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Post-industrial technological mode of production: time of emergence

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Abstract. The article characterizes a postindustrial technological way of production, an indicator, a set of technologies and connection with the pre-industrial and industrial technological methods of production. The development of the sixth technological mode is treated as the beginning of formation of the postindustrial technological way of production. The author reveals possibilities and prospects of post-industrial technologies. Many countries are conducting research on the application of post-industrial technologies despite industrial production, leading in the world. The article draws attention to the strengthening of measures on development of post-industrial technologies in our country.

Key words: technological mode of production, pre-industrial, industrial, post-industrial, indicator, technology, prospect.

Economists have been discussing the basic directions of development of Russia's economy such as neo-industrialism and post-industrialism.

Adherents of post-industrial development believe that "great concentration of industries that used to be the pride of the industrial period, is now a heavy burden (both economic and social) in the current early post-industrial society; and greater importance is attached to indicators characterizing the development of high technology, the rate of renovation of production, the level of development of the social sphere (especially education and healthcare) and the services sector in general" [16].

Supporters of the first trend of economic thought have sharply criticized the ideas of post-industrial society, calling them false targets "used for justifying de-industrialization

of the national economy". Industry in the era of the formation of neo-industrial society, in their opinion, is turned into automated, robotic and "digitized" [30].

The paradox consists in the fact that the alternative concepts have a common original basis: the achievements of science and technology, the use of "smart technology". Then why do the conclusions on economic development diverge so radically? It seems that the reason lies in the differences in the choice of priorities of economic development. It is not a coincidence that publications on this topic contain concepts such as "neo-industrial society" and "post-industrial society". On the other hand, there is an opinion that "clear scientific criteria of post-industrial economy, in contrast to industrial economy, have not been developed so far" [15]. D. Bell, the founder of the conceptual framework of post-industrial society, pointed out: "The term "post-industrialism" relates primarily to changes in the social structure (technological-economic system) of society" [2]. D. Bell made a social forecast of post-industrial society using the analysis of achievements in the field of information technology of the 20th century industrial production (the emergence of electronic systems, miniaturization, conversion of data into digital form, software) and seeing them as tools of social change. But he and his supporters did not associate the characteristic of post-industrial society with the formation of post-industrial technological mode of production. Therefore, we can raise the question concerning the approaches to the disclosure of technological basis of post-industrial production, which, along with social features, can have its specific technology, and mode of production that is basically different from industrial production.

To identify the essential features of post-industrialism, we build our analysis upon the core economic concept of "production" in the technological aspect[1], and attempt to substantiate the criterion on the basis of which we could analyze the structure and status of post-industrial production. Especially since in this regard there is evidence that support the emergence of a set of technologies beyond the framework of industrial methods of production of goods and services[2]. The issue of post-industrial production can not be considered as complete and dealing with its nature and composition; it can be also viewed as an object of scientific analysis, substantiation and addition to the preliminary results.

Criteria of technological eras

Post-industrialism as the era following the industrial society is recognized by many scientists. However, its characteristic as a *technological* community is ambiguous and too general[3]. If pre-industrial and industrial technological eras differ in some typical set of food production methods, then it is difficult to distinguish the technology of post-industrial production from that of industrial production. They are often referred to either industrial or post-industrial modes of production. It is not clear why certain post-industrial technologies cannot be classified as industrial.

[1] The technological mode of production means the unity of the equipment and its technological settings [23].

[2] The object of the research in the article is limited only by technological specifics of production of goods and services, and it is in no way related to its social form.

[3] "The post-industrial [sector] is a *processing* sector. Here the exchange of information and knowledge is going on mainly by means of telecommunication and computers". "Post-industrial society is formed under the influence of *intelligent technology*" [2].

Thus, it is possible to speak about the criteria of technological eras[4]. Obviously, the methodological approach to their establishment can be the *consideration of technology as a means of production-related attitude of man to nature with the purpose of obtaining consumer products that sustain people*. It is the difference between the means of exchange of man with the natural environment that can be the basis for identification of the technological era and its inherent set of technologies.

When the formulated approach is applied in analyzing the historical path of the origin and development of technologies, we can suggest the following criteria of the methods of exchange between man and natural environment. The first one is the use of the fruits of nature. The second method is the use of discovered laws of nature and creation on their basis of "the second, transformed nature" that is a system of machines (machine industry) for production and consumption of vital products and services. The third method is the use of processes occurring in nature itself, when products and services are produced by managing natural processes.

The first criterion identifies the technological era of gathering. Its basic technology includes harvesting, hunting, fishing, the beginnings of handicraft, followed by the technology of agriculture, animal husbandry, utilization of wind energy and water flows (mills) that are the germs of basic technologies of other epochs. The combination of the aforementioned technologies can be classified as the technological basis of pre-industrial production.

The second criterion can describe technologies related to industrial production. Its characteristic features include: 1) application of equipment systems, machines, mechanisms, devices, and 2) operation of large industrial complexes: metallurgical, chemical plants, machine-building giants and other companies focused on serial and mass production. Industrial production is the processing of resources provided by nature: wood, hydrocarbons, ore and non-metallic minerals, and their ultimate destruction (consumption) in the production process. The industrial type of production is accompanied by a huge amount of waste (up to 50% from the weight of natural raw materials), by environmental pollution dangerous to human life, by approaching the limit of growth of productivity of traditional industrial technologies and the necessity of upgrading them according to new technological principles. It is believed that the era of the industrial mode of production – the use of machines – began with the domination of the steam engine in the mid-19th century.

According to the third criterion of the means of exchange with the natural environment we can define the technologies of the post-industrial type of production; they are based on the use of processes occurring in nature itself, when products and services for human activity are derived from controlled natural processes.

[4] Traditionally, the change in technological modes of production is considered in connection with the delimitation of civilizational stages of social development. Their most accepted differences are characterized in accordance with the method of use of technological tools: basic hand and instrumental technology (Savagery and Barbarism), advanced instrumental technology (Cosmogenic civilization), machine technology (Technology-based civilization), information technology (Anthropogenic civilization) [23]. Differentiations of such kind characterize the link between social eras and historically developed technology, whereas our task is to consider the development of technology itself.

An example can be found in technologies for obtaining renewable energy, atomic and molecular technology, laser processing, computer-modelled production of articles from powdered metal without cutting, milling and welding. Today it is hardly possible to characterize the set of technologies that form the technological basis of post-industrial production. However, "the difficulties and limitations arising out of the present state of knowledge (or, rather, ignorance) of the nature of post-industrial society should not be considered as fragments in favor of abandoning its study" [16].

We would like to draw attention to the fact that the development of new technology is regarded, though not often, as the onset of post-industrial production. It is noted that the most fundamental changes connected with biotechnology, gene and cell engineering, nanotechnology, computer designing of molecules of the substance are integrated into the base of the new *post-industrial production* [10].

In our opinion, the available facts show that the use of internal natural processes in the production of goods and services can be interpreted as the initial position that expresses the qualitative basis of post-industrial production. Nowadays, human impact on nature with the use of mechanical instruments of production created by man is decreasing, and now the characteristic feature is the management of natural processes in order to obtain the necessary products and services. Thus, we can conclude that post-industrial production that comes after industrial production is the production of goods using natural processes.

Following this approach, it is difficult to agree with the statements that the leading countries of the West already have a post-industrial society [2, 12].

From the viewpoint of technological aspect, the industrial mode of production still prevails in the world.

According to Eurostat, the share of energy produced from renewable sources in the total energy consumption of the European Union is 10.3% (data for 2008). It is forecasted that by 2020 the contribution of renewable energy sources will have achieved 20%. These figures are differentiated significantly in different EU countries: for example, in the UK – from 2.5% in 2008 to 15% in 2020. In Sweden, which is the leader in renewable energy they range from 44.4% to 49% [21].

The share of energy derived from renewable sources in the U.S., according to the plans of President Barack Obama, should reach 25% by 2025 [13]. According to the forecast of the International Energy Agency, if the current trends in the global energy sector remain the same until 2020, the share of hydrocarbon fuels in the global energy structure should reduce to 83% by this time and to 64% by 2050 [19]. Hydrocarbon raw materials, which are the reserves of solar energy stored in the earth's crust millions of years ago will remain the main source of energy for the coming decades.

Atomic and molecular technologies and nanotechnologies are in the initial stage of scientific research, design, creation of laboratory samples and small-volume production. Western experts say these technologies are not yet ready for wide industrial application[5].

[5] "The time has not yet come for the industrial development of the construction "atom by atom" on the basis of self-organization of matter, in which the components will form a structure through their natural process" [28]. The article [15], along with recognition of the rapid development and growth of the influence of nanotechnology in science and industry, provides just a few specific applications of nanotechnology in the near future.

The same can be said about laser technology of growing products from powdered metal by computer models completely eliminating final finishing.

First steps in the development and application of post-industrial production technologies in the leading Western countries do not afford ground to conclude that they have already formed the technological basis of post-industrial society. We can talk about the new wave of technology (in Russia it is called the sixth technological mode), which can be attributed to the technology of formation of post-industrial production.

The onset of the new (sixth) technological mode is associated with nanotechnology, biomolecular technology, information and communication technology [6]. C. Perez, who studies long waves of techno-economic development, says that "biotechnology, nanotechnology, new energy, new materials, bioelectronics, etc. (in varying combinations) can become the main driving forces of the emerging new wave [24]. The sixth technological mode is identified with the post-industrial technological mode of production: "the sixth technological mode will be fully adequate to post-industrial society" [10].

Although technologies of the sixth technological mode relate to the post-industrial technological era, the first applied achievements in this sphere are oriented toward the industrial mode of production. They become, to a greater or lesser extent, a breakthrough technology in the neo-industrialization of the domestic economy. Large-scale development up to the level of the leading technological basis will already match the post-industrial mode of production.

The above characteristics of technological eras, technological modes of production, are their core characteristics, their technological core. Technologies of other eras, which are not separated from each other, are applied together with them. For instance, post-industrial production can include segments of industrial technologies involved in supporting post-industrial technological processes. To a certain extent, "post-industrial society" (let us say "post-industrial production") is a continuation of trends that arise from industrial society" [2]. On the other hand, the principle of post-industrial production, i.e. the use of natural processes, is inherent to some extent in different technological eras. For example, agriculture, which is based on a relatively inexhaustible resource of land, has been the primary sector of economy for thousands of years; and large hydropower engineering based on the use of the water flows energy defines the image of industrial production, along with other sectors.

Transition to the post-industrial mode of production

Being concerned with the present day situation and with neo-industrialization of economy, we should not neglect the origin and development of technologies of the post-industrial era. Intensive work is being carried out in this sphere all over the world. It is important that our country should also keep pace with the formation of a new technological basis. There are certain encouraging results in scientific research, but the lag in the creation of new industries and in the manufacture of nanoproducts is beginning to take shape. Unfortunately, we will soon face the problem of catching-up development in this sphere. The time factor is becoming more and more important in

the scientific and technological race. We cannot allow the lag to be repeated, like it happened, for example, in microelectronics, the consequences of this lag have to be overcome at present due to the fact that Russia had not joined the global system of development of microelectronics in due time.

Experts forecast that the technologies of the post-industrial mode of production, based on discovered methods of use of renewable energy, application of nanometric material particles, atomic and molecular structures will transform the basic industries of national economy: power, metallurgy, machine building, transport, agriculture and the environment and conditions of human life. Post-industrial technologies give rise to the hopes that depletion of economically acceptable hydrocarbon resources can be delayed, that the environment can be improved cardinally, that large enterprises and a number of industries can be abandoned in favor of technology close to natural processes, that growth of labor productivity can be achieved.

The main post-industrial technologies (excluding large hydropower, nuclear industry, information technology that were developed in the industrial era) in Russia are at the beginning of their formation. Current generation of power from renewable sources is less than 1% of the total power balance in the country. The target for 2020 is set at 4.5%. However, given the planned growth of generating capacities based on renewable energy sources, we note that the share of renewable energy in the country's energy mix by 2020 can be increased only up to 2.5%. For comparison: in Ukraine it is planned to increase the share of power from renewable energy sources to 12% by 2020 and to 15% by 2030 [34]. The development of renewable energy technologies in our country that does not experience a shortage of energy resources will improve the quality of life in the regions remote from power networks, which make up more than half of the country's territory; it will also optimize the structure of power generation. Advantages of renewable energy have been studied quite thoroughly [3, 19], but their implementation is currently constrained by its high production costs compared to hydrocarbon energy. It is estimated that energy from power systems, due to cheap fuel, costs one and a half times less than energy obtained through the use of wind, solar and biomass in the south of Russia; as for its central part, renewable energy resources are 20–40% more expensive there than in the south [17]. A century of experience shows that qualitatively new technological principles, as a rule, are at first less efficient than the old ones. Russia, like other countries, carries out intensive scientific-technological research and industrial development of a new generation of solar panels, wind turbines, including those of a closed type; the research aims to extend the operational properties of power units and compatibility with the existing power networks, to increase the efficiency of energy facilities, reduce energy costs per unit of power.

Other countries demonstrate a steady tendency towards the reduction of costs for renewable energy. For example, specific capital investments in wind-driven power plants decreased from 4000 U.S. dollars/kW in 1980 to 900 US dollars/kW in 1999. During the same period, the unit cost of photovoltaic modules has dropped from 50 thousand to 4–5 thousand U.S. dollars. At the same time renewable energy capacities are developed

at high rates. Industrialized countries are planning to increase the share of renewable energy in their total energy balance up to 20–50% in the first half of the 21st century. The USA and Japan are planning to create space-based solar power plants that transmit power via microwave beam. The Vatican is planning to create a photovoltaic plant that will cover the needs for power through solar energy.

Experts are concerned about the fact that intensive development of renewable energy sources can deprive Russia of the foundation of its development, i.e. oil and gas export, and leave it alone with its hydrocarbon energy [7]. In addition, "the duration of the trade in oil and gas depends more on the reaction of Western countries to the market situation, rather than on the actions of Russia" [25].

The development of renewable energy sources is usually associated with the desire of European countries to reduce its dependency on Russian and OPEC's hydrocarbons and to diversify energy sources. Simultaneously with the solution of this problem a new industry is being formed for the production of high-tech equipment with the development of new technologies, experience and professional competence in this area. A global technological superiority of a group of countries is being established. Their high-tech companies, enjoying intensive state support, become leaders of the new power engineering and enter the markets of developing countries. The richest countries can direct huge subsidies to support their own high-tech companies [20]. Currently, for example, German companies have gained strong leadership positions in the global solar energy market. Almost 40% of solar panels produced in Germany are exported. The annual turnover is several billion euros. Germany is a world leader in the number of constructed wind power stations [7]. Siemens AG has installed more than 6400 wind turbines in the world. It produces equipment for small hydropower plants, installations for conversion of solar energy, which operate on all continents. Vintec (Germany) and NIBE AB (Sweden) are leaders in the production of heat pumps on the markets of Eastern Europe and Scandinavian countries. In Russia the share of foreign equipment in the development of renewable energy sources is 70% [7].

For our country that does not experience a shortage of hydrocarbon raw materials the development of technology and production of equipment for the use of renewable energy is relevant not only for the solution of current problems of energy supply to the population, but also for achieving technological independence in the generation of new energy based on renewables. According to Academician A. Koroteev, the main problem of power in Russia lies in the extreme backwardness of domestic power engineering [7].

According to experts, it is dangerous for Russia to stay away from global trends, since the country has a huge potential of renewable energy of all kinds. "One-sided reliance on basic traditional power threatens us with not just economic, but, rather, military-political problems... There is an enormous gap between Russia and the rest of the world concerning the development of renewable energy sources". A report of the RF State Duma Committee on Energy, Transport and Communications points out: "Due to the depletion of oil and natural gas deposits, Russian energy has to undergo significant structural changes in the course of the 21st century" [7].

It is believed that sustained interaction of hydropower facilities and natural environment, as well as nuclear and wind energy will be the most effective and important spheres for development of renewable energy using the principle of natural-and-technological systems for Russia in the near future [18, 19, 33].

Nanotechnology, the second basic component of post-industrial technologies is the cutting edge of modern research in the natural sciences; today it offers fundamental achievements in the creation of materials with unique properties for many types of products and services, including renewable energy sources. A specific feature of nanoparticles consists in their high activity and ability to join other particles and attach particles of various materials. These properties are effectively used to create new materials with extremely important characteristics [14]. For example, polymers created from nano-components have super-properties: they are harder than diamond and 100 times harder than steel, they have greater smoothness than teflon coating, they are super light and super elastic and have thermal and electrical conductivity even greater than that of copper [28]. Post-industrial technologies implement controlled synthesis of atomic and molecular structures, which is used for producing objects for any purpose not from common raw materials, but directly from atoms and molecules using assembling machines. Machines that are able to perform the necessary operations with atoms are already being created. The foundations are being laid for a technology of atomic and molecular-level assembly to be used in electronics, communications, optics and robotics [27]. Technology of manipulating the smallest particles up to 100 nm can be used almost indefinitely in various sectors of industrial production, agriculture, medicine and information systems.

For instance, R&D carried out at the Central Research Institute of Structural Materials (CRISM) "Prometey" (Saint Petersburg) resulted in the production of semi-finished metallurgical products, in which the structure of steel is crushed down to the nanoscale level. Such materials were used for constructing the offshore ice-resistant platform Prirazlomnaya and the drilling platform Arcticheskaya. The research institute also developed a method of manufacturing components from powdered metal using computer-controlled laser sintering, which excludes industrial technology of machining and welding of materials. This technology was used for making complex components for JSC Klimov and OJSC Kaluga Turbine Works. "The development of a number of new breakthrough technologies may constrain and then close the classical metallurgy, including mining, coke production, blast-furnace metallurgy and converter processes" [8]. According to expert estimates, Russia has established a solid foundation for further development of research into nanotechnology [1]. However, the application of nanotechnology is going on slower than abroad. One of the reasons lies in a small demand for nanoproducts and products created on the basis of nanotechnology, except for the demand on the part of government-controlled strategically important industries (like aviation, aerospace, and nuclear power) [11]. The development of demand is directly connected with necessity to overcome the technological backwardness of a significant

part of production capacities, to carry out large-scale neo-industrialization, including that with the use of nanotechnological components in technological processes. The issue of ecology and effects of new technologies on people remains underexplored. On the one hand, post-industrial technologies exclude contamination typical of industrial production methods; on the other hand, they require the research into possible effects of application of new technological principles.

The main spheres of nanotechnology are still at the stage of research or laboratory specimens. Industrialized countries make enormous investments in this field. For instance, in the USA the amount of budget funding for nanotechnology research is little more than 1 billion U.S. dollars per year [32]. Russian corporation RUSNANO has allocated 64 billion rubles and 180 billion rubles of government guarantees against loan. The main problem is to identify an opportunity and to transfer laboratory nanotechnology developments into industrial technology, which will require high-tech industrial production. Its absence arouses concern among domestic researchers with regard to application of achievements of nanoscience. For example, "the initiators of production of solar converters are faced with a problem that consists in the absence of related materials in the country" [26]. Therefore, the launch of neo-industrial processes in our country in the aspect of transition to post-industrial technology is becoming relevant.

Post-industrial technological line in Russia's economy is based not only on internal, but also on external factors. Scientists warn that the leading countries consider nanotechnology as a lever for gaining global economic, financial, political and military domination [9]. The creation of a post-industrial form of production is associated with extensive research in different fields of science. It requires considerable financial resources. It is estimated that further research on nanotechnology in solid-state physics at the Russian Academy of Sciences requires over 40 billion rubles [1]. Considerable investments will be necessary for its industrial development. Neo-industrialization and care about the future technological foundation of production set out the tasks of accumulation and distribution of funds (neo-industrialization) and strategic directions for post-industrial technology. It is very difficult to solve this problem in the economy with limited budget investments.

Biotechnology as a technology of the post-industrial technological era begins to penetrate into every sphere of modern life. Based on the methods of genetic engineering, it becomes one of the key areas in the development of the world economy [29].

Its progress is marked in the study of biological systems (proteins, microorganisms), biomolecular phenomena (identification of DNA and biological processes), other issues, including the creation of a molecular computer, development and delivery of medicines, surgical techniques, biocompatibility, diagnostics, implants, and prosthetics. "Scientists have realized that they can control the processes designed by the Creator and by millions of years of evolution. They can now create and adjust genetic programs inscribed by nature" [29]. However, this puts forward the issue of bioethics and responsibility for the consequences of the use

of new developments and technologies and the problem of avoiding irreversible adverse effects [22].

Scientific advances suggest possible future dramatic changes in technology of producing goods necessary for human life. Forty years ago, American sociologist A. Toffler wrote: "Today a new science based on the principle of harnessing the development of microorganisms is rapidly emerging and it promises to change the very nature of industry as we know it" [31].

Information technology plays an increasingly important role in the development of neo-industrial and post-industrial technology. The functions of information technology are continuously expanding. Now they are becoming part of material production technology. Information technology is embedded in technological processes of industrial production; it also participates in the creation of complex objects, such as the simulation of airflow about a real aircraft using supercomputing technology. It is noteworthy that in the USA supercomputing is considered a priority area along with alternative energy sources and nanotechnology. Russia has a computer network founded on an academic base. It links the main centers into a single unit. There is a supercomputer with the peak processing capacity of 94 million floating-point operations per second at the Russian Academy of Sciences, and a supercomputer with the capacity of 47 million floating-point operations per second at Lomonosov Moscow State University. The system of education has at least six fairly large supercomputers. The country has created prerequisites for the solution of practical problems. Supercomputers help solve the problems of interaction of substances at the atomic level [4]. Post-industrial technologies will be based on information technology more and more extensively. Therefore, it is hardly justified to associate microelectronics only with the fifth technological mode. The use of information production technologies will require creation of new microelectronic devices in the post-industrial era as well.

Nano-, bio-, and information technology proclaimed as the key directions of the sixth technological mode, are intended to become crucial in geopolitical competition until the middle of the 21st century [5]. Performing this role, they can participate in neo-industrialization by transforming the industrial sector, and also in the formation of an independent part of post-industrial production, i.e. production based on atomic and molecular technology. Gradually its growth in the future, together with the dominance of renewable energy, will mean the transition from industrial to post-industrial production.

The present article considers the development and change of technological eras from the perspective of the evolution of the means of exchange of man with the natural environment with the purpose of receiving consumption products. Using this characteristic we can select the criteria of pre-industrial, industrial and post-industrial technological modes of production. A widespread concept of post-industrial society does not reflect its inherent technological basis, technological mode of production other than industrial. The transition from industrial to post-industrial production marks the use of controlled natural processes as the basic technology.

One of the priority spheres for Russia is neo-industrialization as the necessity to overcome technological backwardness, to catch up with the global technological level and as a condition for the creation of material prerequisites for the emergence of post-industrial technology.

However, already at present we must not allow our country to fall behind in the formation of the scientific-and-technological base for post-industrial production. Insufficient (according to world standards) public funding provided to scientific research and to the formation of post-industrial production can in the near future set a permanent task of catching-up development. We can talk about the coordination of ongoing research in this area in the institutions of the Russian Academy of Sciences, universities, sectoral associations, and research supported by JSC RUSNANO, Research Center SKOLKOVO and investment funds. The set of measures that are implemented at the federal level is intended to prevent our country from lagging behind in its scientific development and to create the material base for the future post-industrial production.

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