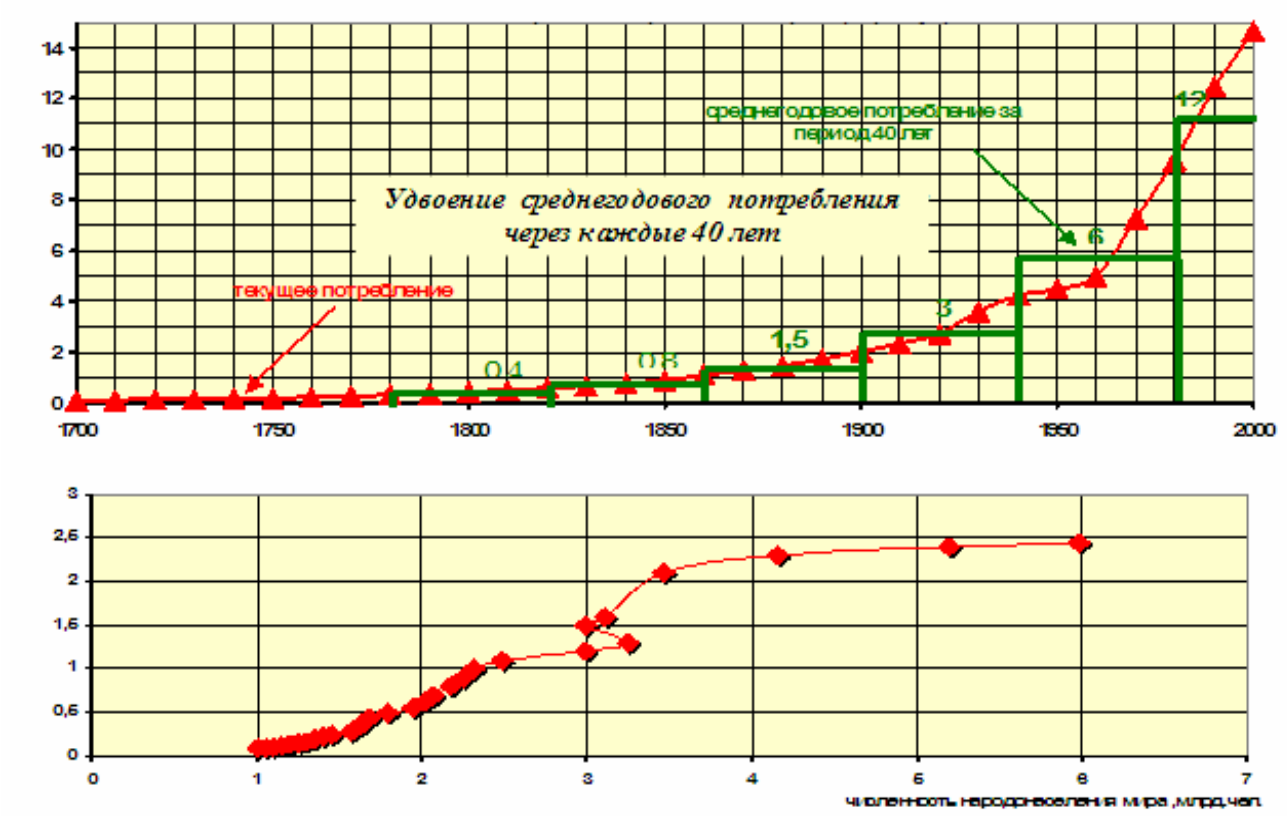

Fig. 9 . Dynamics of world consumption of energy (billions tons of conditional fuel). Dependence of world per capita consumption of energy (tons of conditional fuel/person) on a world population (billions persons)

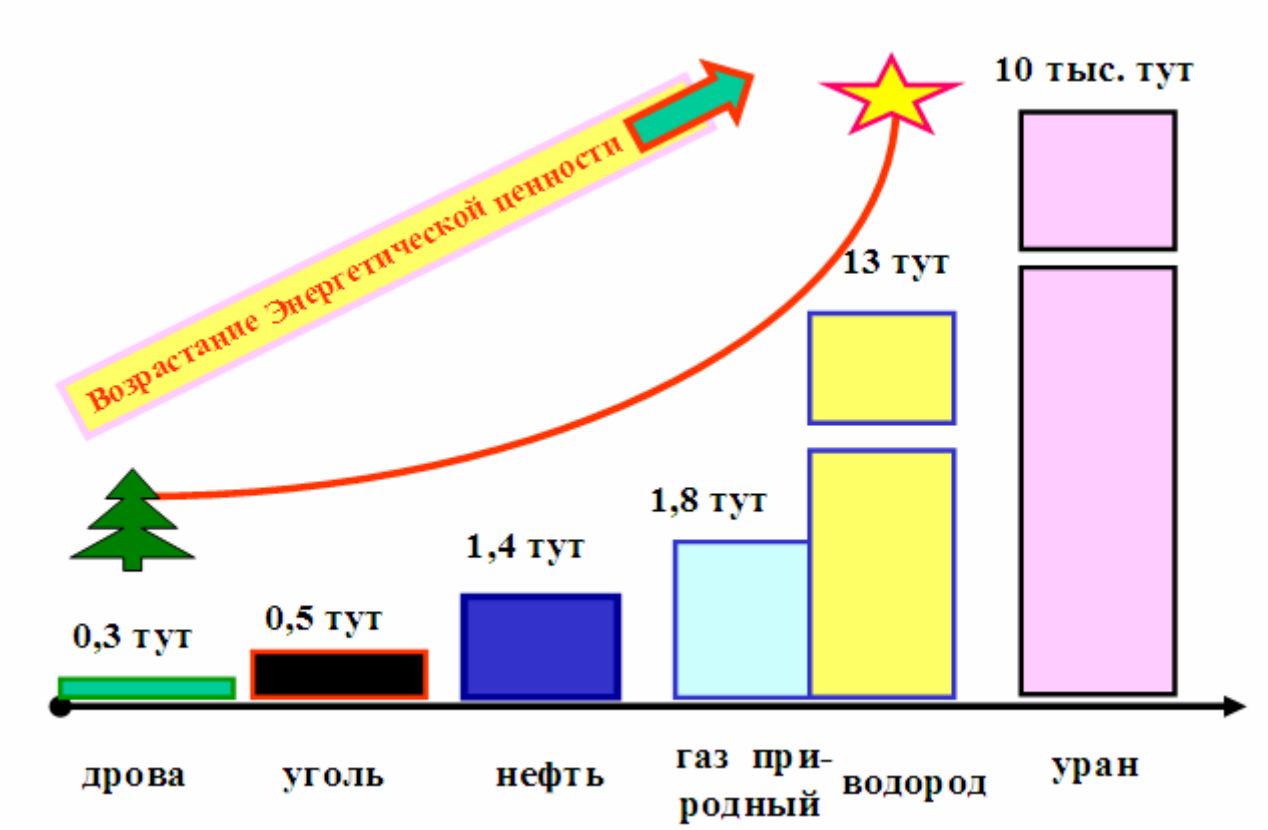

Fig. 10. Power value of 1 ton of a power resource.

In order to find the answer, the dynamics of per capita consumption of energy in relation to world's population was studied. As a result, this Z-form curve was established (fig.9). According to it, per capita energy consumption will not increase at all in prospective period, but will asymptotically approach the value of ~2,5 tons of oil equivalent per capita. However, such regularity is true for world in general, but in various countries the situation may be different. Indeed, developed countries that are located at upper levels of energy consumption will lower their per capita consumption to this average, and developing ones will increase their consumption until it reaches this average level.

Such tendency, coupled with projected dynamics of population growth allows us to come to conclusion that despite declarations of the politicians regarding increasing demand for primary energy (oil, natural gas and coal), in prospective period overall volume of consumption in developed countries will decrease. In accordance with shift of technological stages, the shift of energy pattern will occur in power industry. As well as oil pattern that was active during second technological stage of 20th century succeeded coal, that was energy basis of first technological stage of 20th century, in near future oil patter will be succeeded by natural gas pattern. This pattern will support third technological stage (or the first stage of 21st century) approximately until 2050-2060.

Then it will be succeeded by non-hydrocarbon pattern with full specter of renewable power. The rapid development of non-hydrocarbon pattern within natural gas pattern worth special mentioning.

In light of foregoing, we can point at regularity – each technological stage has it's corresponding energy pattern. The dominant energy source in given period, being at the bottom of economic product processing chain, actually supports the possibilities of new technologies in economy. The "philosophy" of energy patter's shift is increasing energy value of currently dominant energy source. Thus, transition from coal to oil (fig.10) was marked by three-time growth of energy value. Transition from oil to natural gas can increase energy value relative to hydrogen by no les than 9 times.

During realization of natural gas pattern the priorities of energy resources consumption will change. Thus, per capita consumption of oil by developed countries in first half of 21st century will decrease. The same will happen to consumption of coal. Per capita consumption of natural gas in developed countries will be stable, but by 2040 the tendencies for it's decrease will appear. Per capita consumption of renewable power will increase until mid-century, with possible stabilization afterwards.

What ratio between "traditional" (coal, oil and natural gas) power and renewable power is to be expected? In order to answer this question the research of patenting activity in power industry during 1998-2007 was conducted. According to it's results, patent applications increase ratio in power industry is 1,5 times higher than in whole economy.

It indicates the priority of energy issues among challenges faced by world economy. If we split the results by traditional, renewable and nuclear power industry, the following picture will emerge (fig.11).

According to analysis, the rate of increase of patents in the field of non-renewable fossil fuel power industry is two times less than in renewable power, while in nuclear power industry the rate of increase of patenting activity is three times less than in non-renewable fossil-fuel power. The highest average annual increase rates are in wind power (almost 31%), fuel cells (almost 22%), solar power (almost 10%) and geothermal power (11%). In given timescale, "traditional" power has 30% of all patents, renewable has 48% and nuclear power has little more than 22%. Actually, such low results for "large-scale" nuclear power are quite alerting. The nuclear energy's share in patents is lowest as well as increase rate in patenting activity. This clearly indicates that R&D sector in this field is

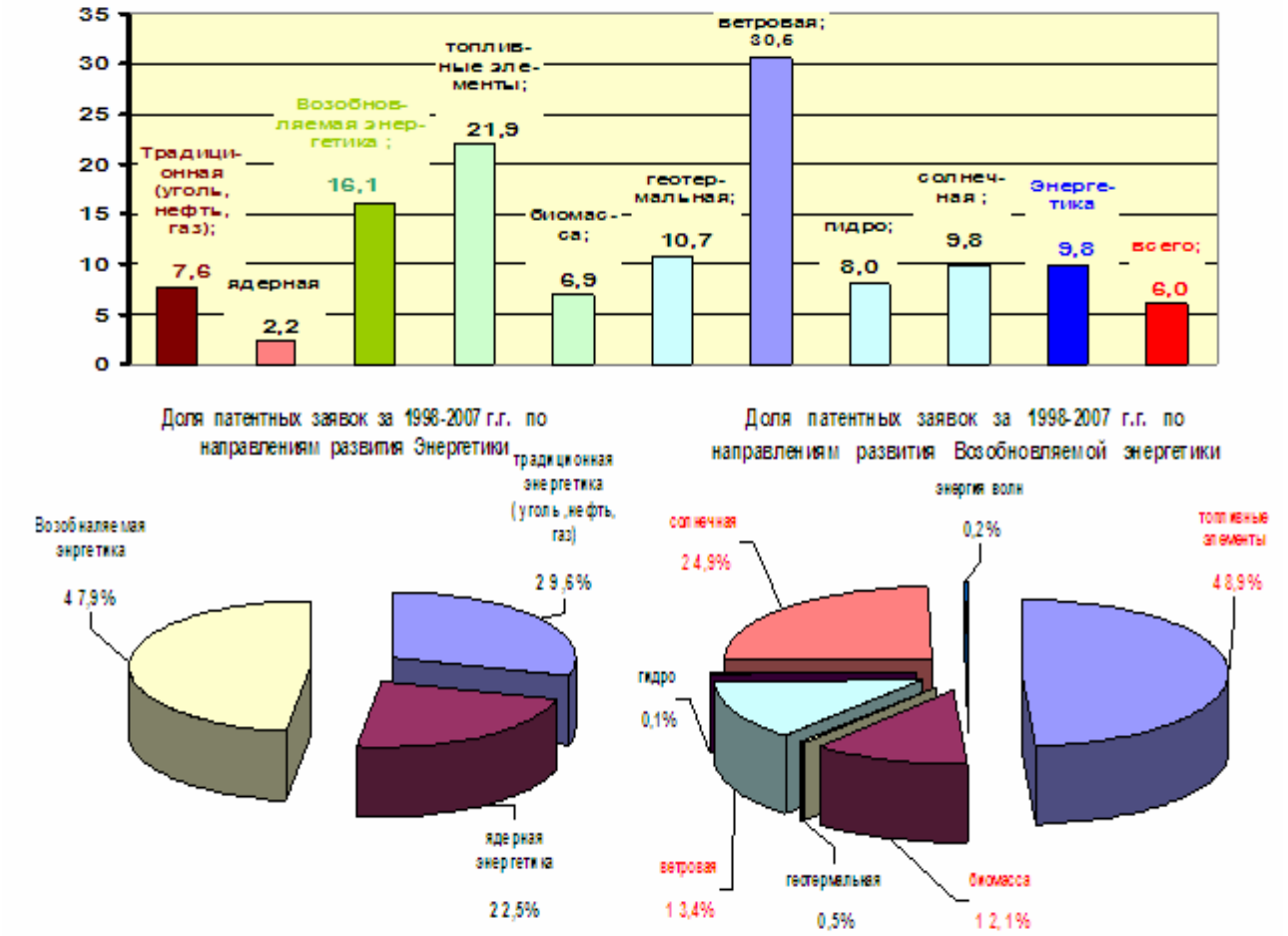

Fig.11. Mid-annual rates of a gain (in percentage) patent demands for 1998-2007 in directions of development of power

narrowing which in long term will lead to decrease of “large-scale” nuclear power share in total energy production. The biggest and the most rapidly growing sector is renewable power (fig. 11). Within that sector the most patent applications are filed in fuel cells (around 50%), solar power (25%) and wind power (13%). All of the aforementioned patent applications will be implemented during first technological tier of 21st century and will remain active up to 2050.

According to calculations, by 2050 the specific weight of oil will decrease from 37% to 19%, coal – from 21% to 12%. The share of natural gas will increase from 20% to 33%, and, of course, the share of renewables will go up from 11% to 30%.

The analysis shows that regularities of the development of world’s power industry are consistent with regularities that will be characteristic to world economy of 21st century – the new postindustrial economy.

These regularities should be taken into account when developing medium- and long-term plans and forecasts of social-economic development of Russia.

BIOGRAPHY

Yury Anatolyevich Plakitkin – professor, doctor of economic sciences, academician of RAEN, state advisor of Russian Federation III class, deputy Director of Energy Research Institute of Russian Academy of Sciences.

In 1982 he became candidate of technical sciences, in 1993 – doctor of economic sciences; in 2001 received the degree of professor in the field of “of RAEN (Russian Academy of Natural Sciences) in Oil and Gas section. From 1992 until 2004 worked in oil and coal industry, was one of the authors of industry restructuring program. In 2004-2008 worked as an advisor to Ministry of Energy, and deputy director of State Energy Policy Department. From August 208 works as deputy director of Energy Research Institute of Russian Academy of Sciences.

Y.Plakitkin is a leading specialist in field of energy policy and energy industry development forecast, and is author of more than 180 scientific papers. Under his direction more than 20 candidates and doctors of sciences were trained.