STRUCTURAL CHANGES IN ECONOMY WHEN ENERGY SYSTEMS CHANGING

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The cyclical development of the economy as a result of resolving the contradiction between the functioning productive forces and the increasing population of the Earth, growth and expansion of needs has been substantiated. The resolution of the contradiction leads to a change in the structure of the economy. A method for determining the cyclicity parameters has been given. A change in the energy systems of the world will lead to a change in the structure of the economy and significant unemployment. The periods of recession and recovery of economic until 2050 have been established.

Introduction

Ukraine is rich with the land that we have inherited from previous generations and the people who live and work on it. And that man is unfortunate who lives on this earth and has no dwelling and a workplace to apply his labor is called unemployed.

The increase in world population at a faster pace than the production of material goods and the rise and expansion of needs highlight the main problems solving of which will form the structure of the economy of the world and Ukraine. These are problems of providing the world's population with food, fresh water and energy. In all these areas, there is a shortage at a current level of development of the productive forces. Thus, according to the UN, the shortage of fresh water in the world is estimated as 230 billion m^3 per year, and by 2025 it will increase to 1.3-2.0 trillion. m3 per year. Thus, according to the UN, the shortage of fresh water in the world is estimated at 230 billion m^3 per year, and by 2025 it will increase by 1.3-2.0 trillion m^3 per year. Solution of these problems is possible by improving the productive forces and the economy structure based on scientific and technical progress. In this case, there is a wave (cyclical) development of the economy characterized by a surge and recession manifested in the emergence of significant unemployment. The causes of structural and cyclical unemployment were studied. However, the laws governing the changes in the parameters of cycles connected with the population increase, the time-varying structure of the economy and unemployment inherited to a market economy are not fully discovered. There is no forecast of possible surges and recessions of the economy after 2015. Depending on the worldwide solution of the above problems, the structure of the economy of the world and Ukraine will be inevitably changed taking into account that the existing structure of the economy of Ukraine has evolved based on natural conditions and in accordance with the planned economy of the USSR and Ukraine. In this regard, it is important to determine which structural changes in the economy of Ukraine may be the most effective. Previously, the problem was not considered in this regard. The sequence of research is as follows. At first, the growth of the Earth's population was determined according to the forecast of S.P. Kapitsa and the UN. Then, the wave development of the economy and its causes were studied. Its essence and features were established. On this basis, a methodology for determining the parameters of cyclicity was developed. The forecast of the demand for electricity in the world and Ukraine based on the forecast of energy consumption per capita and the increase in population over time was performed. Then the regularity of the change over time of the world energy systems was established and the forecast of their development was prepared. It was shown that the functioning energy systems would not meet the need for electric energy in the world and Ukraine. Using the established pattern and the developed methodology for assessing the wave development of the economy, the cyclical nature of its development from ancient times to modernity based on the change of energy systems over time was studied. Periods of recession and economic surge until 2050 were established. On this basis, it has been determined how its development will change, and in what structures, an outbreak of unemployment is possible.

1. Forecast of an increase in the Earth population

In order to establish patterns of wave development of the economy and changes in its structure, as well as the scale of unemployment, an increase in the population of the Earth shall be considered, since a man is the only producer and consumer of material goods. The development of the economy is aimed at meeting his needs. The population of the Earth was taken according to S. P. Kapitsa [1] and the International Institute for Applied Systems Analysis (IIASA) and the UN (Fig. 1). The population of the Earth is predicted to be increased up to 11 billion by 2150

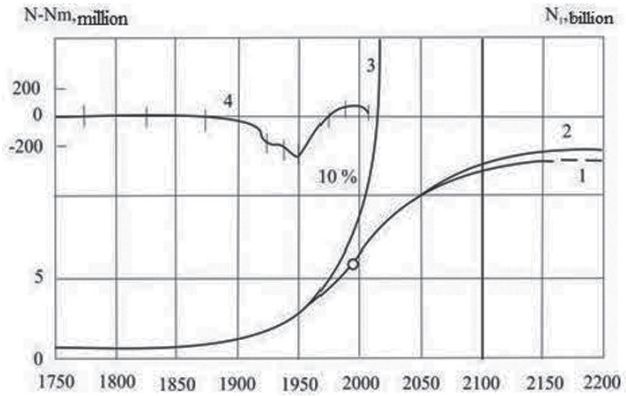


Figure 1. World population increase from 1750 to 2200: 1 – IIASA forecast, 2 – forecast as per Kapitsa model; 3 – the forecast by the formula of Mackendrick and others. 4 – the difference between the number of the actual population of the Earth and calculated by the model, which was increased by 5 times

According to this model, the growth of the system is assumed to be dynamically self-similar. Development is accelerating by itself and each next step uses all knowledge previously accumulated by humankind i.e. primarily information. From our point of view, the proposed model has some drawbacks. The population system of the Earth is developed as a result of the resolution of internal contradictions that arise in it during the development process. This is the main thing that leads to demographic transitions. The system is not developed self-similarly (not fractally) either in size or in structure. This is confirmed by the change in the age structure of the population, namely, the part of the senior generation is constantly increasing, which can lead (and leads) to sharp contradictions in the states. Based on these provisions and mainly taking into account the rapidly increasing population of the Earth, the cyclical development of the economy shall be considered.

2. Patterns and reasons of cyclical economic development

We will proceed from the following provisions, which lead to the cyclical development of the economy:

1. According to the definition of K. Marx [2], the productive forces are tools,

objects of labor and the people that set them in motion. Thus, the younger generation (up to 15 years) and the senior generation (from 65 years and more) which is continuously increasing are not included in the productive forces, since they do not set in motion tools and objects of labor (do not participate in social production). So, in 2050 only 55% of the population can be involved in the productive forces. About 7-15% of them are unemployed. The number of the working population is decreasing, and the number of the senior generation (which needs to be maintained at a new level) is increasing.

2. The production of material goods at a certain stage of the level of the productive forces development does not meet the needs of the population, which grows more intensively than the production of material goods.

3. In connection with the increase in general intelligence and the standard of living of the population, new needs appear which production requires renewal of productive forces such as advanced training of workers and improvement of tools and objects of labor and changes in the economy structure.

4. Extensive research aimed at improving tools and objects of labor to expand human needs shall be carried out.

5. The duration of each subsequent cycle is reduced as the level of manpower training increases, tools and objects of labor are improved. However, each subsequent cycle is shorter, but it covers a larger number of population. This is due to the fact that with each cycle of renewal of fixed capital, a deeper and wider division of labor occurs and the population increases.

These are factors that lead to the cyclical nature of economy development including the change of its structure. Thus, the development of the economy over time occurs in the form of wave movement, namely, periodic surges and recessions. The main driving force is the increase and expansion of human needs, the growth of the world population over time. Moreover, the expansion of needs begins to be of paramount importance. The discrepancy between the level of development of the productive forces and the increased needs leads to their renewal such as up-gradingg of man's skills, improving tools and objects of labor and changing the structure of the economy. It should also be keep in mind that the globalization of economic processes in the world has an impact on national economies [3].

3. Peculiarities of the wave economical movement

When a mechanical wave motion, a wave transfer energy and impulse, but does not transfer matter. The economic wave (term "wave development" is used which is not quite accurate) differs from the mechanical one in that fact that it reflects the change in energy over time and the production of material goods. Wave economic movement is significantly different from the mechanical one and other types of oscillations. Mechanical free oscillations occurs

because the system is out of balance and forced ones occur due to the action of external force. Economic wave movement is characterized by the fact that it is caused by changes in energy over time within the system itself. Economic wave movement occurs only because contradictions arising within the system between needs and the possibility of their satisfaction with a functioning system are resolved. These contradictions are manifested in the surge of the economic development (E_s) and recession (E_r) (Fig. 2), which are amplitudes. The mechanical wave system tends to equilibrium, and the economic one tends to a constant rise. If the economic wave system strives for a balance of economic surge and recession, then the part of the population that is continuously increasing will not meet their needs.

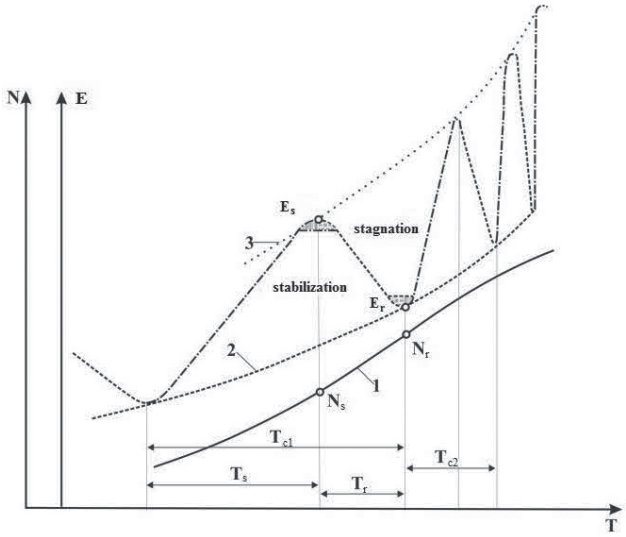


Figure 2. To justify the parameters of the wave development of the economy: 1 – population increase; 2,3 – surge and recession curves of economy

The time of one complete oscillation, which is repeated for equal periods of time in mechanics is called a period and in economics – a cycle. In this case, the duration of economic cycles over time decreases as will be shown later in the contrary to periods in mechanics, which are approximately equal. In the cycle (period), the duration of the economy surge T_S is always longer than the recession duration T_R. Otherwise, the world's economy would not have been risen above the level of the previous cycle, but only have decreased, which in fact does not occur. Therefore, $T_S > T_R$ (see Fig. 2). If we combine the amplitudes of recession and surge of the economy by curves, then we obtain the economy recession curve 2 and the economy surge curve 3. From the experience of over time economic development, it follows that in each subsequent cycle, the growth of the economic surge is higher than in the previous cycle; in each subsequent cycle, the economic recession is not lower than that in the previous cycle. The fact that the economic surge and recession will be repeated more often may be a problem. According to the laws of quantum mechanics, the higher the frequency of the wave, the more energy it carries and the greater destructive force it is. The surge and recession of economic development in the cycle taking into account the change in population are different.

Economic surge is a) improving the living standards of the population, increasing spending on education, science, culture, savings on the renewal of capital funds, military spending, etc.; b) increase in population.

The economic recession is a) a decrease in the living standards of the population, a decrease in expenditures on education, science, culture, etc. b) an increase in the population.

Definition. The economic wave is a real movement over time of living, materialized and accumulated human labor (human energy), in which, as a result of the contradiction between the increasing needs and existing productive forces due to population grows, there are a surge (energy accumulation for the renewal of productive forces) and a recession in economic development during their renewal.

4. Methods for research of cyclicality parameters

Let us introduce such a unit of measurement as demand and consumption of energy per person. This unit of measurement is necessary for us to study the laws governing changes in the parameters of cyclicity i.e. economic surge and recession. For life sustaining (food, shelter) of an adult, about 100 W of energy per day is required. Taking into account the meeting of other vital needs, energy consumption is 20 times higher and is equal to 2.1 kW or about 8000 kW per year; in developed countries (USA) up to 80,000 kW. At this stage of research, the absolute value of energy consumption per person is not necessary. Energy consumption per person consists of two factors:

a – human energy needs necessary for existence (food, shelter, clothing, etc.). They will be taken constant for a person, both during economic surge and during its recession (although this is not quite so, since living conditions are also improved with each subsequent renewal);

$\mathbf{b_s}$ – energy consumption per person for education, science, culture, military spending, etc. during the economic surge. In addition, let us assume that in the surge cycle, funds for their use when changing the structure of the economy are accumulated;

$\mathbf{b_r}$ – energy consumption per person for education, science, culture, military spending, etc. during the economic recession.

These indicators in each cycle are significantly increased as well as between the cycles. The pattern of changes in these consumptions in the cycle and between the cycles is unknown. And, it may be a random value. In each cycle in each year, there is a certain number of unemployed people. At the same time, there are costs for the allowance of the unemployed. Take them as below:

c – energy costs per person for the allowance of the unemployed.

They will be assumed as a share or percentage from the total population. Then the allowance of one unemployed is determined as follows. Suppose that in the t_i year of the cycle, we have number of the population – N_i. Then the number of unemployed N_{un} will be:

$$N_{un} = N_i * n_{un,} \quad (1)$$

where n_{un} – the share of unemployed in the total population.

Energy costs per person for the allowance of the unemployed will be:

$$E_{un} = a^* N_{un} = a^* N_i * n_{un} \quad (2)$$

Then the energy consumption of allowance the unemployed per person will be:

$$c = a^* N_i * n_{un,} / N_i = a^* n_{un} \quad (3)$$

The unemployment share in the cycle of surge and recession is different, the pattern of its change is unknown. Let us assume that n_{uns} is the share of the unemployed people in the economic surge, and n_{unr} when its recession. The recession of the economy occurs as a result of a fundamental change in its structure. This update occurs in a cycle during a recession. For example, there was an economic recession during the transition from water power plants to steam plants. The renewal of capital funds occurs both during the economic surge F_s and during the recession F_r.

However, mainly, renewal of capital funds appears during a recession due to previously accumulated funds, as a result of which an economic recession occurs. Therefore, we assume that the renewal of capital funds occurs during the surge and recession. Then, energy costs E_s of the world's population in amount of N_s in the surge cycle in its last year will be:

$$E_s = [a(1+ n_{uns}) + F_s + b_s] N_s. \quad (4)$$

Then, energy costs E_r of the world's population in amount of N_r in the recession cycle in its last year will be:

$$E_r = [a(1+ n_{unr}) + b_r + F_r] N_c \quad (5)$$

Let us determine the value by which energy costs will decrease during an economic recession $\Delta E = E_s - E_r$. From the above, it follows that an economic recession will not occur under the condition $\Delta E = 0$. And this is possible if $E_s = E_r$ that is:

$$[F_r + b_r + a(1+ n_{unr})] Nc = [a(1+ n_{uns}) + F_s + b_s] N_s. \quad (6)$$

From the example (6), it follows that reducing the economic recession can be achieved under the following conditions. In the process of economic surge:

a) the accumulation of funds for changing the structure of the economy (renewal of capital funds) should be made taking into account population growth; b) savings should be made (spent during a recession) on science, culture, military spending, etc. with taking into account population growth; c) funds must be accumulated (spent during its recession) to maintain the living standards of the population and the allowance of the unemployed (taking into account their increase), as well as considering the increase in the population. As follows from the conducted research, the wave economy development is influenced not only by the process of accumulating funds to change the structure of the economy (renewal of capital funds and their creation), but also an increase in population. According to studies [1], the population of the Earth will be stabilized since 2050. Then, the wave development of the economy will be mainly influenced by the renewal and expansion of needs.

5. Structural changes in the economy and their impact on unemployment on the example of the development of the electric power complex

5.1. Over time change of energy systems in the world

In [4], the types of energy supply of the world community from ancient times to modernity are considered. The theory of over time change of the energy systems of the world is given, which is based on the established patterns of reducing the time of their effective application allows us to determine the transition time to the next one. This replacement is accompanied by changes in technic and technology and has an impact on the sustainable development of industry, economy and social state of society. The time duration of use of each subsequent type of

energy supply is decreasing (Fig. 3). The time of the most effective use of each type of energy supply has been determined, as well as the duration of its use:

$$T_d = 0.0004\ T^2 - 2.669T + 3895.1 \quad (7)$$

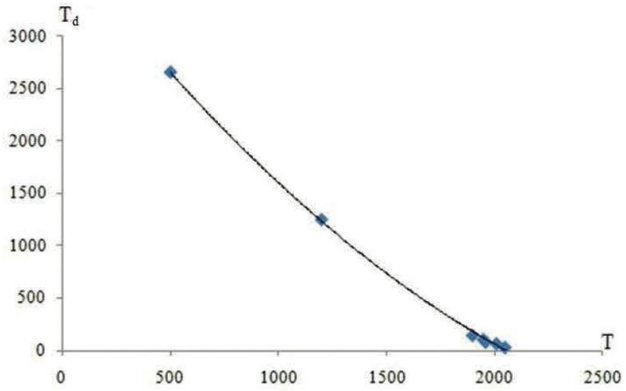


Figure 3. The dependence of the duration of the energy systems operation over time

5.2. Forecast of electrical energy consumption in the world and Ukraine

Electricity production in the world is developing unevenly. Thus, the rapid development of the industry of the People's Republic of China (PRC), the increase in electricity consumption by the population taking into account its increase, the skillful combination of state planning and market relations, public and private capital allowed the PRC to become the leading country in electricity production (Fig. 4). If in China, energy development is rapidly increasing and in five years (from 2005 to 2010), it has reached the level of the United States and then substantially surpassed it, then in all other countries such an energy development is absent. The United States is the second energy power state in the world.

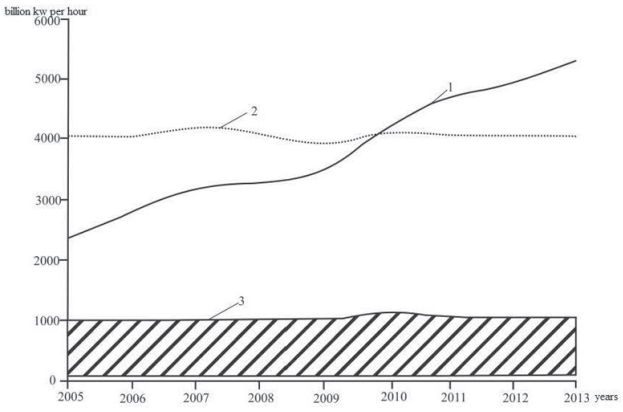


Figure 4. Electricity production in the world: 1 – China; 2 – United States; 3 – Russia, India, Japan, Canada, Germany, France, Brazil, Republic of Korea, Ukraine, Kazakhstan

Thermal power plants carry out the main energy supply in the world. More than 6.5 billion tons of coal is required for the production of electricity by thermal power plants. Out of these, China produces 3 billion tons and about one billion tons is mined in the United States. These countries also produce the largest amount of electricity (see Fig. 4). It should be noted that in China, the cost of electricity is twice as high as the world average, which is due to the high prime cost of coal. An indicator of the economic and social level of a country's development is the production of electric energy per capita, which varies by country from 566 to 15000 kW·h. The forecast of consumption of electric energy per capita was determined by the following ratio:

$$E_{pc} = B/(T_1 - T)^2, \quad (8)$$

where E_{pc} – consumption of electric energy per capita, kWh/person per year; B – constant equals $B = 8400*10^3$, calculated in kWh/person per year; T_1, T – final and forecasted years; T_1 = 2060 year.

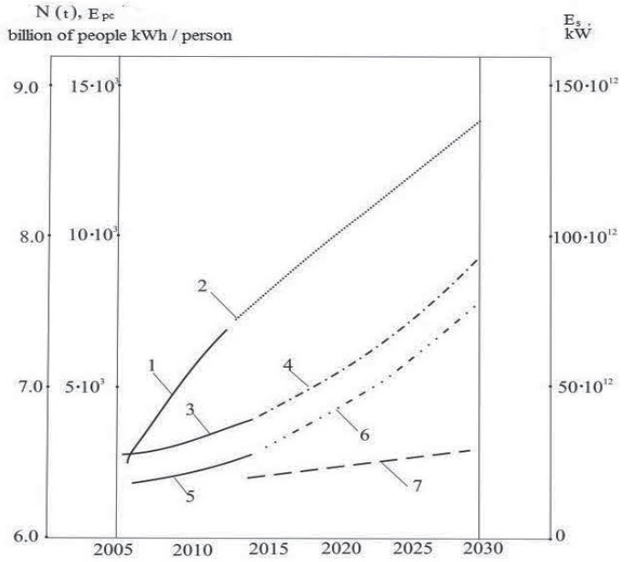


Figure 5. To the definition of the consumption and production of electrical energy in the world. Change in population: 1 – actual; 2 – according to the forecast of S.P. Kapitsa; 3.4 – actual electricity consumption per capita and forecast; 5.6 – the actual consumption of electrical energy in the world and the forecast; 7 – forecast of the need for world electrical energy based on the development of the countries and regions (according to Russia)

The forecast of electricity production in Ukraine was prepared based on data indicated below. The following data were taken into account as the initial data, namely, actual data on the population in Ukraine, actual electricity consumption per capita and total. The forecast of electricity production per capita in Ukraine was determined by the expression below:

$$E_{ppcU} = B/(T_1 - T), \quad (9)$$

Where B – constant; B = 235 thous. kWh/person; T_1 – counting year; T_1 = 2060.

Electricity production in Ukraine in the future was determined by the expression:

$$E_{pu} = N(T)*B/(T_1 - T), \quad (10)$$

where N – the forecast of over time T change of population in Ukraine as per forecast from Ptoukha Institute for Demography and Social Studies of the National Academy of Sciences of Ukraine.

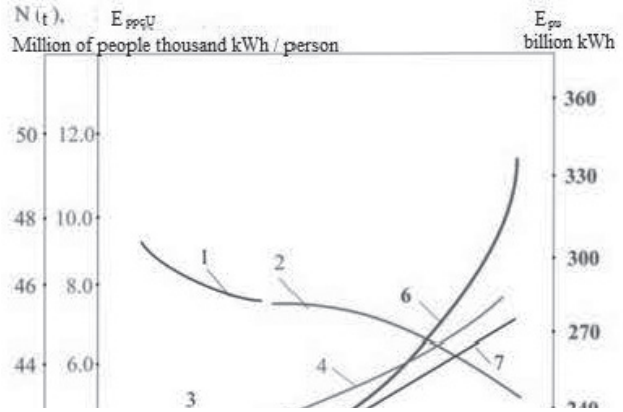


Figure. 6. To the definition of consumption and production of electric energy in Ukraine in the future. Population change in Ukraine: 1 – actual; 2 – according to the forecast of the Ptoukha Institute for Demography and Social Studies of the National Academy of Sciences of Ukraine; 3.4 – actual electricity consumption per capita and its forecast; 5.6 – the actual consumption of electricity and the forecast; 7 – forecast of electricity consumption according to the Ministry of Energy and Coal Industry of Ukraine

The forecast of electricity demand in the world and Ukraine was carried out based on the above forecast of world population increase and its decrese in Ukraine as well as the growth of energy consumption per capita.

Table 1. Production of electricity in the world and Ukraine

Indicators	World	Ukraine
Electricity production (in 2014 approx), kW.h	25×10^{12}	210×10^{9}
Forecast of demand for electricity in 2030 kW.h	75×10^{12}	330×10^{9}
Capacity of power plants for the production of electrical energy, (actual, approx), kW	$7{,}5 \times 10^{9}$	55×10^{6}
The required capacity of power plants in 2030, kW	$18{,}7 \times 10^{9}$	$82{,}5 \times 10^{6}$

5.3. The possibilities of producing the required amount of electricity by existing energy supply systems

Despite the widespread use of thermal power plants (TPPs) all over the world since the 1960s, their effective use has begun to decline: thermal power plants have reached the limit of their perfection. The cost of electricity production from coal has risen acutely. As for the thermal power plants of Ukraine, their technical level does not comply with the world level [5]. In Ukraine, the part of electricity produced by hydroelectric power plants is constantly decreasing. The creation of powerful nuclear power plants leads to the following negative consequences i. e. great capital investments, long construction periods that reach from 5 to 10 years. Because of this, the prime cost of electricity increases. In addition, the failure at large nuclear power plants causes pollution of a larger area. As for other sources of electric energy, they can increase the balance in the production of electricity, but due to the large growth in its need, they cannot be the main source. Thus, the need of the world and Ukraine for electricity until 2030 cannot be met by using existing energy systems.

5.4. New branches in nuclear power industry

The analysis of nuclear reactors, their parameters in Russia and other countries (USA, Japan, France, China) shows that there are two main directions in the atomic energy industry. The first is the development and creation of atomic fast-neutron reactors (instead of thermal-neutron reactors used in existing nuclear power plants). The second is the creation and use of low-capacity nuclear power plants (LCNPP). The capacity of these power plants varies from 10 to 1000 MW. Small modular nuclear power plants can be used in the following areas, namely, using LCNPP as an autonomous power supply in remote areas; as an autonomous energy supply of enterprises; replacement of existing coal-fired power plants with nuclear modular power plants consisting of several units.

The transition to new types of energy supply is inevitable and occurs at an accelerated pace.

5.5. Wave development of the economy when energy systems changing

Using the methodology described above, the wave development of the economy was calculated when the change of energy systems from ancient times (fifth century) to the present with a forecast to 2050. Calculations were made in unit fractions indicated below. It was accepted that in the 5th century, the energy needs of a person **(a)** required for existence (food, dweling, clothing, etc.) amounted to 0.02 units of the total amount of energy consumption when $\mathbf{E_s}$, which were assumed to be equal to one. Then they

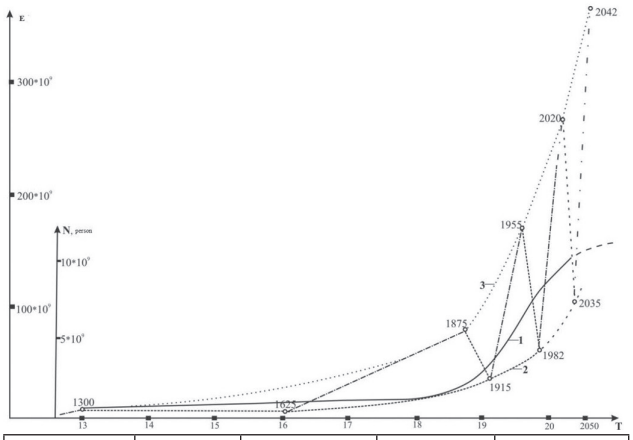
increased proportionally in cycles taking into account the growth of the Earth's population at the given time of the cycle (Fig. 7).

Figure 7. Wave development of the economy when change of energy systems: 1 – an increase in the population of the Earth; 2 – recession curve; 3 – surge curve

The cycles of the wave movement of the economy are established based on the data given in [4]. It is assumed that the cycle time is determined by the time between two economic surges (as in mechanics: one full-wave oscillation).

Table 2. The cycles of economic surge and recession during the change of energy systems

Numbers of cycles	Surge year	Recession year	Surge year	Duration, years
1.	500	900	1300	800
2.	1300	1625	1875	575
3.	1875	1915	1955	80



4.	1955	1982	2020	65
5.	2020	2035	2042	22
Numbers of cycles	Surge year	Recession year	Surge year	Duration, years
1.	500	900	1300	800
2.	1300	1625	1875	575
3.	1875	1915	1955	80
4.	1955	1982	2020	65
5.	2020	2035	2042	22

At the same time, energy consumption in each cycle increase significantly (see Fig. 7). The cyclical development of the economy when change of energy systems can be represented by the following ratio:

$$T_c = 3708,8\, e^{-0,002\,T}., \text{ year}, \quad (11)$$

where T_c – duration of cycle, years; T – current years.

This ratio indicates that the duration of cycles (surge – recession – surge) decreases and asymptotically approaches the axis T. This means that in the future, fluctuations in the economy will be shorter, but frequent and with a large amplitude. As follows from the conducted research, the economic surge (see Fig. 7) in the world will occur until 2020 (with slight ups and downs between 2015 and 2020). And then from 2020 to 2035 will be a recession. This will be caused by the transition to a new energy system possibly the replacement of thermal power plants with low capacity nuclear power plants.

5.6. The impact of changing the world energy systems to the sustainable development of the economy and society

The energy supply of the world is constantly being improved. And in the future, it can be foreseen what follows from extensive research in various fields on the development and justification of new energy supply systems, a possible transition to an autonomous energy supply not only for enterprises, towns, but also for individual buildings. And this may occur, as follows from Fig. 7, from the beginning of the 50s of this century. Such inevitable development of energy supply will lead to significant changes in industry, economy, ecology, social state of society. It comes from the following. The main energy supply in the world as noted above is carried out by thermal power plants. For the extraction of coal a huge amount of metal, railway transpotations, electric energy, etc is used. To perform these works, a large number of workers or the population is engaged. As follows from the forecast for the development of thermal power, coal mining in the world in the next 15–20 years may significally been decreased [6]. And, therefore, the demand for metal, electricity and labor in coal, metallurgical, mining as well as in other industries will be correspondingly reduced. This can lead not only to lower production costs, but also to major social problems. To replace at the existing thermal power plants of coal units with mini-nuclear units or replacing of thermal power plants with nuclear power plants may be promising. This may lead to the following situation. In order to not reduce the scopes of coal production, countries in which it is mined at low prime cost will export coal to other countries, where coal is not produced or it is mined at a higher cost. For example, the prime cost of coal production in the United States is low. As planned in the United States, part of the coal can be exported when replacing of 100 coal units with low-capacity nuclear power plants. For example, in Poland, about 80% of electric energy is produced at coal-fired thermal power plants. Receipt of cheaper coal or the replacement of thermal power plants with at LCNPP will lead to the closure

of mining sites. Ukrainian TPPs can be re-equipped to NPPs with low-modular reactors. That will lead to the closure of mining sites producing power plant coal as well as of thermal power plants. This may improve the ecological condition of the regions, but will result in major social problems. Nevertheless, the more preferable option is if the thermal power plants of Ukraine will be updgraded on a fundamentally new technical base, namely, replaced with LCNPP. Then the production or export of cheaper electric power will solve both social and environmental problems. Closing of mining sites in Ukraine will reduce the need for metal, electric power, rail transportation, etc. There will be a significant unemployment (see Fig. 8).

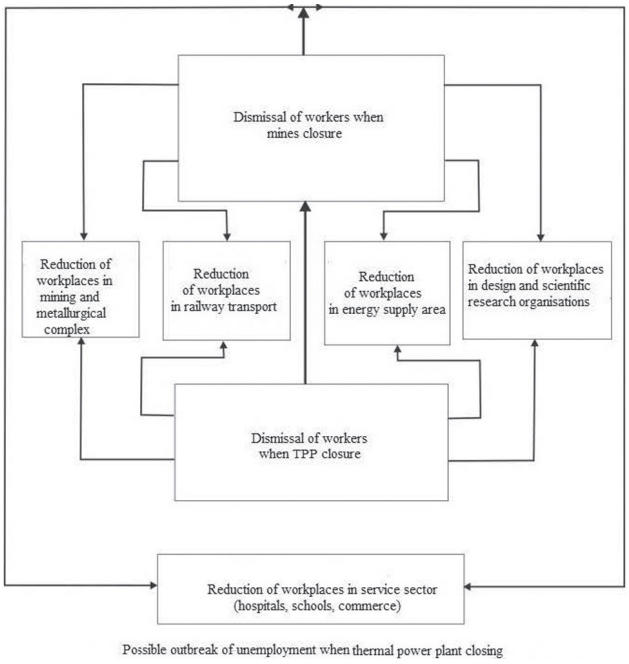


Figure 8. Possible outbreak of unemployment when closing of thermal power plants and coal mines

At the same time, significant segments of the population in various areas including scientific and project ones will have a lot of unemployed people. This will lead to an economic recession and further changes in the structure of the economy.

Conclusion.

1. Economic wave (cyclical) movement occurs because contradictions arising within the system between growing and expanding needs due to the increase in the world population and the possibility of satisfying them with functioning production forces are resolved. The discrepancy between the level of productive forces and the increased needs leads to their renewal: advancing the level of man's skills, improving tools and objects of labor and changing the structure of the economy.

2. The change of the world energy systems with the transition to low-capacity nuclear power plants (or other energy supply systems) will lead to a change in the structure of the economy and significant unemployment.

3. Structural and cyclical unemployments have the same genesis occurring in part of the economic recession cycle corresponding to a change in the structure of the economy and renewal of productive forces.

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