DEVELOPMENT AND IMPLEMENTATION OF CONVERGING TECHNOLOGIES IN UKRAINE UNDER CONDITIONS OF A NEW INDUSTRIAL REVOLUTION: ORGANIZATION OF STATE SUPPORT: MONOGRAPH KHARKIV, 2016. 556 P.

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ABSTRACT

In the monograph from the position of synergetic paradigm substantiates the concept of development of convergent technologies as a key factor in solving global problems in the new industrial revolution. The main trends in the development of convergent technologies and identifies advanced manufacturing technologies, the most promising for the consumer in developed countries. The evaluation conditions for the establishment, status and innovation potential, based on simulation model and scenarios of scientific and innovative development of Ukraine. Methodical approach to foresight-prediction of the priority directions of development of convergent technologies and identified priority areas for development and their introduction into the economy of Ukraine on the example of nanotechnology. The analysis of prospects of the use of convergent technologies in the sectors of Ukraine's economy. Introduced a scientific and methodical approach to the creation of institutional support mechanism for the development and implementation of convergent technologies in Ukraine in conditions of formation of a common research area with the EU. The monograph is intended for a wide circle of readers interested in the characteristics of the development of convergent technologies and new industrial revolution in the Ukraine in terms of its integration into the world economic system.

Keywords: convergent technologies, new industrial revolution, model and scenarios of scientific and innovative development, foresighting priority directions, institutional support mechanism, solving global problems.

INTRODUCTION

The development of every country should be subject to a definite purpose such as improvement of the quality of life. Today humanity is faced with a number of global issues and with specific national problems that exist in every country. So all efforts of the state and society have to be directed to the solution of this problem. As international experience shows, only advanced development model is able to provide solutions to these problems through the successful development of scientific, technical and innovative sphere.

The world economy develops by replacement of one technological way with another. Change of the next technological ways is always connected with the emergence of a number of basic innovations “inside” the previous way. They will later become the core of the new technological way and will lead to rapid increase in efficiency of the economy: it becomes less material and energy intensive, costs are reduced, new human needs appears.

At the end of the XX century, it became clear that in any field of human activity progress in the next 10-20 years will be connected first of all with atomic and molecular constructions.

Convergence of nano- bio- info- and cognitive (NBIC) technologies means their mutual influence and mutual penetration, when these areas merge into a single area of scientific and technological knowledge, that will inevitably lead to a revision of traditional ideas of such fundamental values as life, mind, people, nature, life.

Besides, after the crisis of 2008-2009, almost all developed countries revise their views on the role of industry as a major tool for economic growth and perceive convergent technologies as the main tool, which can help to solve global problems in the nearest future, to provide considerable development of social sphere to a qualitatively new level. Therefore, since 2011 government policy in these countries is more clearly formed and it is aimed at the development of key factors of the third industrial revolution, and also it is aimed at solution of the problem of matching the level of scientific and innovative potential to those requirements which are made by new industrial revolution and emerging technologies of the XXI century.

As a result, within the last twenty-five years, the main problem is: which of the existing models of economic development Ukraine has to choose to make an innovative breakthrough in the new technological way and to provide economic and social prosperity of the country in the 21st century? This problem has acquired special relevance for the modern economic development of Ukraine in terms of association with the EU.

Chapter 1. Conceptual principles of identifying key factors in the scientific and innovative development of countries of the world and Ukraine under conditions of a new industrial revolution

The monograph shows that today humanity is faced with a number of global issues, which include such problems from the material sphere:

(1) depopulation and population ageing;

(2) food shortage and exhaustion of stocks of some raw materials;

(3) environmental problems, lack of some types of fuel, new energetic and energy saving;

(4) slow scientific and technical progress and gap with the leading countries in the transition to a new technological way.

The activity of any state and society should be aimed at solving these problems. There is author's vision of the concept of a periodization which connects economic, technological and socio-political development factors, and also it describes the structure of the sixth technological way. The condition of convergent NBIC-technologies will be a key factor.

The core of new sixth technological way will be created by such areas as nanomaterials and materials for growth technologies, nanoelectronics and nanophotonics, nanosystem machinery, nano-factories and 3D-printing, genetic engineering, molecular biotechnology, cloud computing and multidimensional modeling, the Internet of things, artificial intelligence. The medicine and pharmacy; an agrifood complex based on nanobiotechnologies; microelectronics, robotics; information and communication industry; education, scientific and practical researches; new nuclear and thermonuclear energy; renewable energy; aircraft industry and spacecraft; automotive industry, shipbuilding, machine-tool construction; chemical and metallurgical complex will be the leading industries.

The author's vision of the essence of new industrial revolution is offered, and it is directed to the solution of global problems and includes an organic combination of convergent NBIC-technologies and key factors of "the Industry 4.0" such as enhanced integration of CPS in production processes (fig. 1).

The combination of "Industry 4.0" technologies with factors of the advanced production system Smart TEMP (T – technology; E – environment; M – manufacturing; P – products) creates new markets and industries, promote the growth of labor productivity, increase in competitiveness of certain sectors and national economies. It is proved that in the leading countries in their regional groups there is a close link between priorities of scientific and technological research, innovation and advanced production technologies. However, since 2013-2014 almost all these countries have adopted state programs to support such a link and it is properly funded such convergent projects and technologies.

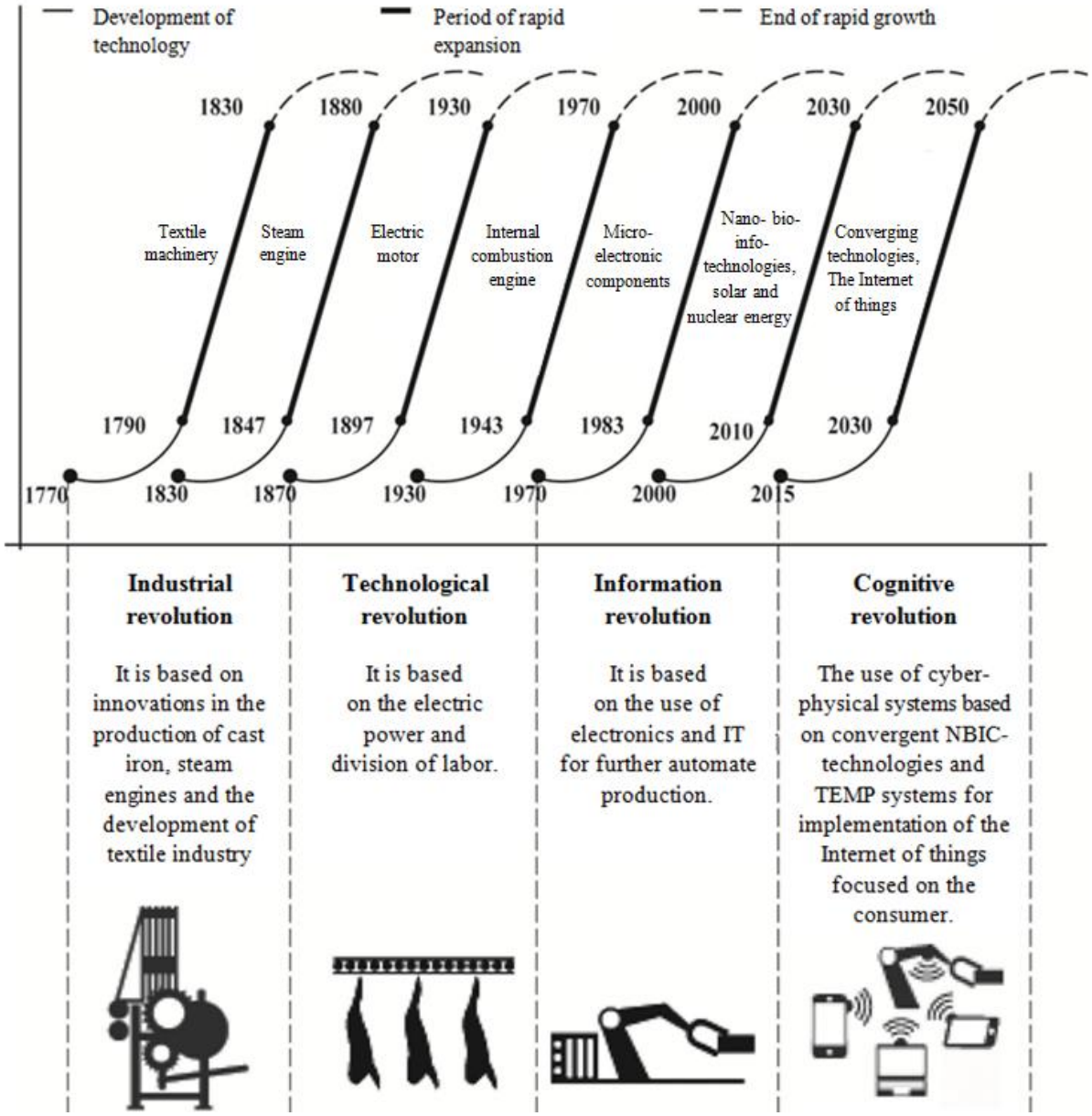

Figure 1. Ratio of industrial revolutions and technological ways in future economy

It is proved that the implementation of convergent technologies in Ukraine is caused by the need to improve the competitiveness of domestic manufacturers on foreign and domestic markets in conditions of profound integration especially with the countries of the European Union and the implementation of the Association Agreement between Ukraine and the EU. So the analysis of the structure of the world and Ukrainian volumes of expenses on the scientific and technological development and high-technology exports indicates discrepancy of the structure of Ukrainian high-technology exports to the world structure. At the same time the share of total Ukrainian high-technology exports in the world market in 2014 was 0.07%, including in aerospace industry – 0.38%, in pharmaceutical – 0.05%, in office equipment – 0.01%, in communications – 0.06% and industrial equipment – 0.02% (that is almost insignificant volumes). As for a share of export of high-tech production in total exports of goods, it was 4.07% in Ukraine in 2014 compared to the global rate of 17.5%. Thus, Ukraine lags far behind the leading countries in the market of high-tech production, and this gap continues to increase during 2012-2014.

In order to increase the production and high-technology exports, it is necessary to concentrate funds and measures of the state support on the *priority areas of development of advanced manufacturing technologies* based on its own unique scientific and technological groundwork, and to start buying ready-made projects and patents and produce high-tech products now (as it is done by China).

It is found that such technologies as:

(1) photonics;
(2) biotechnologies;
(3) nano- & micro-technologies;
(4) ICT in production systems;
(5) advanced materials;
(6) additive manufacturing;
(7) energy and environmental technologies are the most perspective from the point of view of today consumers.

In other words, advanced production technologies are, first of all, 3D-printing, “cloud” technologies, the “Internet of Things”, new materials, robotics.

These technological areas have multi- and interdisciplinary character and their development leads to breakthroughs in physics, chemistry, materials science and biology, and also brings these disciplines closer. They are connected with the high intensity of knowledge, high costs of scientific and technical research, accelerated innovation cycles, high capital expenditure, and highly skilled labor. In addition, these technologies have systemic importance, interdisciplinary and cross-cutting character in many areas and tendency to convergence.

Figure 2 demonstrates the authors’ view on solving global problems based on the implementation of convergent NBIC technologies as the core of development and distribution of Smart TEMP (Figure 2).

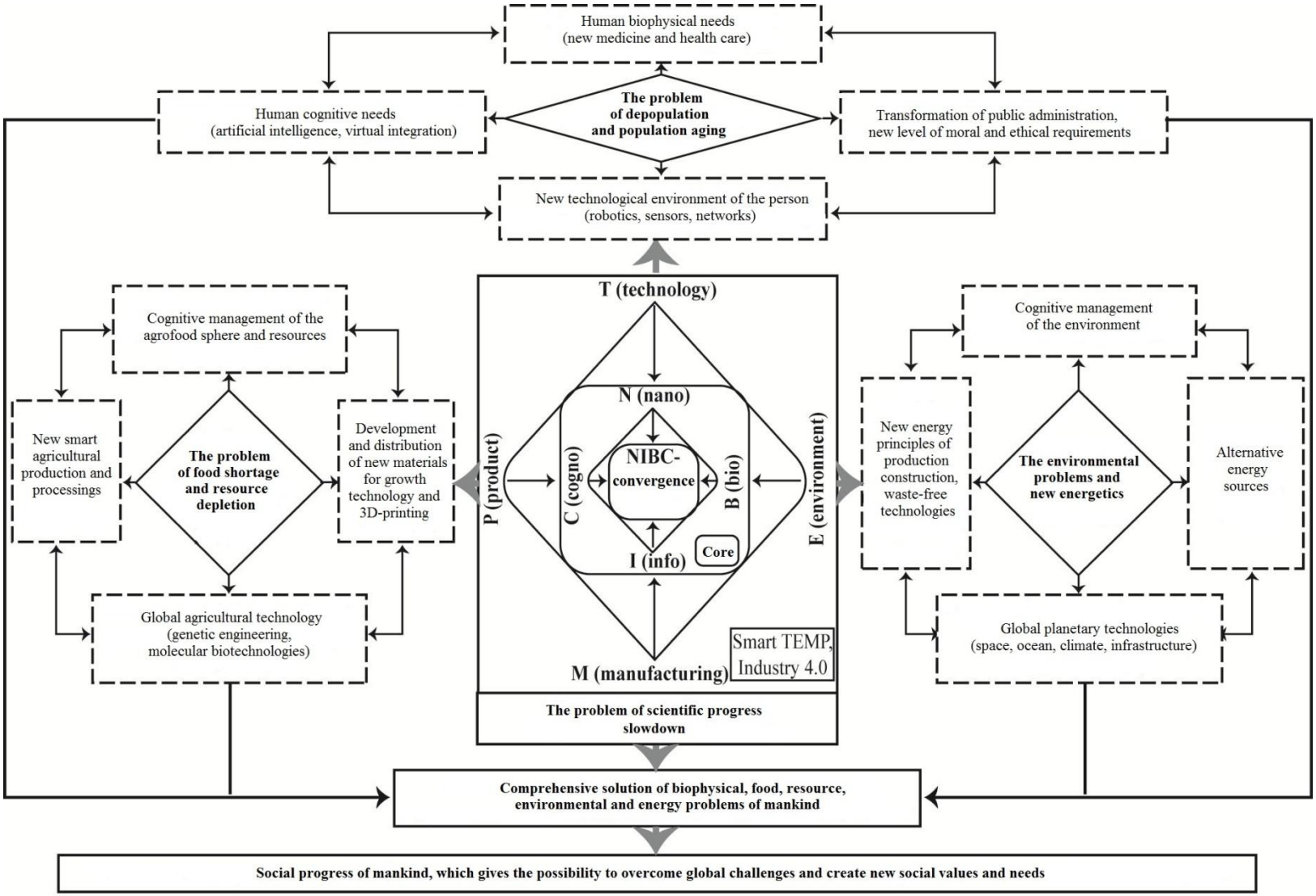

Figure 2. Scheme of solving global problems through the implementation of convergent NBIC-technologies as the core of Smart TEMP advanced production technologies (Industry 4.0)

Shown in Figure 2 scheme provides four main directions and tools:

(1) to solve global problem of scientific progress slowdown through the implementation of convergent NBIC-technologies as core of the development and distribution of Smart TEMP advanced production technologies;

(2) to solve the problem of depopulation and population aging by meeting human biophysical needs (new medicine and health care); realization of human cognitive needs (artificial intelligence, virtual integration, etc.); new technological environment of the person (robotics, sensors, networks); transformation of public administration, new level of moral and ethical requirements;

(3) to overcome the global problem of food shortage and resource depletion through the development of global agricultural technology (genetic engineering, molecular biotechnologies); creation of new smart agricultural production and processings; development and distribution of new materials for growth technology and 3D-printing; cognitive management of the agrifood sphere and resources;

(4) to overcome environmental problems and create new energy through global planetary technologies (space, ocean, climate, infrastructure); new energy principles of production construction, waste-free technologies; alternative energy sources; cognitive management of the environment;

(5) to comprehensive solution of biophysical, food, resource, environmental and energy problems of mankind as a foundation for further social progress of mankind, which gives the possibility to overcome global challenges and create new social values and needs.

Chapter 2. Assessing and modelling the scientific and innovative development of Ukraine's economy

Methodical approach to evaluation of innovative development of Ukraine and the EU countries is developed, ant it includes the following stages:

(1) assessment of conditions of creation and innovation potential of the countries;

(2) assessment of conditions and realization of innovation potential of the countries under study;

(3) study the components of integrated indicators of conditions of creation and level, conditions and realization of innovation potential of the countries.

Presented in this work structural analysis of components and integrated indicators and comparison of components of integrated indicators by the method of the cluster analysis allowed to make a comparative matrix of conditions of creation and level, conditions and realization of innovation potential of Ukraine, to identify its relative advantages and weaknesses, and to identify the strategic directions of development of the country in the innovation sphere. It was found that Ukraine has:

(1) comparative advantages of innovation potential in such areas as financial support of educational potential, level and quality of education of the population, internal patent activity of the population, export of the knowledge-intensive services;

(2) insignificant potential comparative advantages in such areas as length of education, quality of university education, financing and employment in the sphere of research and development and the income from inventive activity;

(3) the greatest part of characteristics of innovative potential of Ukraine is made by relative shortcomings disadvantages such as: number of researchers and quality of research institutions, access, use and practical implementation of ICT, general patent activity of the population, development of innovation clusters, creation of scientific and technological productions and products, export of high-tech and creative products, manufacturing of innovative products by small and medium-sized enterprises, legal protection.

The imitating model of scientific and technological development of Ukraine which is constructed according to structure of the revealed links between components of scientific, educational and

institutional potentials, and results of scientific, technical and innovative activity is developed, and includes such components as:

(1) formation of educational potential; (2) creation of institutional potential;
(3) management of activation of educational and institutional potentials;
(4) modeling of results of scientific and technological activity;
(5) results of commercialization of innovations;
(6) evaluation of results of scientific, technical and innovative activity for economy in general.

It is shown that the model generated 65 feedback loops that cover the whole process from creation of educational or institutional potential to results of scientific and technical and innovative activity, and allow to investigate the influence of certain directions of educational, scientific, institutional potentials development and certain actions for intensification of scientific, technical and innovative activity on results for the economy in general and identify the most appropriate and effective measures.

It is shown that used in work scenario modeling was carried out on the basis of the plan of imitating experiments with a change of parameters one by one and allows to reveal the sensitivity of the system to each of parameters and to identify those parameters, increase (reduction) in which allows reaching the greatest desirable effect. It is proved that to achieve significant results of scientific and technological development of Ukraine there should be:

(1) implementation of the best scenario of increasing research and development spending to 2.5% of GDP in the medium term that will create sufficient resources for long-term development;
(2) increase in expenses on research and development that has to be followed by development of clusters, increase in level of protection of investors, development of high-tech industries and employment in such industries, as well as facilitating access to ICT;
(3) stimulation of interest of the population in receiving quality professional education, including encouragement from employers.

Chapter 3. Foresighting priority directions in the development of components of converging technologies

It is found that in most countries that claim to leadership both at the regional and global level, technology foresight is an effective instrument of choice of priorities in science and technology according to global challenges that humanity had already faced with and whose impact in the medium and long term will increase. As a result, (1) system targets at the macro level considering influence on the sphere of science and technologies of political, economic and social conditions; (2) functional priorities connected with factors of development of national science, technology and innovation policy and innovation systems of all levels; (3) proper scientific and technological priorities are considered as priorities of scientific and technological development.

It is shown that the practice of setting national priorities of science and technology development in Ukraine for 2004-2015 shows that there is a lot of them to concentrate small amounts of budget funds for the really important areas that have to solve general and specific problems that Ukraine faces with. Based on the analysis of the results of state programs forecasting scientific and technological development of Ukraine, it is found that the critical technologies which are selected by groups of experts meet the strategic priorities of innovation development of the country during this period, namely: nanotechnologies, biotechnologies, microelectronics, new materials, stainless steel). At the same time, the strategic innovative priorities of Ukraine which are officially approved and financed practically don't correspond to innovative priorities and the advanced production

technologies which are the focus of scientific, technical and innovative policy of the developed countries (except the second and fourth priority).

According to the results of foresight of Ukrainian economy that was carried out in 2015 it was found that:

(1) agrarian sector and military industrial complex have high possibility of implementation;

(2) creation of new substances and materials and nanotechnology, information and telecommunication technologies, energetics, high-tech engineering have medium possibility of implementation;

(3) development of sciences about the person, biomedical engineering, cellular medicine, and pharmacy have low possibility of implementation in 2020-2025.

At the same time, studies need better formalization and certain priorities need better objectivity through the use of mathematical methods and information technologies. In Ukraine, in the conditions of limited budget resources, there is a need for further adaptation of the existing methods of forecasting the future and, first of all, the maximum automation of foresight methods that will allow to considerably decrease expenses on carrying out such research.

A new procedure of foresight research is offered by author and in comparison with traditional foresight research (2004 - 2006) it has fundamental differences, as follows:

(1) unlike usage of the method of "snowball" for formation of an expert group in foresight research (when experts are selected randomly based on interviews and in such situation received selections are not representative) it should use formal methods of selection of experts who take into account the competence of experts in a particular subject;

(2) at the stage of formation of the initial list of thematic areas in a foresight research it is proposed to use such technologies as bibliometrics, scientometrics and patent analysis that allows providing objective basic data of foresight research;

(3) at the stage of evaluation and clarification of thematic areas of foresight technology it is proposed to use the principle of Pareto optimality, because its implementation allows to display qualitative and quantitative nature of criteria for evaluation of the thematic areas and improve the adequacy of expert assessment in selecting these areas.

As a result, the structure of the improved procedure of carrying out a national foresight research on the choice of priorities of scientific and technological development of Ukraine is developed.

Advantages of the described procedure of foresight-research are illustrated by the setting of scientific and technological priorities of nanotechnology as the multicriterial task of decision making, the purpose of which is to allocate Pareto efficient that means receiving directions with the highest score for each criterion. It is proved that from all directions of development of nanotechnologies (nanomaterials, nanoelectronics, nanophotonics, nanomedicine, nanobiotechnologies, methods and tools of a research and certification of nanomaterials and nanodevices, technologies and special equipment for creation and production of nanomaterials and nanodevices) elected at the initial stage, the most priority directions of development of nanotechnology in Ukraine are: (1) nanomaterials and technologies; (2) the special equipment for creation and production of nanomaterials and nanodevices because their vector estimates make Pareto efficient.

Chapter 4. Prospects for the use of converging technologies in industries of Ukraine

It is proved that determination of the potential of convergent technologies development in Ukraine becomes one of the priorities of scientific and innovative development of the country under conditions of new industrial revolution and Association with the EU. Therefore, usage of

convergent technologies in biomedicine, according to various estimates, leads to the most radical breakthrough achievements in molecular biology and genetics, molecular medicine and pharmacology, including development of unique high-tech types of diagnostics and treatment and development of personalized medicine as a basis for prevention and treatment of common infectious diseases and non-communicable diseases, including cardiovascular, cancer, degenerative nerve diseases, metabolic disorders.

Studies of the National Academy of Sciences (NAS) of Ukraine in this direction were aimed at:

(1) studying of characteristics of human transcriptome, proteome, immunome, interactome and metabolome when they are normal and pathological for the purpose of developing personalized medicine and modern methods for prevention and diagnosis of diseases of people and animals;

(2) development of modern methods of cellular biotechnologies and metabolic engineering for creation of superproducers of biologically active agents, new forms of plants and microorganisms for needs of medicine and industries (for cellular and tissue engineering);

(3) focused search for new or modified biologically active agents, ways and means of their operated delivery managed to create advanced medicines;

(4) molecular and genetic aspects of studying of structural and functional organization of genomes of plants and microorganisms as fundamental component of molecular biotechnology;

(5) genetic basis of constructing of improved strains of microorganisms and lines of plant and animal cells for development of medical and agricultural biotechnology.

It is shown that in 2003-2015 NAS of Ukraine developed and manufactured a number of tools for medical, environmental, industrial and technological needs and their trial operation has shown that they can:

(1) provide faster, more reliable, more responsive and cheap analysis of various substances in comparison with existing analytical methods;

(2) improve quality and availability of medical diagnostics;

(3) prevent environmental pollution; prevent the entry of contaminated food in retail chain stores;

(4) prevent the consumption of drinking water contaminated with harmful chemical compounds and causative agents of infectious diseases;

(5) improve control of technological processes of pharmaceutical, biotechnological and chemical industries.

Besides, in order to solve the problems of sustainable development, rational environmental management and environmental protection new biomedical and bioengineering technologies have been developed for human health and national economy, biologically active agents for human health, ecological and economic mechanisms of rational use, protection and monitoring of natural resources, new technologies for energy efficiency.

It is defined that during 2007-2015 for the purpose of expansion of use of alternative fuels, NAS of Ukraine continued to work on:

(1) involvement of perspective biological resources, development and implementation of the advanced bioenergy conversion technologies for liquid biofuels and expansion of their use;

(2) implementation of use of the most effective sources of raw materials for biofuels, including non-traditional and alternative sources;

(3) receiving high-quality raw materials from energy crops, including improvement of indicators of their productivity and a final exit of alcohol and oils;

(4) increase in qualitative structure and quantitative content of energetically valuable substances (starch, sugar, oil, etc.) in bio-raw materials for receiving liquid biofuels;

(5) creation of new strains of microorganisms, fungi and microalgae, as well as expansion of their genetic resource base for receiving liquid biofuels;

(6) improvement and development of new chemical technologies and new approaches for bioenergy conversion;

(7) improvement of technologies of chemical transformation from fatty acids to oils to produce biodiesel;

(8) improvement of existing and development of alternative technologies of receiving the fuel components required for the production of biofuel;

(9) usage of agriculture, forestry, food and household wastes as raw materials for biofuels;

(10) practical usage of by-products and wastes of biofuel production;

(11) comparative analysis of various sources of bioenergy raw materials based on prime cost, environmental safety, and also a ability to obtain additional useful products at the same time.

It is proved that nanotechnologies are one of the main trends of science and technology development today. Nanotechnology is already affecting and fundamentally change medicine and biotechnology, energy, electronics, manufacturing and many other industries around the world. Transition to nanotechnologies, namely to nuclear constructing of any materials, provides the most important result such as dematerialization of production and makes production less energy and resource intensive. It is found, that in 2003-2014 in NAS institutions of Ukraine a number of programs was carried out in such directions as nanobiotechnology; nanoelectronics and nanophotonics; nanomaterials; diagnostics of nanostructures; technologies of semiconductor nanostructures; physics of nanostructures; nanochemistry; nanosafety. However, financing of projects according to these state programs remained extremely low and, as a result, planned by the program of work haven't been executed in full. However, funding for these projects by the state program remained extremely low and, consequently, planned by the program volume of work has not been met.

It is defined that since 2015 in order to extend interdisciplinary research, NAS of Ukraine began implementation of a comprehensive program, as a result of which:

(1) light, strong and corrosion-resistant structural materials with the set properties for mechanical engineering, aerospace engineering, protection systems from electromagnetic fields will be created;

(2) nanotechnologies used to connect constructional materials will be developed; heat-resistant, high-strength, corrosion-resistant coverings of different designs will be created;

(3) miniature and high-speed electronic devices of new generation, sensors, and systems for information technology and medicine will be created;

(4) highly effective devices and systems for small-scale power generation such as solar and fuel elements, chemical sources of energy, materials for accumulation of electric energy and hydrogen will be created;

(5) nanostructural catalysts for use in energy saving and environmentally friendly industries and vehicles will be received; simple and cheap methods of cleaning of the polluted waters and highly effective sorbents will be produced;

(6) new pharmaceuticals and medical supplies based on nanotechnology for treatment of the most widespread and dangerous diseases (targeted drug delivery, diagnostics of living cells, biocompatible implants) will be produced;

(7) new medicines for agricultural purposes will be created; potential orders on defense issues will be met.

It is shown that in 2012-2015 works of NASU institutions were also continued in such directions as:

(1) new organic substances, materials, and composites on their basis for the equipment of new generation;

(2) new inorganic materials for the modern equipment;

(3) new polymeric materials of different functions;

(4) new substances and materials for needs of medicine and agriculture;

(5) creation of new energy – and resource-saving and ecologically ways of producing low-tonnage substances and materials of chemical production.

It is proved that modern information technologies are the driving force in leading countries of the world, but the convergence of NBIC technologies extremely expand opportunities of information technologies, qualitatively changing their direction, and create opportunities for development of other fields of science and technologies. The explosive progress of NBIC technologies over the past decade changes a condition of development of information society in Ukraine rapidly. It is shown that in 2006-2013 Ukrainian national Grid-network (UNG) was actively developed as part of the implementation of state scientific and technical programs, and today these performances are going in such priority directions as:

(1) formation of modern electronic infrastructure which provides creation and application of Grid-clusters software and hardware, telecommunication networks and Grid-systems, "cloud" and other advanced technologies;

(2) increase in power and quality of Grid-infrastructure using existing Grid-computing clusters, creation of the national directory services;

(3) creation of flexible virtual research environment with the simplified access to the resources of Ukrainian and world information space;

(4) creation of conditions and mechanisms of interaction between researchers and IT collaborations, projects from different countries; formation and support of the virtual national competence center, and its interaction with the competence center EGI;

(5) expansion of scope of Grid-, cloud and other advanced technologies application in scientific research.

It is defined that during 2000-2011 NAS of Ukraine carried out works on the enhancement of existing and development of a new scheme of supercomputers which allowed to create three generations of supercomputers SCIT and to implement the new complex architectural project of development of energy efficient cluster SCIT-4 with the productivity of 12 of TFLOPS. Since 2012 works on the accumulation of power of SCIT-4 are continued within the program of scientific research of NASU "Intelligence".

It was found that due to the widespread use of convergent technologies the development of microelectronic technology in the leading countries has led to technological breakthroughs in miniaturization, improving the speed and performance of devices, device processing, and transmission. In Ukraine the development of microelectronic technology has shown that today it has the best starting position for the competition in the world markets in:

(1) lighting engineering on the basis of superbright LEDs;

(2) microwave electronics;

(3) optic- and infrared electronics, while in micro photo electronics Ukraine has shorted production and open cooperations that allow creating highly profitable domestic advanced manufacturing without billion capital investments.

In 2007-2012 a number of state programs that support the development of electronics as material resources of ICT acted in Ukraine and their financing was unsatisfactory. From 2008 until today the state scientific and technical program of development and creation of sensor knowledge-intensive products operates, and its aim is to create a fundamentally new competitive sensor knowledge-intensive products (materials, sensors, analytical devices and intelligent systems) and their implementation to all areas of industry and consumption.

It is proved that the wide involvement of new convergent technologies in the development of nuclear energy, fusion energy and expanded use of renewable energy and search for new environmentally friendly energy sources is becoming increasingly question for the majority of the countries of the

world in conditions of escalation of energetic and environmental problems of fossil hydrocarbons depletion. In particular, today's final energy consumer may be replaced by systems of reproducing objects of nature, based on NBIC-convergence of technologies that are most promising in photovoltaics(solar elements), hydrogen conversion (fuel elements), thermoelectricity (thermoelectric devices), improved carbohydrate energy (catalysts, components); production of LED technology, in particular with use of OLED.

It is shown that in 2004-2010 the state research program on problems of use of nuclear materials, nuclear and radiation technologies in the fields of economy was executed in NAN of Ukraine for the solution of problems of nuclear power engineering, but the actual level of funding of this program was about 52% of the prescribed amount. In 2011-2015 NAS institutions carried out the comprehensive program within which it was received a number of important results, namely:

(1) new methods of applying functional coatings;
(2) modification of materials with powerful streams of plasma;
(3) plasma source of intensive X-ray and extreme ultraviolet radiation;
(4) plasma ozonizers;
(5) low-temperature plasma ultrasonic ozone sterilizers;
(6) helicon technological sources;
(7) plasma chemical reactors;
(8) plasma steam technology for waste recycling;
(9) creation of environmentally friendly plasma technologies for industry, medicine, agriculture and environmental protection.

It is defined that the NAS scientific institutions of Ukraine actively participate in joint research with the EU and Russia laboratories on the creation of technologies of controlled fusion power. Besides, in 2014-2015 the most important results of this research became:

(1) new knowledge of the physical phenomena that occurring in high-temperature plasma, including in case of its interaction with solid surfaces;
(2) development of basic aspects of future thermonuclear energetics;
(3) development of physical principles and advanced equipment for ion-plasma technologies for industrial processing of materials, environmental protections, agriculture, medicine, substance diagnostics, etc;
(4) development of plasma electronics, plasma dynamics and physical foundations of collective methods of acceleration of the charged particles;
(5) impetus to development of the industry of hi-tech production which is almost totally imported now.

It is found that in 2006-2015 Ukraine continues intensive fundamental and applied research on development of technologies for getting hydrogen, creation of appropriate materials and highly effective processes that can lead to significant reduction in cost of both the hydrogen and auxiliary systems such as fuel cells, and moreover it will promote wide commercialization of technologies of hydrogen energy and will be coordinated with the general trend of increasing use of alternative energy and the maximum possible decentralization of energy supply.

Identification of research priorities of convergent technologies in Ukraine has unsystematic character and does not meet the priorities of funding. Development of *the Strategy of development of converging technologies in Ukraine* according to global and specific national problems, creation of *the National program of development of converging technologies in Ukraine* which will have clear priorities of scientific research, securing the financing (on stages of operations), organizational support of the state, mechanisms of implementation in a business sector, performance criteria of interventions and accountability of executives to the government (for government funding) and to businessmen (for extrabudgetary funds) is necessary. It is proved that there is a need for creation of

the Advisory Work Groups that will include both employees of NAS of Ukraine and from other scientific institutions and independent experts who have some experience in a certain area of research, to analyze the current implementation of the programs of converging technologies, to make forecasts and clarify priorities of converging technologies development in Ukraine.

Chapter 5. Organizational mechanisms to support t he development and implementation of converging technologies in countries of the world and Ukraine

It is found that in the period of 2004-2015 rapid growth of volumes of interdisciplinary research in the most major industries of developed countries, and widespread of convergent NBIC technologies and formation of leading production technologies on their basis which have the greatest commercial prospects for 2020, caused need for use of more general instruments of control of research and innovation, than technological platforms or clusters. At the same time world technology leaders began to build the scientific and innovative policy based on model of four spirals 'the power - science - civil society – business" which has many players that prevents absorption by one structure (even by powerful multinational corporation) and in which the principal element is not the cluster or a technology platform, but an innovative ecosystem.

It is shown that to implement the provided advantages of the convergence of knowledge, technologies, and society through the use of converging technologies, the World Technology Evaluation Center (WTEC) proposed such mechanism as creation of *national CKTS-initiatives* that can be organized as a group of centers in educational and research institutions, technology platforms, programs and organizations and appropriate communication and coordination with public authorities.

Meanwhile it will be necessary to direct the government program of convergence to those areas which are of national interest, namely:

(1) convergent revolutionary technologies for personal services;
(2) cognitive society and lifelong wellbeing;
(3) diversified production based on NBIC-technologies;
(4) convergence in biomedicine;
(5) improving human potential;
(6) sustainable earth system;
(7) assistance to development of creativity, innovation and analysis of decisions in the sphere of value added;
(8) creation of the central authority on convergence of knowledge and technologies which will focus on approaches to convergence, as well as planning for priority convergence platforms (for example, for government programs on science, technologies and investment planning).

It is found that since 2012 the EU countries and associated countries became participants of the development of the European Research Area (ERA) which is based on three priorities - Open Science, Open Innovations, Open to the World. It is shown that the paradigm of Open Science provides creation of the unified electronic infrastructure with open access for researchers from any place. Within this paradigm, European Open Science Cloud is created, that provides technologies of combining and rendering of services to the state and private users as well as free access to end users of the system. Besides, in 2015 Digital Single Market policy is approved within which European Open Science Cloud will be open, service-oriented, inclusive for all stakeholders and research will be raised to the next level. The Work program 2016-2017 for the development of ERA was approved during the Ministerial conference within holding the regular meeting of The Competitiveness Council of the EU in May 2016. It clearly formulated priorities of science and innovations development at the supranational and national levels and set the following objectives:

(1) to provide strategic recommendations at an initial stage by development of a policy in science and innovations;

(2) to consider impact of other policies on R & I agendas and to make recommendations for appropriate actions;

(3) to carry out consultation on implementation and policy support in R & I area.

It is established that till April 22, 2016, Ukraine has not provided their proposals for the National Action Plan for the implementation of the ERA Roadmap 2015-2020. It is a direct violation of the new Act of Ukraine On Scientific and Technical Activity as well as the relevant provisions of the EU-Ukraine Association Agreement. Implementation of ERA Roadmap 2015-2020 in Ukraine requires:

(1) creation and provision of services of Identification Committee, for selecting members of Scientific committee of National Council for Science, Technology and Innovation of Ukraine;

(2) implementation of the European standards to improve the efficiency of the Ukrainian national research system in close cooperation with European Science Foundation (ESF);

(3) the organization of the international expertise (expert base) and an expert procedure for evaluation of quality of research at different institutions (the research and development organizations, higher educational institutions);

(4) implementation of the European type research institutions as part of network of the European research universities in Ukraine in cooperation with League of European Research Universities (LERU);

(5) the organization of work of the National Research Foundation in cooperation with Science Europe and the organizations which finance scientific research in the EU;

(6) development of interdisciplinary research and integration into ERA that requires an involvement of representatives of the authorities of Ukraine that finance research as well as scientific experts groups related to ERA (ESFRI, e-IRG, ERIC committees, the international expert working groups for development of roadmaps of research infrastructures and centers of excellence taking into account the Strategy of reasonable specialization;

(7) coordination of the priority directions of scientific and technical development set by the law of Ukraine on the basis of which the State Target Scientific And Technical Programs are developed; coordination of these STSTP with similar programs of other countries of the EU within GPC committee;

(8) removal of barriers to the involvement to the free market of researchers, implementation of codes on hiring of experts, insurance of pensions for mobile scientists provided the participation of Ukraine in the Steering Groupon Human Resources and Mobility (SGHRM);

(9) implementation of evaluating indicators of Ukrainian involvement to ERA, cooperation with a monitoring system of integration in ERA that are possible only with participation of Ukraine in ERA Committee (ERAC).

Figure 3 demonstrates the authors' view on reconciliation of ERA Roadmap 2020 and the Roadmap on the UNRA realization on the assumption of ERA's implementation in Ukraine by 2020.

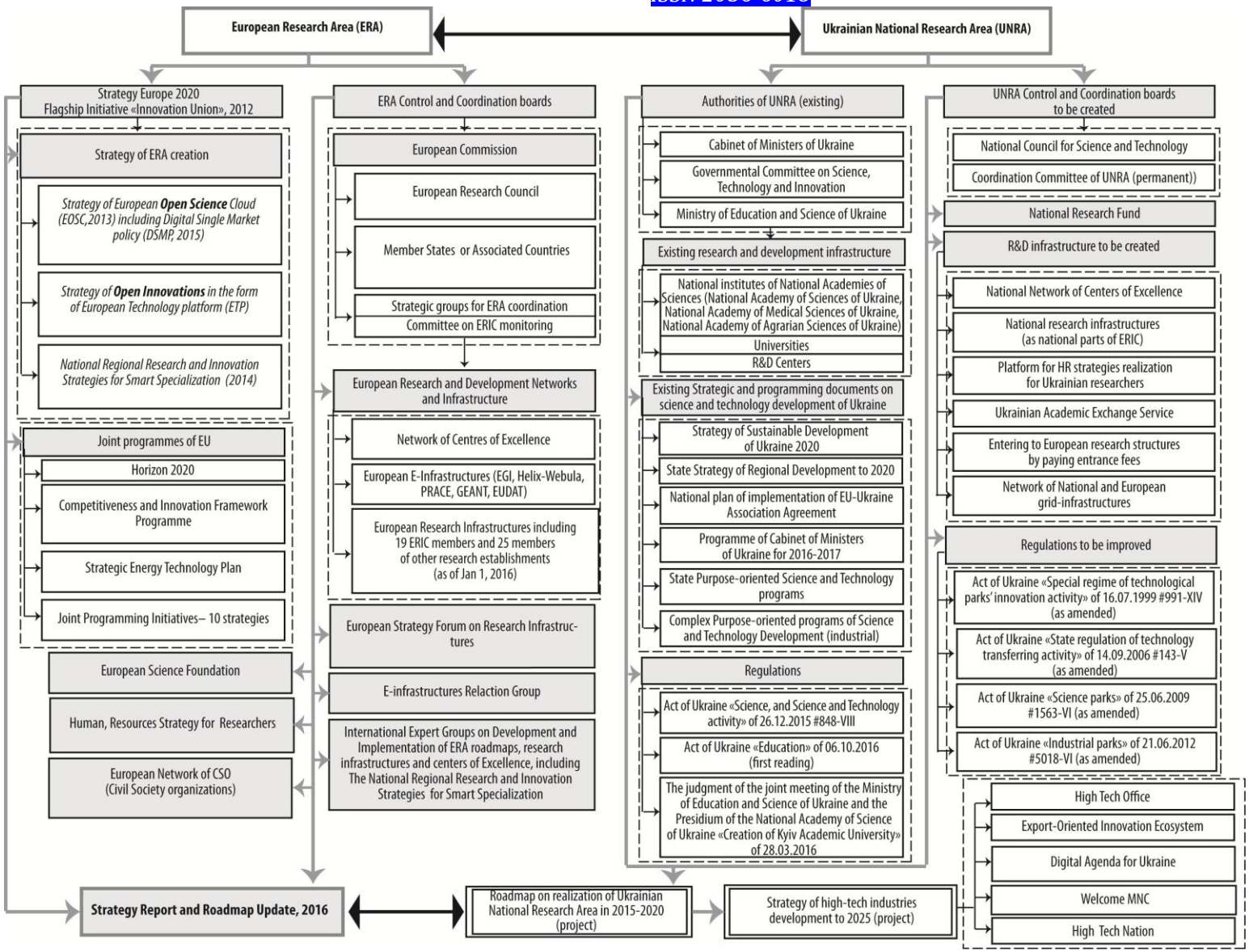

Figure 3. Reconciliation of ERA Roadmap 2020 and the Roadmap on the UNRA realization on the assumption of ERA's implementation in Ukraine by 2020

It is proved that for implementation of Ukrainian National Research Area (UNRA), Cabinet of Ministers, Ministry of Education and Science of Ukraine, and also National academy of Sciences of Ukraine (NAS of Ukraine) should:

(1) make the plan of formation of UNRA which can be integrated into ERA by parts and in general;

(2) coordinate actions of NAS of Ukraine with the National Academy of Medical Sciences (NAMS) and the National Academy of Agricultural Sciences (NAAS), and also with public scientific organizations for development of Strategy of Reasonable Specialization of Regions of Ukraine and integration into the ERA through implementation of the ERA Roadmap 2015-2020;

(3) develop the mechanism of realization of the National Action Plan for implementation of the ERA Roadmap 2015-2020 for innovative development through (a) Open Science; (B) Open Innovations; (C) the Strategy of Reasonable Specialization; (D) support from the EU through technical assistance on implementation of the ERA agreed national priorities;

(4) create the Council of the EU – Ukraine for reforming of science and innovation system of Ukraine involving the main actors of ERA and UNRA for step-by-step implementation of the ERA Roadmap 2015-2020;

(5) to hold the Forum for presentation of the National Action Plan for implementation of the ERA Roadmap 2015-2020 with an involvement of the main actors of ERA and UNRA, including ESFRI, ERIC Consortium and European Institute of Innovation and Technology.

It is shown, in the implementation of the Ukrainian Roadmap, first of all, it will be necessary to create:

(1) National Council for Science and Technology (NCST);

(2) Scientific Committee of NCST as the basis of Coordination Committee of UNRA;

(3) National Research Fund;

(4) basic elements of research and development infrastructure, including (A) National Network of Centers of excellence; (B) National research infrastructure as Ukrainian parts of ERIC, as well as entering to European research structures buy paying entrance fees; (C) Network of National and European grid-infrastructures; (D) Platform for HR Strategies realization for Ukrainian researchers; (D) Ukrainian Academic Exchange Service and others.

It is proved what a basic element of network structures of support the development of interdisciplinary research and development of convergent technologies in the countries - technological leaders is the scientific and educational centers (SEC) as structural units of the scientific, research and industrial organization or university, that conduct the appropriate research, training of highly qualified personnel in the field of convergent technologies, and also use results of scientific research in education.

Cluster-network model of SEC interaction is the most modern model that is, on the one hand, cluster formation with a full cycle of research and development and university education and a cycle of implementation of a range of products of convergent technologies, and on the other hand, it is complemented by the opportunities of joint laboratory complexes, shared infrastructure, and specialized complexes focused on the decision of small application-oriented tasks for creation of convergent technologies.

It is proved that creation and successful functioning of research and development universities in the regions of Ukraine with the largest concentration research and development (including structures of NAS of Ukraine) and higher educational institutions can become the beginning of real reforms of the scientific and technical sphere in Ukraine and allow NAS of Ukraine to become the real leader in key scientific research (including the creation of converging technologies) that meets pressing global challenges. Besides, it can start innovative reforms in the country according to reasonable specialization and integration into European Research Area and taking into account provisions of the EU-Ukraine Association Agreement, Ukraine 2020 Strategy – "European Standards and Rightful Place for Ukraine in the World", provisions of the new Act of Ukraine "Science, and Science and Technology activity" of 26.12.2015 and the Act of Ukraine "Education" of 01.07.2014 and the new Act "Education" of 06.10.2016.

It is shown that legislative provisions on such elements of research and development infrastructure as science and technology parks, scientific parks, industrial parks, special economic zones, the provision on a transfer of technologies, setting of innovation priorities and others require considerable revision in view of the future implementation by Ukraine of basic provisions of the EU-Ukraine Association Agreement as well as preparation of the National Plan of implementation of the ERA Roadmap 2015-2020.

APPENDIX
CONTENTS of monograph