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SUSTAINABLE DEVELOPMENT: EU Experience and Practice of Ukraine

(Master's Degree Course)

Edited by Leonid Melnyk

A study guide

UNIVERSITY BOOK

СТАЛИЙ РОЗВИТОК: досвід ЄС та практика України

(Магістерський курс)

За ред. д.е.н., проф. Л. Г. Мельника

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Reviewers:
L. L. Kalinichenko – Doctor of Economics, professor, Head of the Department of Economics and Business, Kharkiv National University of Construction and Architecture, Kharkiv;
T. M. Stepura – Doctor of Economics, professor of the Department of Enterprise and Investment Economics of Lviv National University “Lviv Polytechnic”, Lviv;
V. M. Tarasevich – Doctor of Economics, Professor, Corresponding Member of the Academy of Science of Ukraine, Head of the Department of International Economics and Social and Humanitarian Disciplines, Ukrainian State University of Science and Technology, Dnipro

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S 94 **Sustainable development: EU experience and practice of Ukraine:** a study guide / edited by Leonid Melnyk. Sumy: University book, 2025. 480 p.

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The textbook introduces one of the most relevant categories of modernity, such as sustainable development of socio-economic systems. The features, mutual relations and processes of evolution of various sectors of economies towards sustainization of production are characterized. The features of the formation of modern trends in various spheres of activity are shown: sustainization, informatization, digitalization, cyborgization of the economy and its branches, development of the technological base, new materials, Internet of Things. Special attention is paid to modern industrial revolutions (Industries 3.0; 4.0; 5.0) and the phase transition to a new socio-economic formation.

Intended for teachers and students of educational institutions, as well as for researchers, specialists of enterprises, specialists of local administration bodies.

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Table of contents

Introduction

For a decade and a half now, the world has been living under the sign of a new ideological doctrine called “sustainable development.”

This strategy for human development was approved in 1992 in Rio de Janeiro at the UN World Conference on Environment and Development, and the definition of sustainable development was adopted.

Sustainable development helps meet the needs of the present but does not jeopardise the interests and needs of future generations. The authors successfully solved the problem of choosing the doctrine's central symbol and its basic definition.

The significance of the proposed definition also lies in the fact that it transfers the solution to the problem of sustainable development from the external technocratic sphere to the internal personal sphere. After all, the criteria for balanced (equilibrium, controlled, amortised, etc.) development will always remain indicators of material and energy balances calculated and monitored by some technical specialists (for example, the exchange between production and nature). The fundamental pillar of sustainable development is the moral foundations of each person and his responsibility for what he passes on to his descendants.

Moreover, the demand for natural resources and a clean environment will not limit future generations' needs. Human social development can only be carried out in an adequate environment, which presupposes the presence of both primary natural landscapes and full-fledged components of the cultural environment. Consequently, the environmental aspect of sustainable development, although extremely important, is not the only one.

Man depends on nature – this is an axiom. But this is only part of the truth. In modern conditions, nature itself is already largely dependent on human activity. Consequently, its state can be considered one maintained by a person. Therefore, sustainable development is supported not only by development but also by development. The English term sustainable allows for such an interpretation.

The above is the result of the primary understanding of the specified concept, which has, in all likelihood, an infinite semantic capacity. This demonstrates a telescopic effect because it can reveal all-new semantic levels and facets of the specified concept. In particular, nature then supports man's existence so that he has a subject of awareness (reflection) of his existence.

The issue of sustainable development is often associated only with solving environmental problems. Meanwhile, this is a highly complex and multifaceted set of issues that ensure the effective functioning of the biosphere-anthropogenic unity within the planet, which belongs to the class of open stationary systems. These problems must be solved everywhere, at every moment, in every corner of the earth where human civilisation exists. Moreover, each of its representatives must take part in this process. Success on this path is possible only if humanity can master systemic, ecologized thinking built on the perception of uniform development patterns of the systems that make up the universe.

The socio-economic potential of sustainable development is the entire toolkit (regularities, principles, mechanisms, methods, motivational tools, etc.) that can be mobilised to create absolute prerequisites for sustainable development.

The purpose of teaching the course “Sustainable Development” is to develop in students the knowledge, skills and worldview necessary for making decisions and implementing activities within the framework of sustainable development.

Authors:

Dr., prof. Leonid Melnyk (editor); PhD, As. prof. Yuriy Derevyanko; Dr., As. prof. Victoria Dudchenko; PhD, As. prof. Inna Koblianska; PhD, As. prof. Oleksandr Matsenko

Technical editor – Yuliia Zavdovieva

1. On the way to sustainable development

Sustainable development is a concept that is simple in its key idea but infinitely complex in its content and implementation mechanism.

The simplicity of the underlying idea is apparent. We must stay within the limits of our influence on nature so that natural systems have time to self-heal over time: day after day, year after year, generation after generation.

However, implementing this task turns out to take a lot of work. Behind the laconic definition lies an infinitely complex and profound phenomenon. The starting point for its study is the fundamental principles of developing open stationary systems.

Without understanding what homeostasis and metabolism of systems are, it is impossible to transform them; without studying the feedback mechanisms, how adaptations and bifurcations of the system occur, as well as other fundamental concepts, it is difficult to count on a deep, meaningful perception of the issues under consideration. After all, ensuring the stability of any system is nothing more than maintaining a certain level of homeostasis. And it can be maintained only through constant negative and positive feedback mechanisms that support or transform the system's state.

It is essential to understand the fundamental essence of system formation, particularly the trinity of their material (material-energy), information, and synergetic (system-forming) principles. In the triune essence of systems' reproductive mechanisms, one must most likely find the keys to exiting the dead-end labyrinths of the industrialised economy's unsustainable development.

The main point is that industrial production can break out of the vicious circle of economic insolvency only through a qualitative leap in economic system efficiency, dematerialisation (reducing material and energy intensity), and system integration. Modern industrial revolutions, Industries 3.0, 4.0, and 5.0, are designed to solve these problems.

Man occupies a leading position in the concept of sustainable development. It was created for his physical and spiritual salvation. But it is up to the person to bring this concept to life, transforming production, economic relations, life-support systems, and the entire way of life. To change all this, a person needs, first of all, to change himself.

The paradox is that maintaining the stability of a person's physical (i.e., material) nature (the natural homeostasis of his body) can only be ensured at the cost of extremely rapid changes in his informational (personal) essence, which represents a single triune systemic integrity (bio-socio-labor).

The methodological complexity of the perception of the concept of sustainable development is enhanced by the fact that talking about the need to manage the state of the existing systemic whole (man-nature-society), determined, in turn, by the levels of homeostasis of three critical systems: the human body (and, billions of individuals, living on Earth), the biosphere (trillions of individuals that make up the planet's ecosystems) and the economy (millions of economic entities that ensure the functioning of the world's economic systems). This task is also challenging due to the systemic triad's dynamism under consideration. Any of its states must be reproduced anew simultaneously at every point in space.

For the mentioned triune systemic whole (man – biosphere – economy) to maintain its stability, it is necessary to keep the stability of each of the mentioned systems. The biological nature of man has extremely limited the environmental conditions in which he can physically exist, maintaining the level of his homeostasis. Any deviation in one direction or another in temperature, pressure, solar radiation and hundreds of other environmental parameters on which the conditions of human life and activity depend will be fatal for him. To maintain the natural conditions existing on Earth, the biosphere must maintain the parameters of its homeostasis and, consequently, the quantitative composition of its ecosystems and the qualitative characteristics of the processes occurring in them.

The paradox is that man himself destroys the existing homeostasis of the biosphere. This happens for two reasons:

- firstly, due to the growth of the planet's population (new inhabitants need new natural factors that are no longer left on Earth);
- secondly, due to qualitative changes in people's needs.

By rebuilding his life, a person changes nature.

In conditions when the processes of human influence on nature have reached a global scale, he has only two options left in his arsenal to preserve the stability of natural conditions on the planet (and therefore himself): the first is to limit the growth of the Earth's population, the second is to learn to change the processes of social production and consumption of products, causing an increase in negative impact on nature. This can be done only by rapidly reducing human life support systems' environmental intensity (material intensity, energy intensity). Moreover, the rate of this decline should exceed the rate of population growth or at least correspond to it. Thus, to maintain the homeostasis of humans and the biosphere, a constant change in the homeostasis of the economy towards its dematerialisation is necessary. To implement such changes, a person must constantly modify production technologies, the nature of the products consumed, and economic relations and (as we have already mentioned above) transform his inner world.

It took humanity decades to realise that the way out of environmental dead ends lies in qualitative progressive transformations of production systems, economic relations, and social structure. It is also understood that the seemingly life-saving total expansion of treatment facilities can only aggravate the situation due to its colossal material consumption.

Managing the development process of any system necessarily presupposes the presence of standards and indicators that characterise the normal and current state of the initial parameters.

2. Fundamentals of systems sustainable development

To deepen one's understanding of sustainable development prerequisites, one must research the fundamentals of systems development. Detailed analysis of development mechanisms and factors allows the introduction of the diagram of their integral interaction (Figure 1).

The *system* is a material and information entity (whole) consisting of different components. The system possesses properties that are not present for its components (the entity is greater than the sum of its components). *Development* is an irreversible, directed, and logical change in the system.

The main postulates of the mentioned mechanisms are the following:

1. Only *open stationary systems* can develop.

The *system's openness* means it carries out metabolism, i.e., exchanging material, power, and information with the environment. Metabolism serves as a form of free energy entering the system and removes vital activity wastes from it.

The system can maintain stable (sustainable) dynamic equilibrium – homeostasis if it is stationary. Homeostasis is characterised by a dynamic relative constancy of the system's composition and properties. It is needed for maintaining the required difference in physical and chemical potentials (temperature potential, chemical potential, electromagnetic potential, etc.) between the system and the environment, as well as between separate components within the system. The system can only carry specific homeostasis values that fall into narrow intervals of the mentioned potentials.

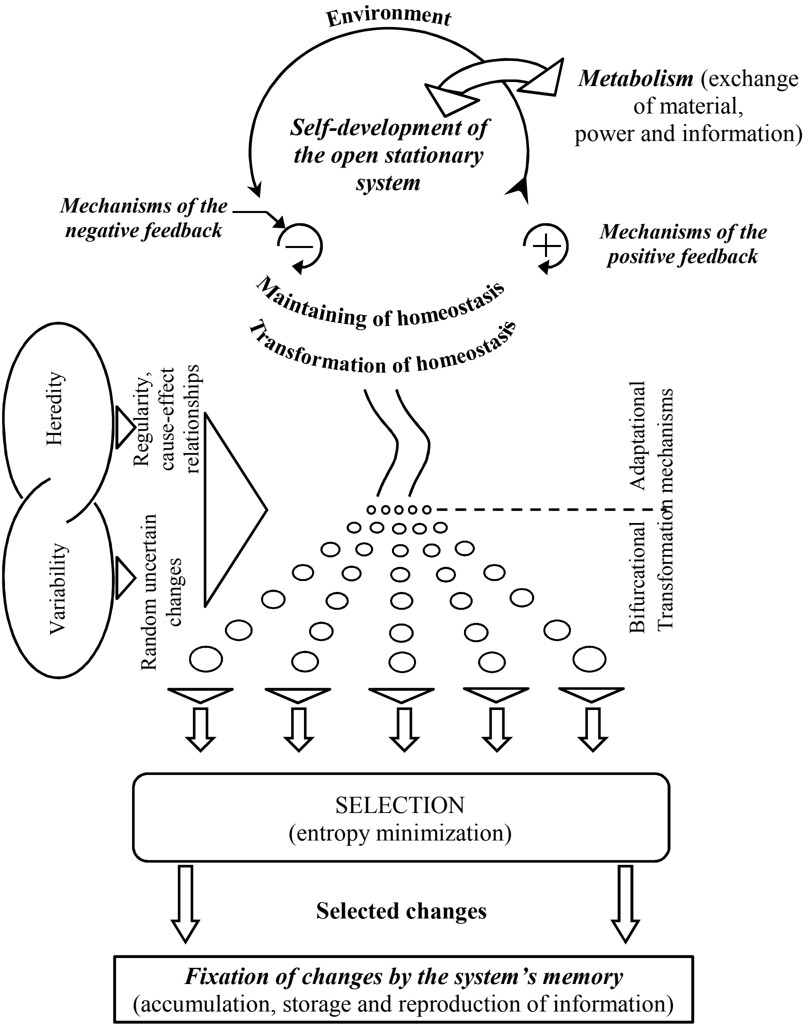

Figure 1: The integration diagram of development mechanisms and factors

The deviation of the system's parameters determining the level of homeostasis from its optimal values leads to damage to its functionality or to the termination of its existence as a self-developing system. It is necessary to reorganise the whole system to change the homeostasis level, i.e., to introduce radical changes to interactions between the system's components.

Open stationary systems include inanimate structures exhibiting cooperative behaviour, live organisms, ecosystems, and social organisations (firms, associations, markets, microeconomic systems).

2. To *carry (maintain) homeostasis,* the system uses negative feedback mechanisms to compensate for the influence of environmental factors. Negative feedback mechanisms act in the opposite direction to the influencing factors. To implement negative feedback mechanisms, the system has to spend *free energy.*

3. If the system's energy balance is disrupted and its total energy consumption becomes larger or smaller than the free energy inflow, the system gets reorganised. So, the system changes its homeostasis level, increasing or reducing it accordingly (if the system is elastic enough for such a reorganisation). *The change in homeostasis level* related to the reorganisation of the system's structure is achieved using *positive feedback mechanisms.* Those mechanisms require free energy as well.

4. The system's development is accomplished due to the interaction of three factors: *variability, heredity, and selection.*

Variability provides *random uncertain* fluctuations, i.e., deviations from the system's equilibrium state.

Heredity guarantees the *regularity* of changes. *Cause-effect relationships* between the processes determine it. Due to this feature, *the future* is *dependent on the past*.

Selection chooses the most effective states of a system, i.e., the changes that the system has experienced. *The selection criterion* is the minimisation of the system's entropy. Only the system states with *the maximum information value* can be selected. Eventually, this leads to the *minimisation of energy dissipation (irreversible dispersion)*. Thus, only the most effective states of the system survive.

5. The system can implement the mentioned development factors via adaptational and bifurcational mechanisms.

Adaptational mechanisms implement functions of variability, heredity and selection under the rule of preserving the main characteristics of the existing system, i.e., within the limits of the same biological organism, ecosystems, firm, and country.

Bifurcational (branched) mechanisms implement the mentioned functions based on the consecutive change in qualitatively new system states that lose the main characteristics of their predecessor, although keeping hereditary links with it. Biological organism generations change, firms restructuring, radical changes in the form of government, etc., are examples of such processes.

Bifurcation mechanisms allow for reaching the most favourable conditions for development. Discontinuity and branching will enable the system to “forget” the former, less effective state and to select a new, more effective one (or new ones) using multivariant search. The exact mechanisms not only assure the irreversibility of the process but also implement another essential property of fixing the occurred changes. Bifurcational mechanisms are much more effective than adaptational mechanisms as they allow considerably increasing development rates.

The origin of the intellect, with its ability to form and select virtual bifurcations, allowed for significant acceleration of the development processes (functions of variability, heredity, and selection). *It played the role of impulse in avalanche-like acceleration rates* in nature’s evolution. The computer era reinforced these processes.

6. Information fixing of the changes is the last stage in every system development cycle. The system memory plays the leading role here. *The memory* can *accumulate*, *store* and *reproduce* information. New standards of the system's behaviour are fixed there. The system will function according to them until new changes are fixed. To function for the system means repeatedly duplicating and reproducing the system processes of vital activity. Thus, memory serves as the means for the fixation of the most effective system states. As we see, memory is the last and crucial component of every development cycle.

7. All systems' functioning and development processes happen due to the interaction between three natural origins: *energy potency, information reality,* and *synergetic phenomenon.*

Energy potency stipulates the system's ability to fulfil work (change).

Information reality is realised in the system as the system's energy potential, fixed by memory, i.e., its ability to change in space and time in concordance with strictly defined programs (the ability to reproduce definite states of the system). It means the ability to store or change different parameters of the system: form, colour, scent, vibrancy, other movements, *etc.*

Synergetic phenomenon stipulates the interactions of the separate parts of the system. As a result, they begin to behave as a whole unit. For this to happen, two conditions are necessary:

(a) first, separate parts of the system must react to (external) environmental changes;

(b) second, separate parts must show coherent actions, i.e. "interact" as synchronising their changes. The synergetic phenomenon leads to the so-called emergency effect, when components from the system, i.e. the whole, are greater than the sum of its parts.

Acting so, the triad of the abovementioned phenomena forms the fourth origin of nature – the reproduction phenomenon, which reproduces a particular natural essence, being able to reproduce (sustainably renew) its characteristic features in time. Elementary particles, atoms, molecules, cells, biological species, and social structures (families, firms, and countries) can be considered as such essences.

The mechanisms and factors mentioned above create necessary and sufficient conditions for realising evolutionary processes. They make a multilevel system that constantly reproduces those necessary *irreversible,* direct, and regular changes of systems in stochastic conditions and indefinite states of the environment. Socio-economic development can be sustainable if natural systems' self-organisation, self-regulation, and self-reproduction mechanisms are preserved.

Reproduction processes unite three factors: energy, information, and synergetic phenomena. Every natural essence (plant, animal, ecosystem and the biosphere) is a unique system that constantly reproduces the unity of three natural origins (material basis, information and synergetic phenomenon) in time and space. The reproduction of every natural essence, including the biosphere (which guarantees necessary life conditions for human beings), is a very complex task. Human beings will only be able to understand this reproduction mechanism partially. Moreover, human beings will only partially control these processes. It means a human being must not exceed the level of impact on nature's reproduction mechanism and its three critical subsystems:

a) material (critical margins of material component derivation – plants, animals);

b) information (withdrawal, distorting and collecting the new information);

c) synergetic (impede communication links between biological species)

Preserving the reproduction mechanism is a necessary condition of life sustainability on the Earth and a prerequisite of its development in all forms, including social. Development can happen only due to sufficient development factors: *variability, heredity and selection*.

3. Basics of reproduction of systemic human triad and functions of nature

Problems of sustainable socio-economic development deal with managing the three interrelated systems: human biological nature ("bio-person"), the biosphere and the socio-economic system. The human factor, the leading subject and object of current changes, is critical to their functioning and development.

The complexity and difficulty of solving the problems of sustainable development relate to the complexity of human nature itself. Human is a unified system (whole), which includes three interrelated and interconnected systems:

- As a biological creature, a man is a part of the natural environment in the physiological constitution.
- A man as a social creature (personality) is a part of society and its social nature.
- A man, as a component of the economic system, is a workforce, a labour resource.

Environmental factors influence a human via the following functions that can be united into four main groups (Figure 2).

1. Physiological functions support a person's life as a sociological constitution ("bio-person").
2. Social functions support the development of a person's personality ("socio-person").

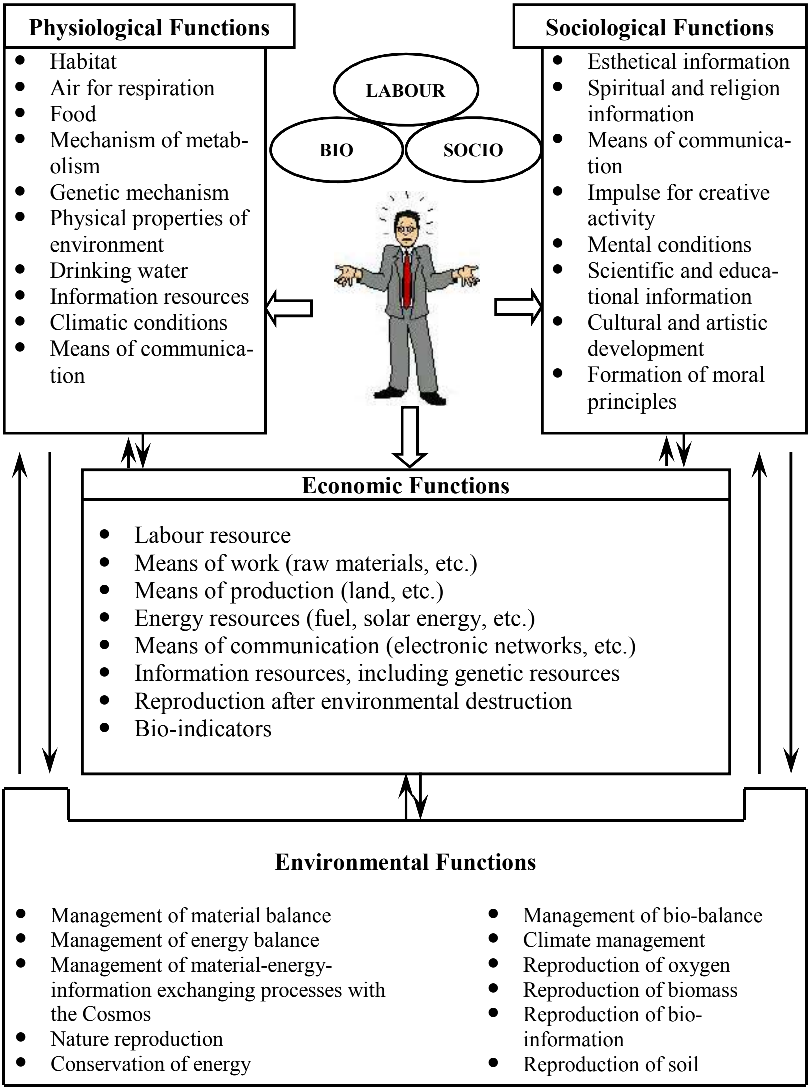

Figure 2: Environmental functions

3. Economic functions determine the activity of the economic system, including labour resource reproduction ("labour-person").

4. Environmental functions form, support, and govern the state of the ecosystem where a person lives.

Even though three persons (bio-, socio-, and labour-) exist in one physical body, they differ from each other to a great extent in their vital needs, such as:

- *"Bio-person's"* needs are related to the satisfaction of the natural necessities in food, water, and air that are essential for life and physiological comfort (temperature, pressure, humidity, etc).
- *"Socio-person's"* needs are related to developing personality and fulfilling social interests.
- *"Labour-person's"* needs are related to achieving specific economic aims (profit maximisation, cost minimisation, reproduction of skills).

Everybody can identify the differences between the functions and motives of each person's actions. Fear, starvation, and other instincts urge the psychological person. "Socio-person" is guided by duty, aspiration for self-expression, and public recognition. The motives of a "labour-person" are the tendency to make a profit and career goals, among others.

Undoubtedly, it is a very simplified scheme because the given trinity is not a simple sum of its components; it is a highly complex system. It is well known that a person may be called the "microspace". Successes or failures of the "labour-person" in many cases depend upon the "bio-person's" health and "socio-person's" creative abilities. The "bio-person" and "socio-person" are closely connected to economic functions.

Emphasising the environmental and economic conditions and the environmental functions closely related to the components forming the person's trinity is necessary. The prerequisites for solving the given contradictions are, in fact, achieved mainly at the expense of realising the person's physiological and social needs, which, in turn, depend upon the successes of the economic system.

Why is it necessary to know the tri-union system of human essence and the corresponding functions of nature to understand and solve the problems of sustainable development (SD)?

(a) Breaking the impact margins on the planet's biosphere will be ruinous for human biological nature ("bio-person"). This stipulates one of SD's objectives: preserving and conserving conditions supporting human life.

(b) Problems of sustainable development deal with the necessity of "bio-person" survival and the provision of conditions for "socio-person" development. This requires preserving the information value of natural systems where a "socio-person" lives and develops. It is also essential to solve the problems of sustainable development itself. Only a socially developed person (i.e., the one that has sufficient knowledge, outlook and moral principles) can adequately estimate the problems of SD, make correct decisions and have the will to implement them.

(c) Solving SD problems depends on a "labour person's" ability to achieve adequate transformation. Their ability to change themselves and the economic system (to improve knowledge and human skills, make the demand and supply "green," increase the efficiency of processes, and decrease the resource intensity of production and consumption of goods and services) will determine their level of success in achieving SD.

Achieving sustainable development is a complex and dynamic task. As a result, the art of SD management means the ability to *preserve* (conserve) some functions of nature that support the needs of "bio-person" and partially "socio-person" and very rapidly change some other functions of nature that satisfy the needs of "labour-person" and partially "socio-person".

4. Sustainable development: goals, objectives, problems

At large, sustainable development includes the following three elements – each of which belongs to the class of open stationary systems:

- a man as a biological organism and as a social being;
- ecosystem and biosphere in general;
- social-economic system.

Systems analysis can provide us with fundamental differences in sustainable development objectives from a concept of pure economic development. The principle goal of sustainable development is associated with the infinite existence of human civilisation and its evolutionary development (Figure 3). This goal is applied at two levels: (i) Necessary level, also known as subsistence level, which means the physical survival of a biological human being; 2) Sufficient level, which means the spiritual development of a social human being. Both levels are critical.

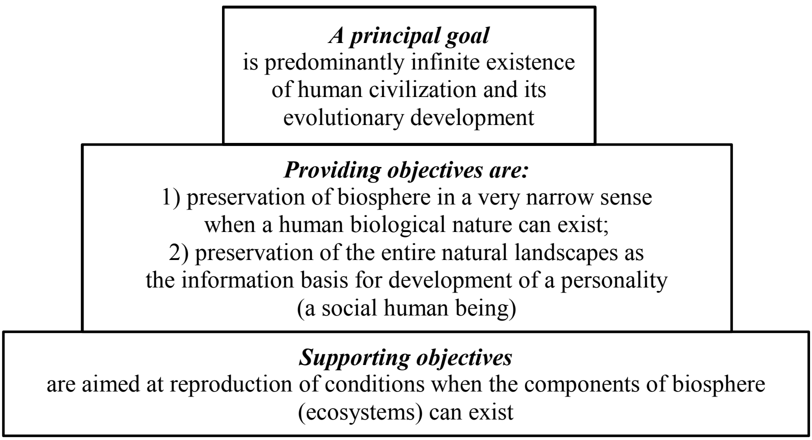

Figure 3: Objectives of sustainable development

Among the objectives of sustainable development are *objectives* that are aimed at (i) preservation of the biosphere in a very narrow sense when human biological beings can exist (i.e., the human organism can maintain its homeostasis level); this depends on such parameters as key climate characteristics and physical parameters (temperature, electromagnetic features, cosmic emanation), atmosphere and water composition, the composition of soil used for agricultural production; (ii) preservation of the entire landscapes as an informational basis for development of a personality (a social human being).

As well there are *supporting objectives* that stipulate the creation and maintenance of the conditions when the biosphere and its components can exist, which provides some vital conditions for a human being as a biological being and as a homo sapience.

The social-economic system also helps to achieve some goals of sustainable development. These goals are (i) provision of biological metabolism (nutrition and drinking water supply), (ii) provision of optimal physical conditions, and (iii) provision of material and informational flows for the spiritual development of a human being.

The principal difference among the three components of sustainable development mentioned above is as follows (Figure 4). As a biological being, a man can live only within a very narrow interval of physical and environmental parameters set by nature. Any deviation from these parameters threatens the entire existence of human civilisation. Some negative feedback mechanism is required to preserve this narrow interval based on constraints, standards, bans, sanctions, etc. This is how, ideally, economic mechanisms should work to achieve sustainable development goals.

In contrast, constraints associated with the necessity of preserving the biosphere and ecosystem elements' homeostasis are relative in nature.

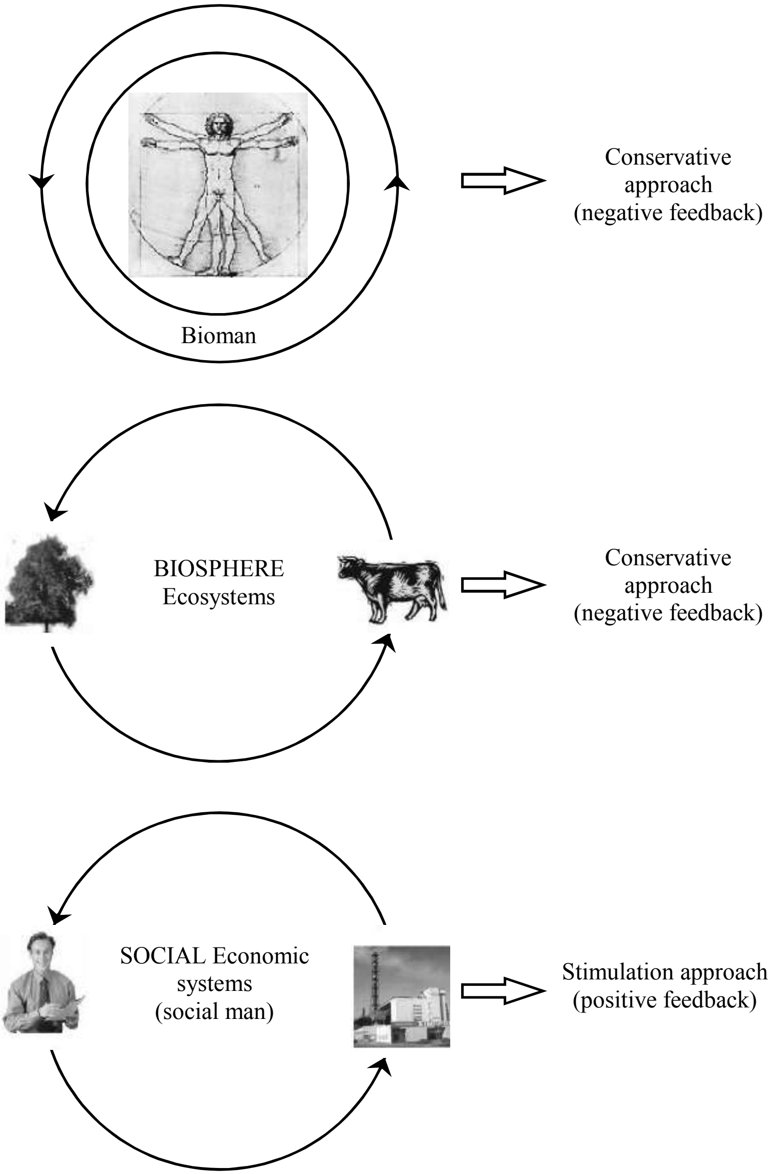

Figure 4: Approaches to formation of economic instruments of sustainable development

Changes in environmental conditions and the biosphere's homeostasis, as well as the preservation of the ecosystem's homeostasis, are required conditions for human beings. Negative feedback loops, including economic instruments, are needed to preserve the original power of land (reserves and national parks) and reduce the ecological impact on all the natural environment components.

The social-economic system is the only element that can and must transform rapidly. It is necessary because of the satisfaction of the social needs of a human being that change very quickly or, in other words, progress; second, it is essential because of the improvement of the social-economic system itself. The latter is based on production that satisfies ever-increasing human needs. To accommodate the constantly growing population and stay within the ecological system's capacity, production needs have to become more efficient to achieve resource preservation, particularly in terms of reduction in material and energy consumption. So, contrary to a biological human being and biosphere, management of the socioeconomic system should be a target of progressive change in homeostasis instead of just its preservation. In this regard, positive feedback mechanisms should be developed.

Two approaches, *conservative* and *positive changes*, constitute the methodological basis of a modern economic mechanism for achieving sustainable development.

The Conservative approach is based on the use of negative feedback mechanisms. With their help, mankind resists any changes (this is where the name comes from) that can threaten the ecosystem's sustainability. Currently, in environmental sciences, this approach is realised in the following forms (Figure 5):

- *preservation methods:* creation of reserves, national parks – territories, where the impact on nature is reduced; bans on endangered biological species;

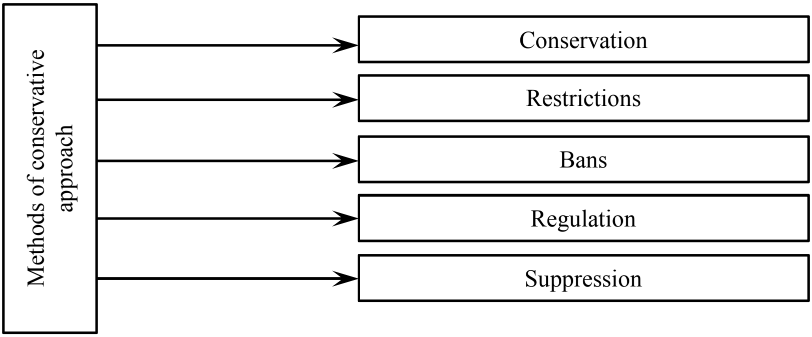

Figure 5: Forms of conservative methods

- *restricting methods:* licenses for the use of natural resources; quotas for wild animals trade; environmental standards; regulation of hunting; birthrate regulation;
- *prohibitive methods:* bans on hunting of certain animals; bans on cloning, bans *on* production and use *of* some substances (pesticides, ozone harmful substances);
- *regulating methods:* soil cultivation (kinds of crops and kinds of cultivation to be used on hills with different angle tilt); transportation and storage of ecologically dangerous substances; use and transportation of biological species and biologically toxic substances;
- *suppressive methods* include economic sanctions, fines, increased prices, and taxes.

The *positive change* approach is associated with incentives to stimulate changes if they help reduce destructive pressure on the environment. Such an approach is based on positive feedback mechanisms and uses different favourable terms, materials, and moral incentives for innovations (Figure 6).

The principal goal of this approach is to provide constant re-production of four essential components of the social-economic system: (1) demand, (2) supply, (3) people, and (4) motifs of human activities.

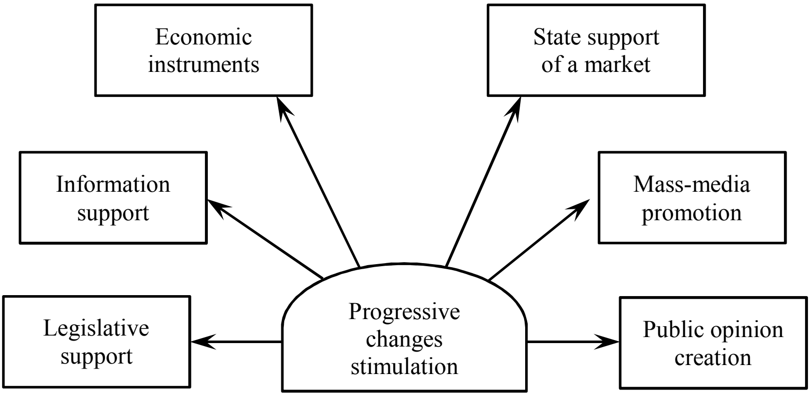

Figure 6: Forms of positive changes methods

The economic mechanism is the basis for sustainable development in countries with a market economy. The economic mechanism includes complex economic structures, institutions, forms, and management methods, with the help of current laws that follow social and private interests. The essential components of such a mechanism are 1) legislative basis of economic activity (rights, duties, licenses, restrictions, procedures); 2) property rights; 3) formal institutions; 4) informal institutions (traditions, morals, religion, spiritual values); 5) economic instruments.

Conditionally, economic instruments can be subdivided into three interdependent and interconnected groups: prices of resources, economic benefits/costs, and transfer payments.

Depending on implementation, systems of ecological and economic instruments can be divided into four primary groups:

1) *Administrative redistribution of funds* (primarily fines and subsidies). This group of economic instruments is a system of well-defined and well-addressed cash flows (for instance, from a guilty party to victims), which is used in cases of environmental emergencies when the consequences of environmental impact are not conventional and specific evaluation is needed.

2) *Financial transfers* are a well-regulated and controlled system of redistributive mechanisms (taxes, payments, credits).

3) *Free market mechanisms of funds redistribution.* An excellent example of this instrument would be the so-called tradable emission permits that have become widely spread in some USA states.

4) *Promotion in the market.* This instrument is related to using non-monetary forms of economic promotion (e.g., rewarding with special incentives, free-of-charge advertising), which gives an additional competitive advantage.

Various countries use different ecological and economic instruments. However, taxes, subsidies, grants, bonuses, payments, fines, promotions, price control, insurance, and amortisation instruments are the most popular.

5. Reproduction mechanism of sustainable oriented transformation of the economy

Success in the sustainable management of human civilisation development depends on effectively transforming economic systems towards permanent perfection and decreasing the natural intensity of conditional production needed for human life support. From now on, this process of economic transformation for sustainable development will be called *ecologization ("greening").* This process is an integral system that stipulates the permanent reproduction of fundamental production factors, including material basis, hardware and people, and managerial methods.

The transition of post-Soviet countries to market economies necessitates treating the decolonisation issue of public production and analysing all complications and communications of the complete production cycle and public consumption in a new way. In market systems, people's needs are the primary incentive for social development in general and production in particular. In the "supply-demand" framework, a demand side determines a long supply chain.

In an industrial, technological society that has reached a climax, the productive sphere is the main point in public life. This sector determines current political, economic, and social processes. Human beings work with this in mind, frequently forgetting that the economy is only a means. Frequently, motivation for economic activity is based on something other than physiological needs or social interests. Very often, this damages human health, spiritual development and personal happiness. Transformation of the countries of the former socialist block looks at the problem of "greening" of social production differently. They analyse the complexity and variety of the relationships through the production cycle and public consumption. In market systems, people's needs are the main driving force of social development and production. The "structure" in the so-called "demand-consumption market structure" is a powerful engine that propels the long chain of decisions.

The "greening" of the national economy implies a targeted process of economic transformation aimed at reducing the integral ecological impact of the production and consumption processes of goods and services on the environment. "Greening" is realised through a system of organised measures, innovations, restructuring of sectors of production and consumption, technological conversion, rationalisation of the use of nature, and transformation of environmental protection activities at both – macro- and micro-levels.

Greening of Industry and Commerce might be considered as a function of a system which continuously reproduces the interaction of the system's elements (figure 7):

(1) the reproduction of green needs;
(2) the reproduction of green technological basis;
(3) the reproduction of green labour factors;

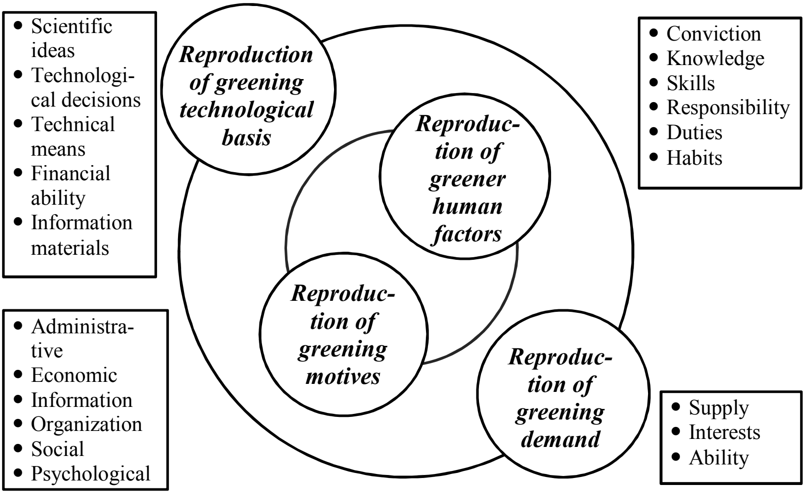

Figure 7: Mechanism of reproduction of greening economy

(4) the reproduction of motives for "greening" production and trade.

"Greening" of demand. Reproduction of sustainable ("green") demand is defined as the permanent process of shaping the needs for sustainable goods and forming financial possibilities for realising identified needs. Sustainable goods are products and services that contribute to the mitigation of integral ecological impact per unit of aggregate public product.

Furthermore, when discussing the reproduction of ecological needs, we must formulate the required economic conditions for the "greening" of the national economy.

Firstly, reducing the material-energy flows of consumed goods must not lead to a lower quality of service from the standpoint of a person's vital needs. Otherwise, an unpredictable supply of goods and services to patch up the "breaches" in consumption standards can occur. Production of these goods can lead to minimum ecological success.

Secondly, the refusal to use ecologically non-friendly products must be compensated by an increase in the use of more environmentally friendly goods. It is necessary to meet the condition that the total volume of goods and services sold (in monetary terms), as well as their production, must remain the same. It is very important because production is only one side of human activity in modern world. Even a small decrease in numerous inter-connections can lead to considerable socioeconomic consequences, including a decline in living conditions and an increase in unemployment. In addition, a decrease in national income can weaken the technical-scientific potential, reduce the budget of different sectors, and worsen ecological problems. So, the demand for the reproduction of sustainable commodities is the leading link to "greening" the economy.

Finally, demand for sustainable goods must result from three interconnected economic elements: needs, elements, and possibilities. *Needs* are motives for the consumption of goods that have been realised by people and communities. *Needs* are transformed into *interests. Demand* is undermined by financial capability, and the ability to pay for goods and services.

It is possible to identify four stages of the development of sustainable needs.

1. The first stage is associated with the means of controlling environmental destruction ("the end of the pipe").
2. The second stage is related to the environmental improvement of technology ("wasteless technology").
3. The third stage is associated with substitution of undesirable goods and service by "greener" ones ("more efficient goods").
4. The fourth stage is associated with the production and consumption of goods for sustainable development ("sustainable lifestyle").

Evolution of greening cycles of production and consumption of various products can be divided in two possible stages of development.

(1) Greening of individual components of the production-consumption cycle: production, packaging, communication, storage, trade, consumption, waste disposal.

(2) The transition of economic systems from producing individual (separate) material benefits and services to forming life-prosperity.

The "life-beneficent complex" is regarded as a destiny for human life and as an aggregate system of material objects, cultural values, information, and natural ecosystems that ensure prosperity and people's physical and spiritual development.

"Greening" of supply. Reproduction of sustainable production is considered as the generation of scientific ideas and information and the formation of technical means needed to develop the green output. Social, economic, and technological causes for "greening" should and can be formulated. Social causes emerge when social interests, cultural values, and private interests of people facilitate the development of ecological needs. Economic causes are set in motion when economic conditions and organisational mechanisms make the supply of "green" goods and services profitable. Technological causes arise when sufficient technical means exist to realise ecological needs in production.

"Greening" people and motivational instruments. Forming *sustainably oriented people* is considered a continuous training, education, and experience process that provides the required information, knowledge, skills, and desire for "green" production and consumption.

"Greening" of production includes the following:

- Selection of employees with certain qualities.
- Personnel education and training.
- Ecological training and retraining.
- Development of legal standards.
- Activity regulation.
- Development of a system of rewards and penalties.

- Information.
- Control.

Motivational instruments for "greening" imply permanent facilitation of organisational, social, and economic conditions, which promote the desire to achieve the economy's "greening" goals. Motivational instruments involve a system of administrative, ecological, and social-physiological factors. The following are some motivational instruments in well-developed countries.

The policy and strategy of "greening". Specification of "greening" allows us to formulate local objectives for the transformation of the national economy as follows:

- Restructuring of the economy.
- Restructuring of enterprises.
- Remove the need for non-environmentally friendly products or services.
- Change of ecologically non-friendly technological processes.
- Lowering of the resource capacity of the products.

The principles that must be used in the process of "greening" the economy include:

- Integral approach – it stipulates the necessity to take into account all effects within the cycle of production and consumption of goods.
- Orientation according to the causes – it addresses the causes, not the consequences.
- Division of responsibility – it identifies the impact and the degree of eco-destructive activity.
- Formulation of motivational instruments under given conditions.
- The systems approach identifies direct and indirect influences on all objects and subjects "greening" the economy.

- Maximum efficiency – it stipulates achievement of the goals of “greening” with minimum expenses and maximum return.

Considering the principles mentioned above and analysing criteria for the eco-destructive influence of the production-consumption cycle allow the formulation of the main directions for the “greening” of the national economy (Figure 8).

• throughput economy	→ • ecologically managed material flows
• wasting material	→ • material productivity
• wasting energy	→ • energy efficiency
• towards orientation products	→ • orientation towards function
• reactive environmental protection	→ • preventive environment protection
• (over-) exploitation of natural resource	→ • sustainable use of natural stock
• control of natural processes	→ • orientation towards natural processes
• throw-away mentality	→ • mentality of esteem

Figure 8: Conceptual directions of the development of environmental tasks (Oosterhuis et al., 1996)

One can foresee the following main stages of the evolution of ecological needs. The first stage is associated with developing means of protecting the environment from destruction processes (pollution). In the second stage, priorities will be given to substituting ecologically non-friendly goods and services for environmentally friendly ones. There are three main strategies for “greening” the economy.

- Influence on supply, “pull strategy,” the “production-consumption train.” One can pull the links of “greening” production by influencing supply. The essence of this strategy lies in convincing a consumer psychologically and economically to use ecologically friendly products.
- Influence on demand is called a “push strategy.” The essence of this strategy is to create a system of motivational

influence (ecological standards, economic instruments, information supply) that will push the producer to manufacture "green" products.

- Influence on the communication between producers and consumers is called "interface strategy" (as in Figure 9).

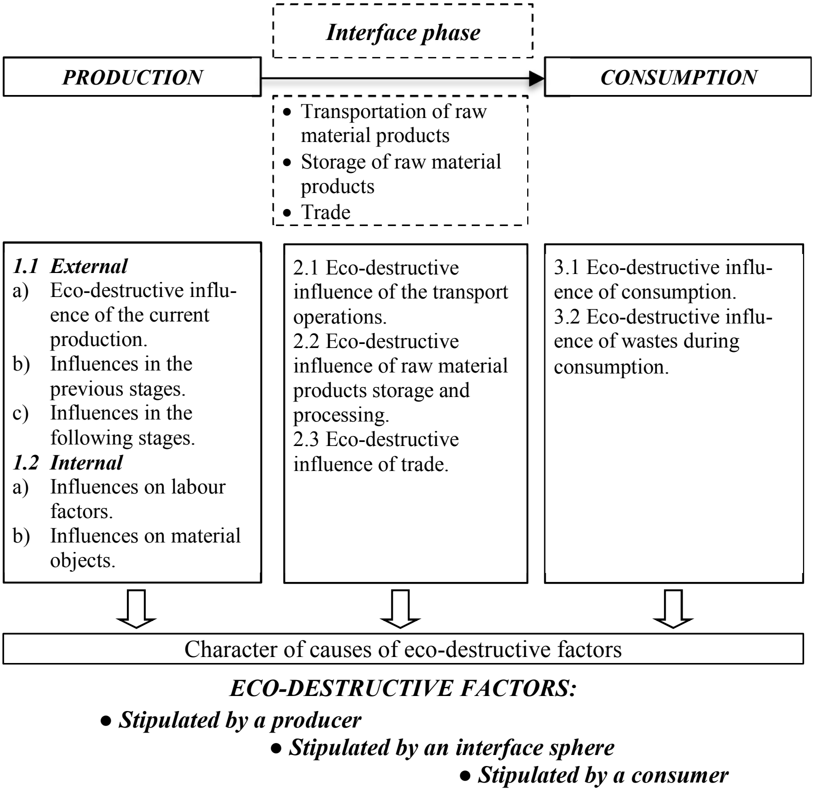

Figure 9: Formation of the eco-destructive factors in the main phases of the production-consumption cycle

In "greening" the economy, the intermediate links are between producers and consumers. The following are the ways of realising this strategy: influential communication, mechanism for “green” trade and marketing research, and development of information systems. This strategy has allowed some countries to solve significant environmental problems. The embargo on exchanging rare animals and goods saved wildlife in several African countries. Japan managed to clean its streets and towns by introducing strict non-tariff barriers (ecological standards) on imported transport. Ukraine also lists toxic and dangerous wastes, including import and transit, as forbidden. Any country that uses these three strategies has a good chance of real success in “greening its economy”. Although many economic categories have been mentioned, the primary content of different sides of the production-consumption cycle is a common factor for all these categories. Man is considered to be within this factor. Speaking about the “greening” of supply, demand, trade, and communication means the “greening” of the relations between people. The “greening” of production and consumption can only be realised through people, labour, skills, and desires.

6. Natural and societal underpinnings of sustainability

Sustainability denotes a state of organisation (or reorganisation) of ecological, economic, and social resources that is attained and consistently upheld through feedback mechanisms. In this state, the system can ensure the dynamic equilibrium of its metabolic processes across time and space (Hens et al., 2007).

The sustainability concept essentially encompasses perpetuating a sustainable (dynamically balanced) state within a trifold systemic entirety comprising three fundamental constituents: humankind (as a biological entity), nature, and society.

This task is of unparalleled complexity. It revolves around attaining a state of homeostasis characterised by balanced conditions (i.e., relatively narrow ranges of mutable parameters) across three intricately interconnected systems:

- The human body (extending to billions of individuals populating the Earth).
- The biosphere (embracing trillions of organisms constituting the planet's ecosystems).
- The economy (encompassing hundreds of millions of economic entities that underpin global economic frameworks).

The dynamic nature of this triadic system further compounds the task's boundless intricacy. Each state necessitates perpetual recreation across all points in space and time.

For the tripartite systemic whole – comprising "human (as the human population) – biosphere – economy" – to preserve its cohesion and stability, the stability of each constituent system must be upheld (more precisely, self-sustained). The biological essence of humans significantly constrains the environmental conditions within which they can sustainably exist while preserving their homeostasis levels. Any deviation beyond permissible thresholds in environmental factors such as temperature, pressure, solar radiation, and myriad others crucial to human life and activities would be fatal. Simultaneously, to uphold the prevailing conducive conditions on Earth – still suitable for human habitation – the biosphere, in turn, must safeguard its self-replicating potential, homeostasis parameters, ecosystem composition, and qualitative attributes of the processes they host (Fig. 10).

The biosphere is pivotal in providing the necessary conditions for human biological existence and individual (social) identity progression. It concurrently serves as the physical basis environment for socio-economic system operations, functioning as both a resource repository and a venue for waste disposal (Wilderer et al, 2022). In return, the socioeconomic system fulfils many modern human material and informational requirements. This is particularly true given contemporary humans' existence within an industrialised societal milieu.

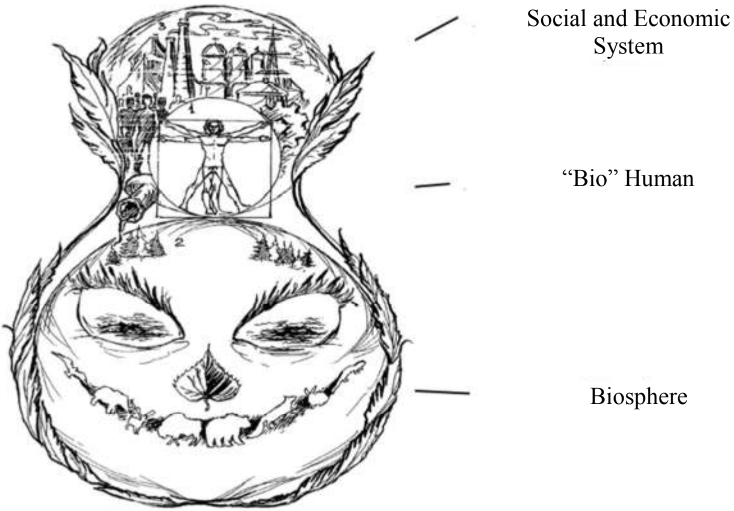

Figure 10: Conventional scheme of relationships between the processes of maintenance of three critical systems: human biological nature, biosphere, socio-economic system

The biosphere and its constituent ecosystems possess a finite "carrying capacity", capable of sustaining a specific planetary population size without jeopardising their well-being. This capacity is determined by the ecological load introduced by the production systems responsible for nourishing and facilitating living conditions for the given number of individuals inhabiting the planet (Costanza et al., 2017; Daly, 2007; Plummer et al., 2020).

In the absence of changes in the technological dimension of production and unaltered levels of specific ecological load attributed to servicing a single planetary inhabitant (measured through indicators such as nature intensity, material intensity, energy intensity, "ecological footprint", etc.), and population growth unavoidably strains the natural systems of Earth. Once the anthropogenic load surpasses a critical threshold, ecosystems, unable to endure such stress and lacking sufficient time for self-renewal, begin to deteriorate (Folke et al., 2021; Wilderer, 2022). This phenomenon is observably unfolding on both local and global scales.

Hence, if the intention is to uphold the biosphere's carrying capacity and maintain the ecosystems' self-renewing foundation, two principal strategies must be pursued (Costanza et al., 2017; Martínez-Fernández et al., 2021; Victor, 2010):

1) Halt the expansion of the global population and maintain its stability within the bounds that the biosphere can viably support with essential resources.

2) Or acquire the capability to qualitatively reshape the production complex (alongside the population's needs) so that the specific environmental load (per individual) impacting the planet's nature diminishes, ideally at a rate equal to or even exceeding the pace of Earth's population growth.

However, the physical equilibrium of the aforementioned system (human – biosphere – economy) solely constitutes a prerequisite for what was denominated as sustainable development during the 1992 Rio Summit. This development encompasses more than human civilisation's physical endurance; it also encompasses its unceasing societal advancement (Sineviciene et al., 2021; Thanh Son, 2021; Williams et al., 2017).

Paradoxically, humanity disrupts the existing biospheric homeostasis, driven by two factors: the expansion of the global population and a qualitative transformation in human needs. As scientific progress unfolds, novel forms of environmental impact emerge. Concurrently, as individuals reshape their lives, they also transform nature (Stegeman et al., 2020; Voulvoulis et al., 2022).

Projections from various sources indicate that the Earth's population may stabilise by 2050, a process referred to as demographic transition.

Acknowledging the industrial complex's undeniable harmful influence on nature necessitates acknowledging this phenomenon's significant catalysing role in human progress. Imagining a scenario where humanity coexists harmoniously with nature, devoid of ecological crises and corresponding challenges for resolution, implies the cessation of human evolution and a transformation of societal development history into the annals of the human population's biological existence.

Therefore, notwithstanding its ecologically adverse repercussions, population growth is a pivotal propellant of societal advancement. In an era of population stabilisation, novel incentives must be devised to propel progressive social development.

To reiterate, within a context where human-environment interactions have achieved global proportions, only two viable paths remain to secure nature's stability, thus ensuring humanity's stability. The first avenue entails restraining population growth. The second demand is mastering the transformation of social production and consumption processes, minimising their detrimental environmental impact. This endeavour mandates substantially reduced human life support systems resource use intensity (material, energy). Moreover, this reduction rate must outpace or at least correspond with the rate of population growth (Iacovidou et al., 2021; Stegeman et al., 2020; Weizsäcker et al., 2001).

Considering the causal relationships at play (Mishenin et al., 2017), three distinct levels of goals can be discerned: the overarching goal is to preserve humanity as a biological species and to ensure the progressive advancement of individual lives; guaranteeing goals encompass maintaining vital to human existence and development parameters; and supporting goals involve safeguarding the biosphere and localised ecosystems that underpin the prerequisites for human survival.

It is imperative to reiterate that the overarching goal encompasses two distinct levels of measurement:

1) the necessary level involves humanity's physical survival;

2) the sufficient level pertains to the personal development of individuals within a society.

Both levels hold paramount significance, even though this might take time to be apparent.

The guaranteeing goals, arising from the considerations above, manifest at two levels of reference:

1) safeguarding the biosphere parameters within relatively narrow limits that allow for the sustenance of the biological nature of humans (climate characteristics, electromagnetic attributes, cosmic radiation, atmospheric and water quality, and soil composition conducive to agricultural production);

2) upholding intact natural landscapes that foster essential information exchanges vital for the reproduction of the personal attributes of a social individual.

Supporting goals involve creating and maintaining conditions that facilitate the existence of the biosphere and its constituent ecosystems. These ecosystems underpin the vital characteristics of human life both as biological entities and individuals.

Accomplishing these goals constitutes a significant responsibility for humanity. It can be realised through practices like preserving distinct natural landscapes through the establishment of nature reserves, minimising anthropogenic impacts on ecosystems via the creation of reserves and natural parks, and constraining human interventions in nature through the development and adherence to environmental standards (Davilaet al., 2021), as well as the regulation of living and working environments.

However, this only addresses one facet of the challenge. Another crucial aspect involves the reconfiguration of humanity's technological foundation. Technological systems must be enhanced to reduce their relative eco-destructiveness (measured by the ecological consequences per individual on the planet) as the global population expands. Moreover, this environmentally driven transformation of production must be perpetually replicated. In essence, the augmentation of socio-economic system functionality (particularly eco-efficiency) should be perpetually duplicated (Daly, 2007; Martínez-Fernández et al., 2021; Spash, 2020).

7. Systemic basics of natural and social objects functioning

The phenomenon of development is intrinsically intertwined with the notion of a system. This is true for the sustainable development concept (Smith, 2011; Voulvoulis et al., 2022; Williams et al., 2017).

A system is any component (subsystem) unified into an integrated entity through interactive processes, encompassing material and informational exchanges, with the shared purpose of realising a collective function (attaining a common objective).

Not all systems possess the propensity for development; solely those endowed with self-organisation can evolve. These systems exhibit the capacity to regulate their activities, thus furnishing the internal parameters essential for interaction with the external milieu and within the system's constituents.

In a reciprocal manner, for a system to manifest self-organization, it must embody two requisite attributes: first, it must be open, and second, it must be stationary.

The openness of a system is inherently necessitated by the fundamental requirement for the system to acquire energy from its external surroundings. Self-organisation processes within the system, encompassing control over external environmental parameters, movement, and internal state alterations, invariably demand energy expenditure. The system can solely replenish the energy it expends (akin to the mechanisms observed in biological organisms) by engaging with the external environment. This entails an openness that facilitates the exchange of matter, energy, and information between the system and its external surroundings. The system takes essential material and informational resources from its environment while concurrently expelling waste products from its vital operations.

Openness, however, is only a preliminary condition essential for sustaining the system's vitality. An adequate condition demands effective substance, energy, and information exchanges between the system and its external environment and among distinct components of the system itself. External exchanges contribute to the system's nourishment by importing energy and substances from the environment and exporting waste products produced during its life processes. Concurrently, internal exchanges oversee the processing of material and informational flows. Extracted energy and the transformation of acquired substances and energy are employed to refurbish and develop the system. These interactive processes collectively constitute metabolism, a term signifying change or transformation.

Stationarity represents another pivotal attribute of self-organising systems. It epitomises the capability of sustaining the system's condition within a relatively narrow and stable range of its parameters, commonly called homeostasis. Homeostasis embodies the stable distinction in physical and chemical potentials – spanning altitudes, pressures, temperatures, electromagnetic attributes, chemical characteristics, and more – between the system and its external milieu and among distinct segments of the system itself. This differential state facilitates material and information flow, sustaining the system's metabolic exchanges.

Hence, stationarity can also be understood as the system's capacity to uphold homeostasis. The concept of stationarity plays a pivotal role by sustaining the system within the parameters of homeostasis, which optimises the system's operational efficiency and fosters energy accumulation to drive its development.

The Triad of Natural Principles of a System: The creation of any system is grounded upon three inherent natural principles:

- Material and Energy Principle: This principle encompasses material substances and energy that empower the system and its constituent subsystems to move, transform, and perform tasks, enabling change and development.
- Informative Principle: Operating as a guiding force, this principle imparts directionality to movement across space and time. It shapes the information pathways governing interactions between system components and establishes the overarching program for the system's holistic development.
- Synergetic Principle: This principle harmonises the system's parts, consolidating them into a cohesive whole and serving as a unifying force.

The interaction of these principles is essential for their manifestation. For instance, the purposeful utilisation of energy necessitates the directional influence of the informative principle; otherwise, energy merely contributes to random motion, akin to “Brownian motion”. Conversely, only material entities possessing energy potential can be directed and unified.

Isolated implementation of the material, energy, and information principles is implausible without the synergistic principle. The coordinated interaction among the system's components is imperative for any internal or external work to transpire.

These natural principles, coalescing in synergistic collaboration, have engendered and perpetuated various systems – entities prevalent in nature: elementary particles, atoms, molecules, cells, organisms, and societal structures like families, businesses, and nations. The universe, Earth's nature, and human civilisation emerge from this foundational interplay.

Each such entity's existence hinges on the perpetual replication of these three principles within itself: material-energy, informational, and synergistic. This replicative phenomenon guarantees the ongoing recurrence of each entity's characteristic attributes over time (Fig. 11).

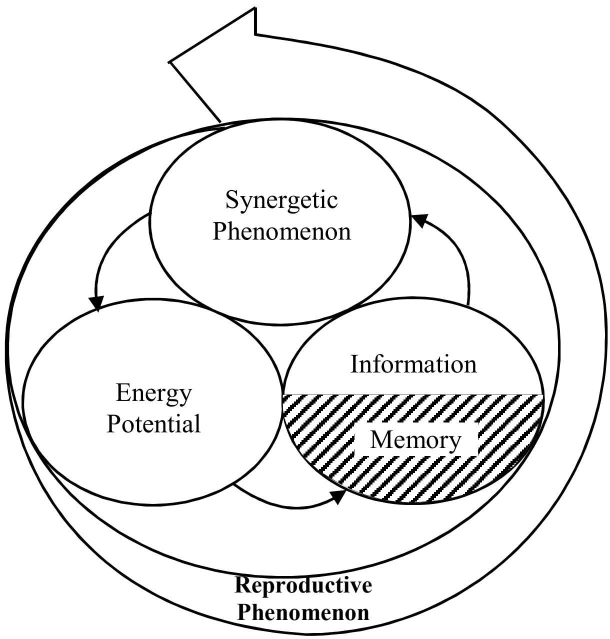

Figure 11: Essential foundations of the system emergence and development

The fabric of the systems surrounding us is inherently triadic. It simultaneously embodies a material essence, an informational program, and the product of synchronised interactions among other systems (subsystems) within nature.

A system embodies a threefold nature, seamlessly integrating material, informational, and synergetic facets.

Material Role: The system operates as a material entity, proficient in accumulating and expending energy through its work performance.

Informational Character: As an information program, it self-organizes, perceives, and processes information from the external milieu, perpetuates its information, and orchestrates the mechanisms governing its establishment, functioning, and advancement.

Synergetic Phenomenon: Functioning as a synergetic phenomenon, the system merges through interactions, fostering mutual adaptation and alignment. This entails adjusting the parameters of its subsystems to fulfil system-wide functions and guiding its conduct in interaction with similar systems on a system level.

It's impossible to privilege one principle – material, information, or synergetic – over the others, as they are inherently interconnected. In their absence, the system would falter: without material, there would be nothing to construct the system from; without information, systems would remain amorphous, engulfed in formless chaos; without synergy, individual parts wouldn't merge into a unified whole.

These principles, integral to each other, underpin systems' formation and dissolution. The process can be illuminated through various system types, such as ecosystems. In the realm of ecosystems, the interplay of these principles can be illustrated as follows:

Actions towards enhancing ecosystem well-being encompass:

- Material and Quantitative Enrichment: Augmenting the presence of plants and animals within the ecosystem.

- Informational Enhancement: Elevating the qualitative status of the ecosystem by optimising the species composition and improving the state of biological species.
- Synergetic Refinement: Enhancing interactions among system elements, mainly through improved communication channels.
- Integral Self-Organization Enhancement: Strengthening the ecosystem's intrinsic mechanism of self-organisation.

In contrast, actions contrary to these directions can lead to ecosystem degradation and eventual collapse:

1. Destruction of Flora and Fauna: Eliminating plants and animals.
2. Decline in Biological Species: Eroding the qualitative condition of biological species disrupts the ecosystem's species composition equilibrium.
3. Disruption of Communications: Blocking species and interspecies communication channels.
4. Impairment of Self-Reproduction Mechanism: Hampering the ecosystem's self-reproduction mechanism.

In this intricate interplay, systems' triune nature—material, informational, and synergistic—dictates their behaviour, development, and sustainability.

8. Contours of a sustainable economy

A sustainable (green) economy is an economic system that enables sustainability goals. Its conceptual foundations are based on three hypotheses (Commoner, 1974; Daly, 2007):

- the infinite expansion of the impact in a limited space is impossible;
- the satisfaction of endlessly growing human material needs within limited resources is impossible;
- everything on the Earth is interconnected.

Existing natural realities (resource limits) ultimately restrict the development of productive forces and human civilisation's material and energy metabolism (Wackernagel et al., 2023). In this context, the main pillars of a sustainable economy become clear (Fig. 12). The Third and Fourth Industrial Revolutions are called to facilitate it (Melnyk et al., 2019).

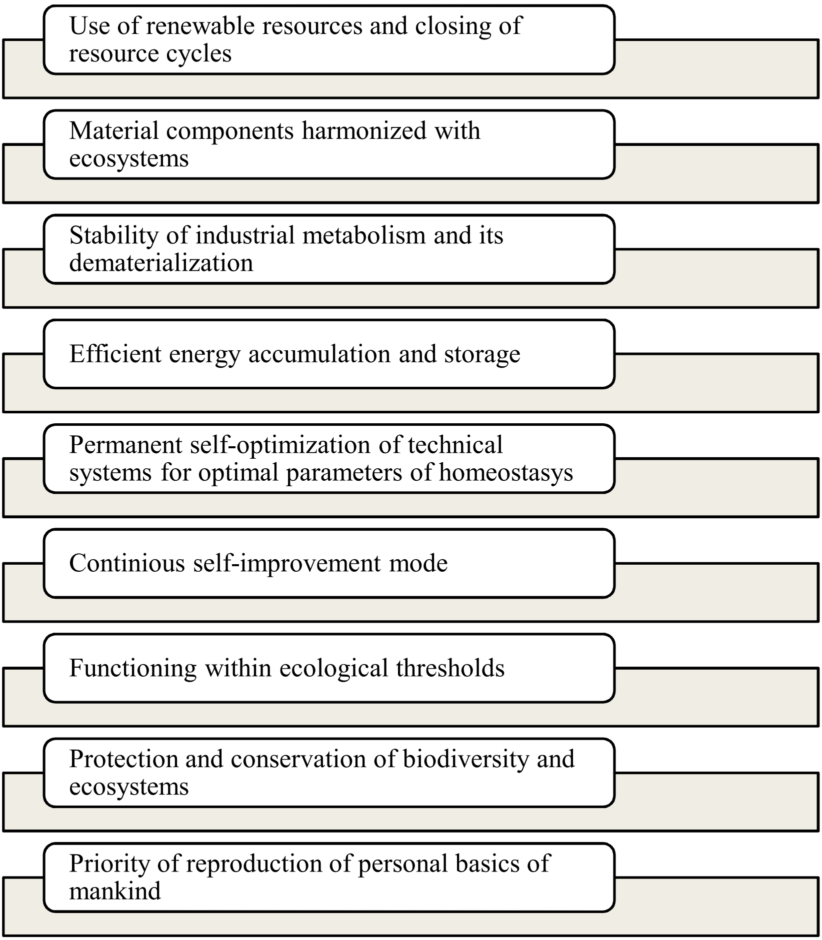

Figure 12: Contours of the sustainable (green) economy

Examining the attributes characterising traditional and sustainable economies facilitates a more comprehensive vision of the latter's distinct essence (Table 1). In numerous aspects, the attributes delineating the sustainable economy mirror the outlines of the previously mentioned "spacemen economy".

Table 1. Comparative analysis of traditional and sustainable economies

Characteristics	Traditional Economic System	Sustainable Economy
The main type of resources and sources of energy	Non-renewable	Renewable
The main basis of development	Strengthening material and energy factors	Improvement of informational and synergistic (communication) factors
The main task of production	Replication of products and services	Generation of design and technological ideas and innovations
Targeted environmental and economic policy	Economic goals with environmental limitations	Environmental goals with economic limitations
Type of nature use	Consumption of components of the natural environment	Use of functions of integrated natural resource potential
Type of natural transformation	Transformation of natural substances; application of man-made processes	Use of natural substances, processes and reproductive cycles
The type of settlement area formation	Industrial-centric: in the center – an industrial object, housing – on the periphery	Nature-centric: in the center of the housing – a natural object (forest, lake, park), the industrial environment is on the periphery
Prior type of consumption	Material goods to ensure the biological nature of a person	Informational goods to develop the personal nature of humans
The degree of needs unification	Convergence (unification) of needs	Divergence (increasing the degree of diversity) of needs

It is pertinent to reference the principles delineated by Daly H. E. (2007) that underpin the fundamental tenets of the sustainable economy:

- Rates of consumption of non-renewable natural resources must not surpass the rates at which renewable ones replenish these resources;
- Rates of utilisation of renewable natural resources should remain below the rates of their replenishment by natural systems;
- The bounds of disturbance and pollution inflicted upon natural systems should not exceed the assimilation and regenerative capacities (carrying capacity).

The cardinal attributes of the sustainable economy are meticulously tailored to propel it toward an elevated echelon of ecological and economic efficacy. This transition aims to facilitate its functioning with minimal impact on natural systems.

9. Key pathways for advancing sustainable economy

It is conceivable to articulate the essential attributes of a sustainable economy. These attributes concurrently guide the trajectory along which the economy must advance in its pursuit of sustainability. The principal qualities encompass:

- Resource Renewability: Nurturing renewable resources to serve as the foundational cornerstone of a sustainable economic model;
- Dematerialisation: Dramatic curtailment of both resource consumption (material and energy) and environmental impact;
- Transformability: Continual progression through evolutionary transformations to enhance system functionality;

- Innovativeness: Predisposition to swift integration of progressive innovations;
- Naturalisation: Aligning the composition of materials used, energy sources, and technologies with those inherent;
- Personal Orientation: Shifting focus from economic objectives to prioritising the social (personal) advancement of individuals;
- Information Orientation: Emphasizing the production and consumption digitisation;
- Ethnoization and Humanization of the Economy: Adherence to ethical foundations fostering sustainable justice;
- Synergization: Coalescing individual economic entities into integrated systems, engendering networks of local, regional, continental, or global scale;
- Decentralisation: Amplifying autonomy for individual economic actors, grounded in the idea: "the centre is everywhere, the periphery is nowhere";
- Self-organisation: Elevating the system's self-organisation, guided by the tenet: "Think globally – act locally".

Interplaying with one another, these attributes forge a multifaceted functionality of the socio-economic system, poised for the transition towards sustainable development. Simultaneously, each attribute is an objective propelling a specific course and facilitating other attributes (directions). For instance, the dematerialisation of social production necessitates the synergy of resource renewability, continuous economic transformation, innovative rejuvenation, naturalisation, and the replication of other attributes, including personal orientation. Likewise, dematerialisation (which fundamentally diminishes costs and endorses environmental consciousness in need satisfaction processes) constitutes a pivotal mechanism of personally oriented (human-centric) development.

System progress entails the augmentation of self-organisation. This process of system organisation is channelled along four primary trajectories: material-energy, informational, synergetic, and integral – the first three result from specific factors governing system formation. The fourth dimension encompasses the comprehensive process of replication of all three groups of factors. It is a phenomenon driven by the pervasive effect of the reproductive mechanism inherent in system formation. The reproductive phenomenon manifests itself in every natural system entity. It embodies the capability of reproducing the triad of specified natural principles – a phenomenon that reveals the system's capacity for self-organisation.

Cognizant of the dialectic nature of the system formation mechanism, it is feasible to delineate four pivotal directions for system sustainability:

1) Transformation of the material and energy component;

2) Enhancement of the information algorithm (program) governing economic system formation;

3) Refinement of the synergetic component (intercommunications, relationships, infrastructure);

4) Elevation of the level of self-organisation within economic systems.

An integral facet of the sustainable economy's realisation encompasses fostering sustainable demand – an appeal for goods (products and services) that facilitate attaining sustainable development goals. This pertains to information goods catalysing individual growth (educational and healthcare services, cultural and artistic products, tourism, scientific pursuits, etc.). Their share within the consumer demand structure must experience continuous augmentation. This augments the reduction of ecological burdens on the natural environment, for in these sectors, the information – as the primary resource – often significantly outweighs the material and energy contribution in producing goods.

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Industries 3.0, 4.0, 5.0 as the Basics for Sustainable Development

Presentation materials

Lecture plan

1. The direction vector of the modern phase transition
2. Key features of Industry 3.0
3. Energy component of Industry 3.0
4. Material component of Industry 3.0
5. Industry 4.0
6. Formation of a phase transition
7. Industry 5.0

1. The direction vector of the modern phase transition

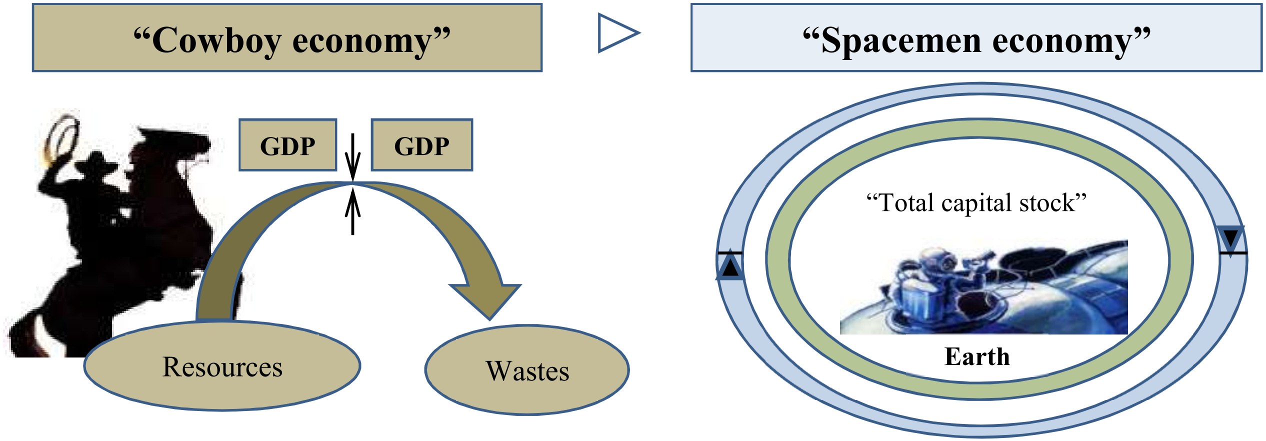
V. I. Vernadskyi

The **noosphere** will rule
the plane

Examples of modern spheres of mind

- Internet
- Mobile Communication
- Social networks
- InterTV
- Internet of Things
- Blockchain
- GPS
- EnerNet
- “Cloud”

From the “cowboy economy” to the “spacemen economy”



- Non-renewable resources.
- Broken cycles.
- Increased material metabolism

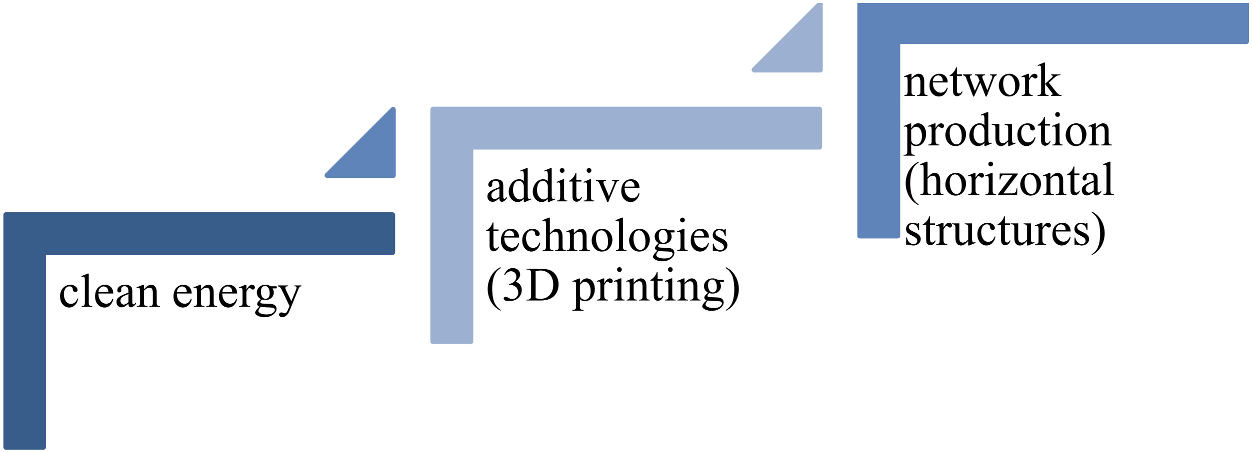
- Renewable resources.
- Closed cycles.
- Constant material metabolism

Directions of modern industrial revolutions

- **Industry 3.0** – Transition to a “green” economy
- **Industry 4.0** – Transition to cyberphysical systems
- **Industry 5.0** – Transition to personal development of mankind

2. Key features of Industry 3.0

The third industrial revolution is the transition to a “green” economy



Key features of the III Industrial Revolution

III Industrial Revolution – the transition to a "green" economy:

- clean energy;
- additive technologies (3D-printing);
- network production (horizontal structures).

Two key tasks of the “green” economy

- **Transition to “green” energy**

  Reducing the energy intensity of the economy –

  at times (!)

- **Transition to “green” technologies and new materials science**

  Reduction of material consumption and nature –

  at times (!)

3. Energy component of Industry 3.0

Roof panels (Germany)

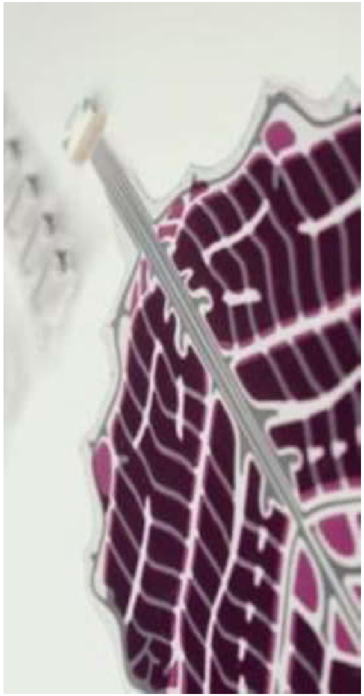
SES on the roof (Ukraine)

Industrial SES on the roof of a multi-storey building in Kyiv (capacity 330 kW)

Mobile shop for installing solar panels

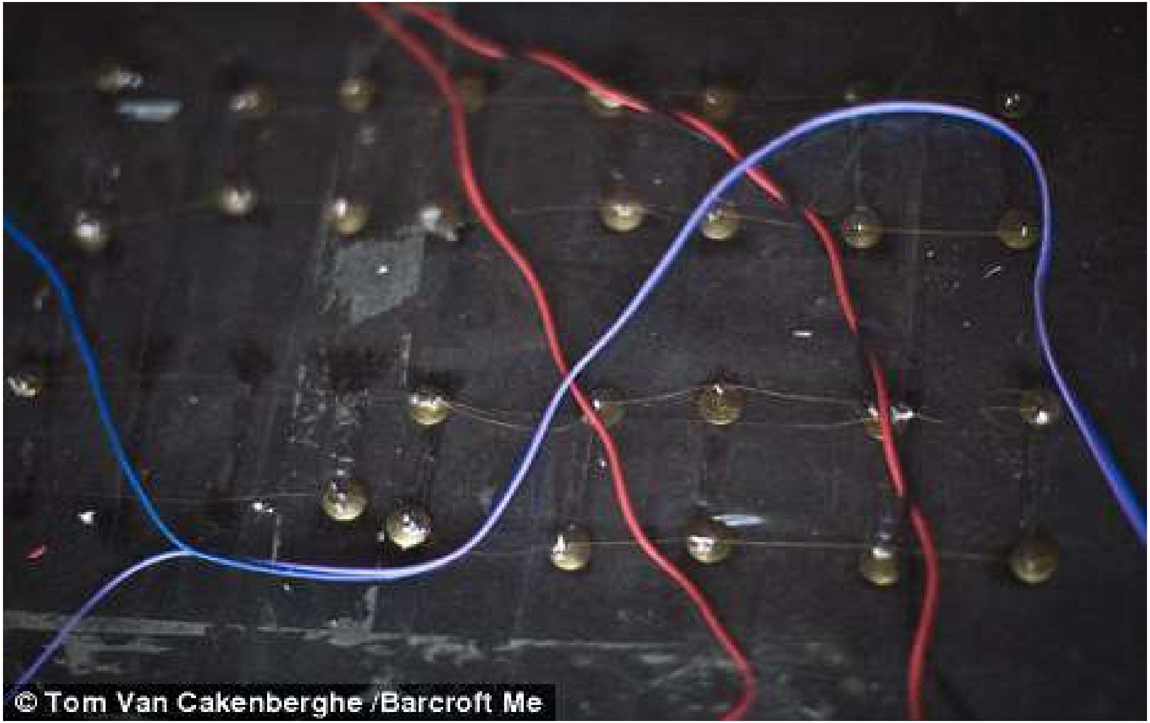
SES window (Germany)

Energy Tree – 3D Printing (Finland)



Flexible solar panel

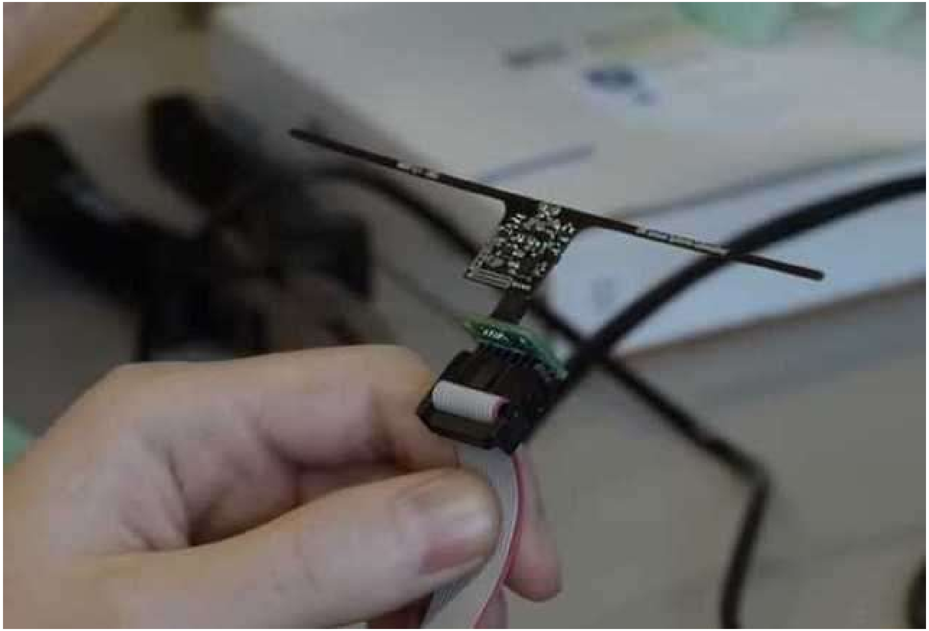
Solar panel with human hair



SALt lamp that runs on a glass of water and two tablespoons of salt

SALt – **S**ustainable **A**lternative **L**ighting

WISP technology: energy straight out from air (electromagnetic waves)

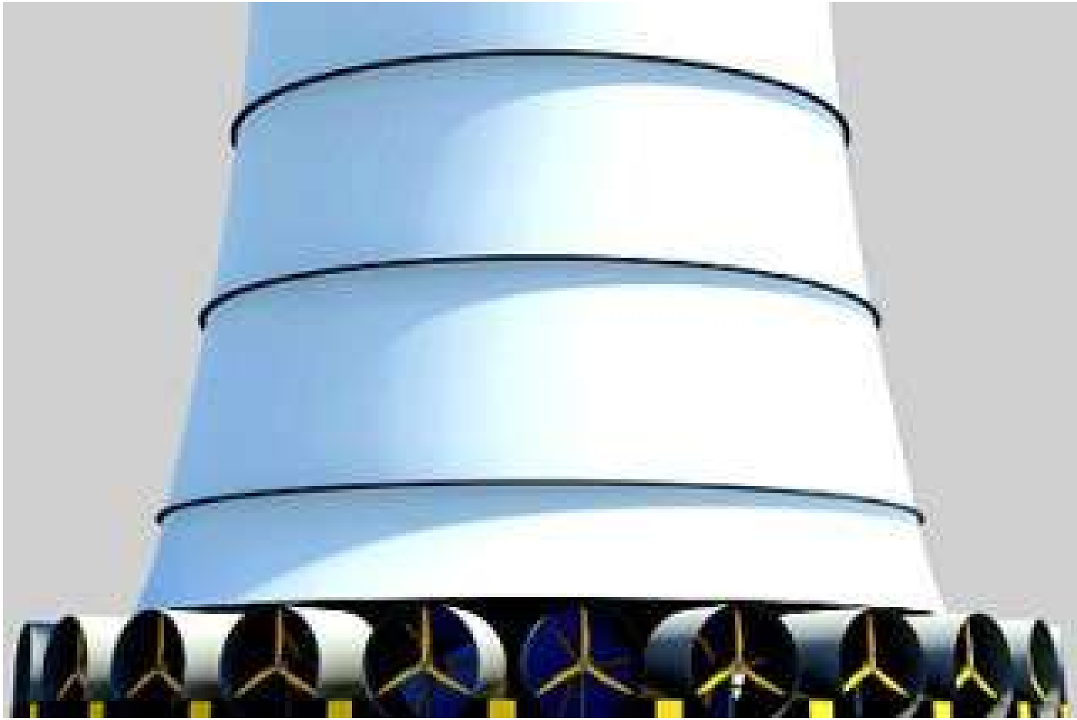


WISP – **W**ireless **I**nternet **S**ervice **P**rovider

Windmill tree (France)

Flying wind turbine

Wind farm operating at full calm



Silent wind generator (Ukraine), up to 30 kW

Shoes-power plant

Dynamics of “green” energy production in the world

Index	Years	
	2010	**2020**
World production of solar (PV) energy, GW	23	627
Multiplicity of growth, times	-	27
The share of renewable energy (including hydro), %	5	30
Specific cost of solar energy (PV), USD / kWh	0,37	0,06

Dynamics of “green” energy production in Ukraine

Index	Years	
	2010	**2020**
Share of renewable energy (including hydro), %	6	16
Share of renewable energy (without hydro), %	1	9
The number of private SPPs	1	40 000
Capacity of private SPPs, MW	0,02	1 000
Number of electric cars	1	30 000

The main directions of energy accumulation

- Hydro-.
- Electro-.
- Hydrogen technologies.
- Thermal.
- Chemical.

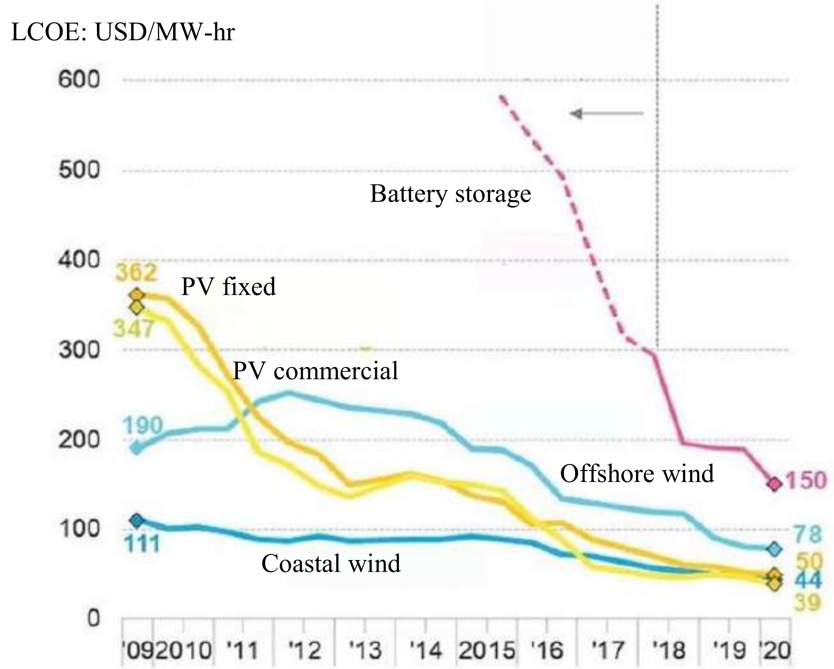
Properties of new batteries

- Car drive between charges – 1000 km.
- Charging time – 10 – 15 min

Accumulation news

- There are already 10 large-scale storage systems (CAS) in the world (Australia, China, USA, Canada)
- In Ukraine, a 1 MW CAS should be put into operation by the end of 2020.

Dynamics of specific costs (for the entire technological cycle – LCOE) for the production and storage of one kWh of electricity

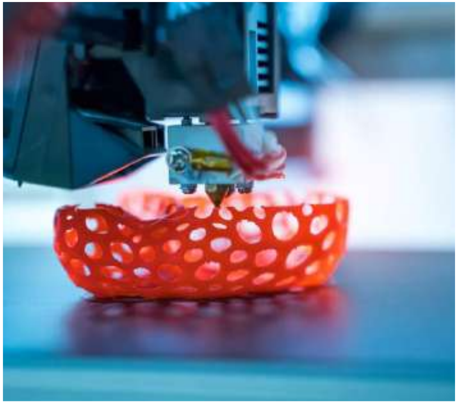


The results of the “green” revolution

- Horizontal networks
- “Production-consumption”.
- Renewable energy.
- EnerNet.
- Additive technologies (3D printers).
- Renewable resources.
- Electrification of transport.

The results of the “green” revolution

- Hydrogen technologies.
- Dematerialization of transport.
- “Smart” structures (enterprise, city, etc.).
- Efficient energy storage.
- “Cloud” technologies.
- Introduction of cyborgs.



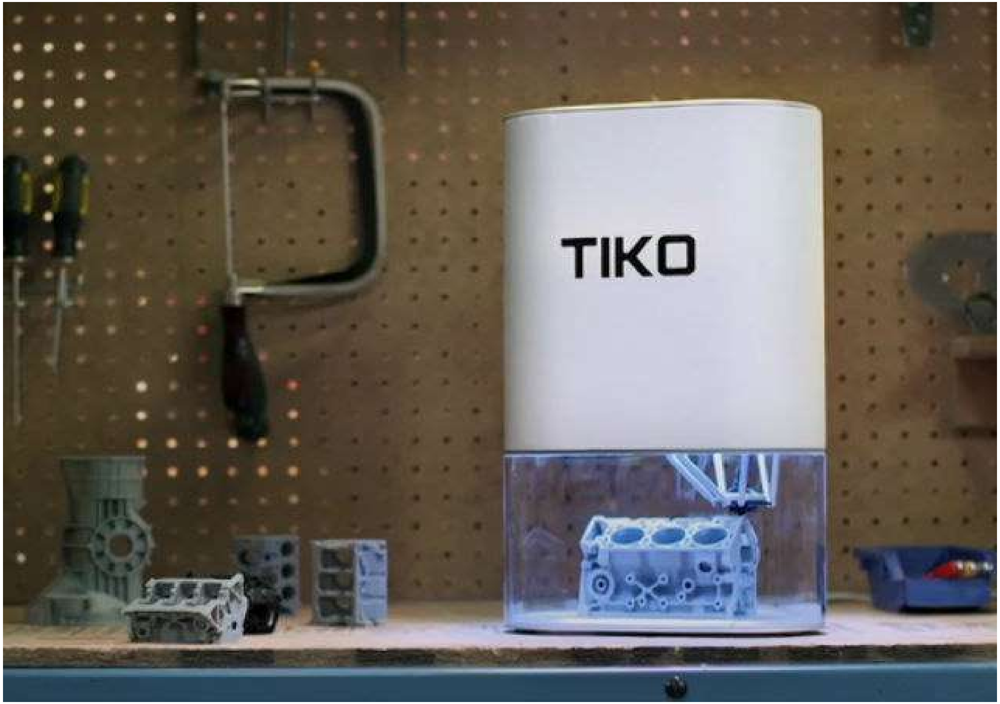
4. Material component of Industry 3.0

The 3D printer works with 10 materials

Massachusetts Institute of Technology:

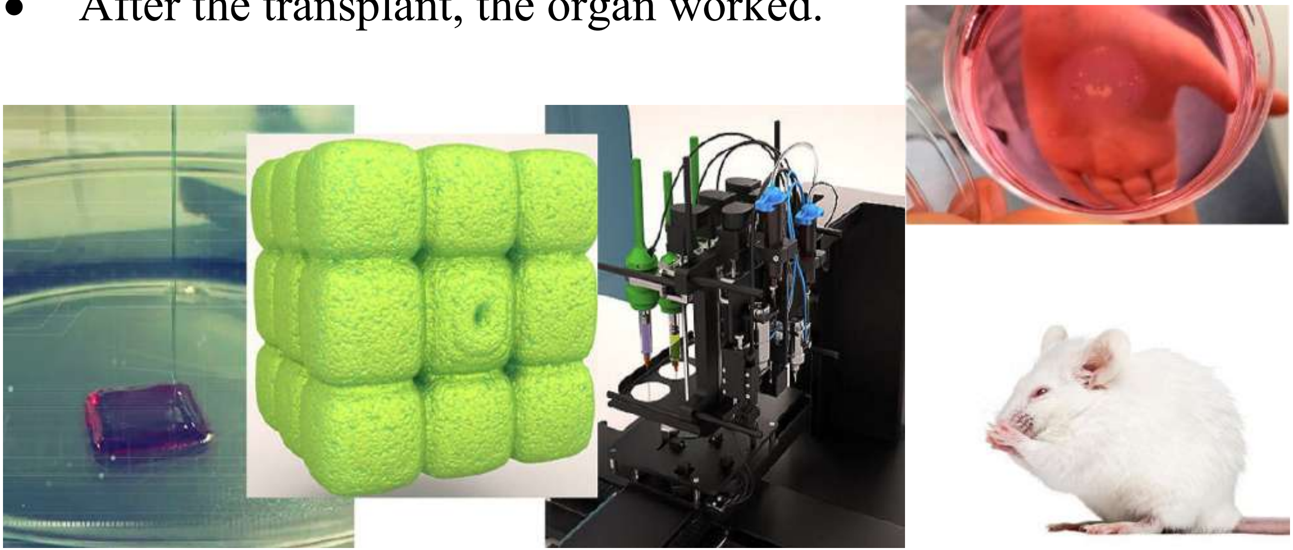
- The device works with **ten** different materials at once.
- Uses the technique ***3D scanning.***

3D printer that costs as a refrigerator ($179)

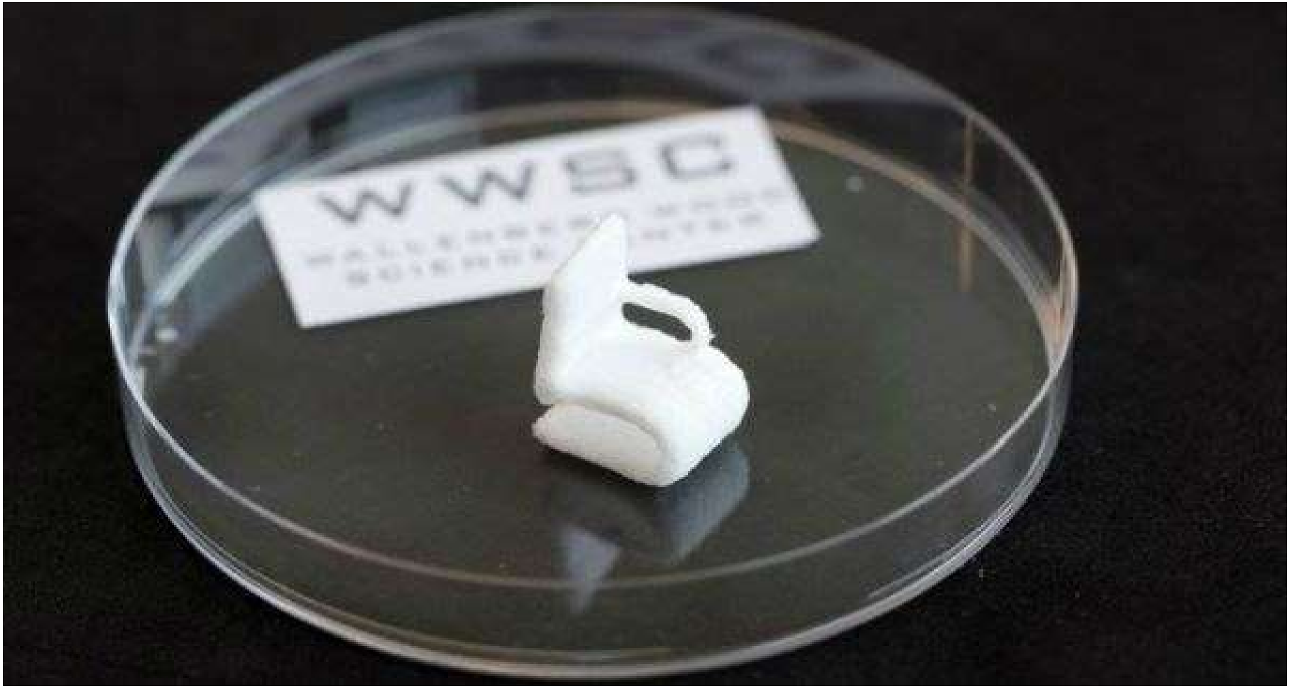


The bio-printer printed a human organ

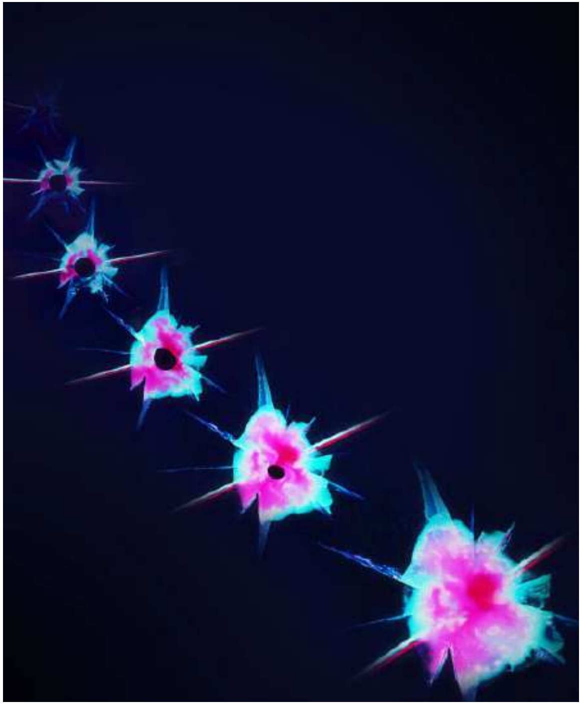
- The 3D printer printed the mouse's thyroid gland.
- After the transplant, the organ worked.



“Ink” for the 3D printer from cellulose



4D printing (self-restoring plastic)



3D devices in a regular store in Brussels

3D devices in a regular store in Brussels

3D devices in a regular store in Brussels

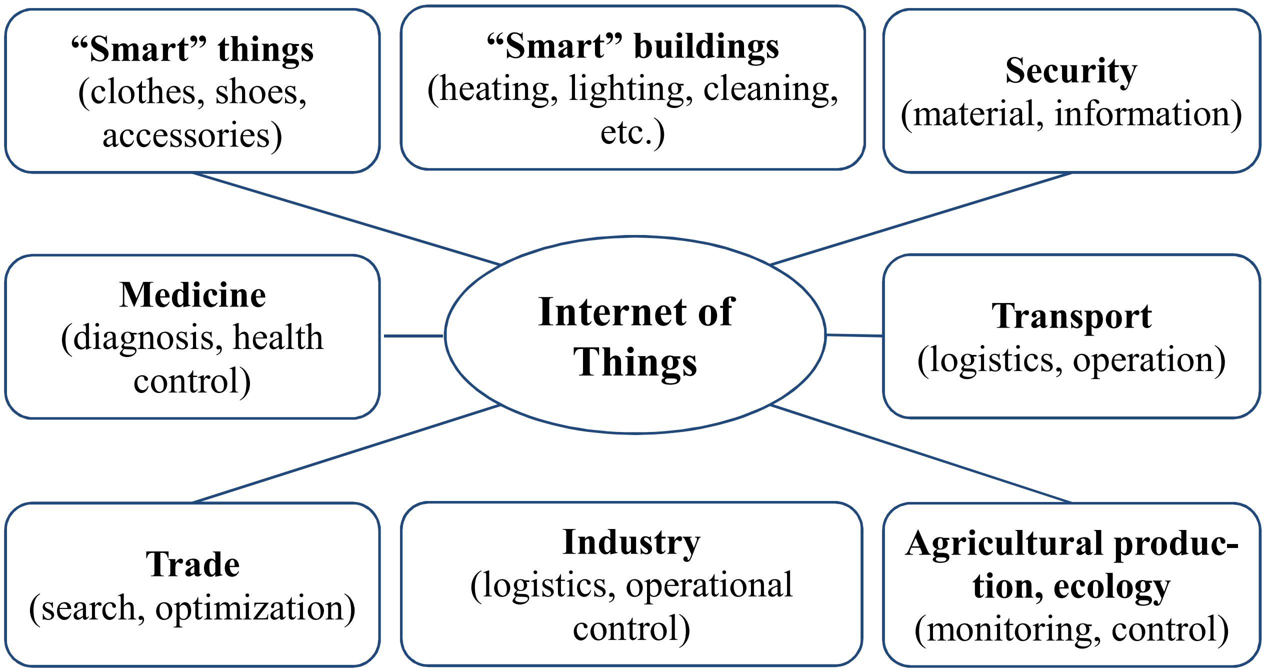
3D scanner products

5. Industry 4.0

IV Industrial Revolution

IV Industrial Revolution *(Industry 4.0) –*
the transition to cyberphysical systems.

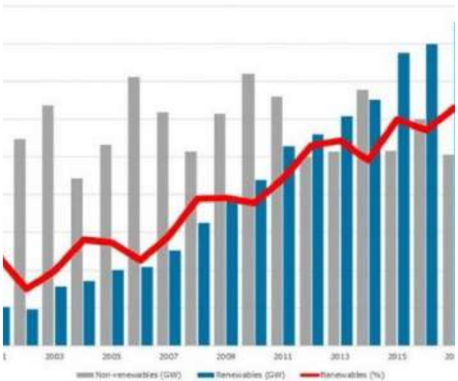
“Internet of Things”



Events that precede the "Internet of Things"

1. Personal computer – PC	1973 – 2010
2. Mobile phone	1973, 1996, 2010
3. Internet	1973 – 2010
4. Wi-fi	1971 – 2011
5. Renewable energy	1973 – 2010
6. 3D-printer	1981 – 2010
7. Digital technology	1973 – 2010
8. Artificial intelligence	1972 – 2010
9. RFID	1973 – 2010
10. GPS	1973 – 2010
11. Robot, drone	1968 – 2010
12. "Cloud"	1972 – 2011
"Internet of Things"	**2012**

6. Formation of a phase transition



Traffic in the city of Sumy at the beginning XX Century

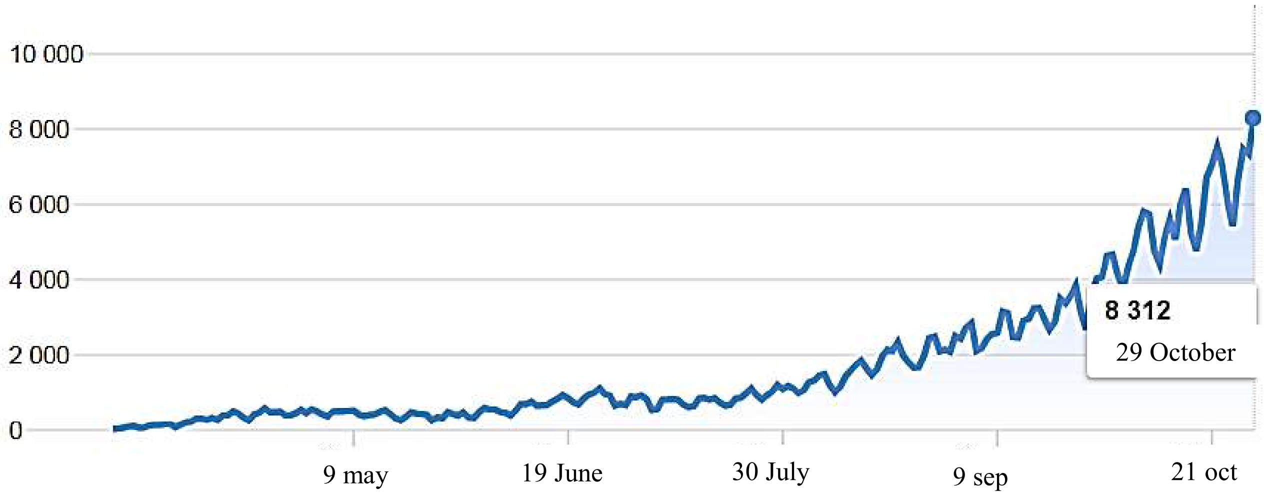
The “green” economy is a phase transition to:

- new energy;
- new communications;
- new settlements;
- new economic relations;
- new lifestyle;
- new needs;
- new person.

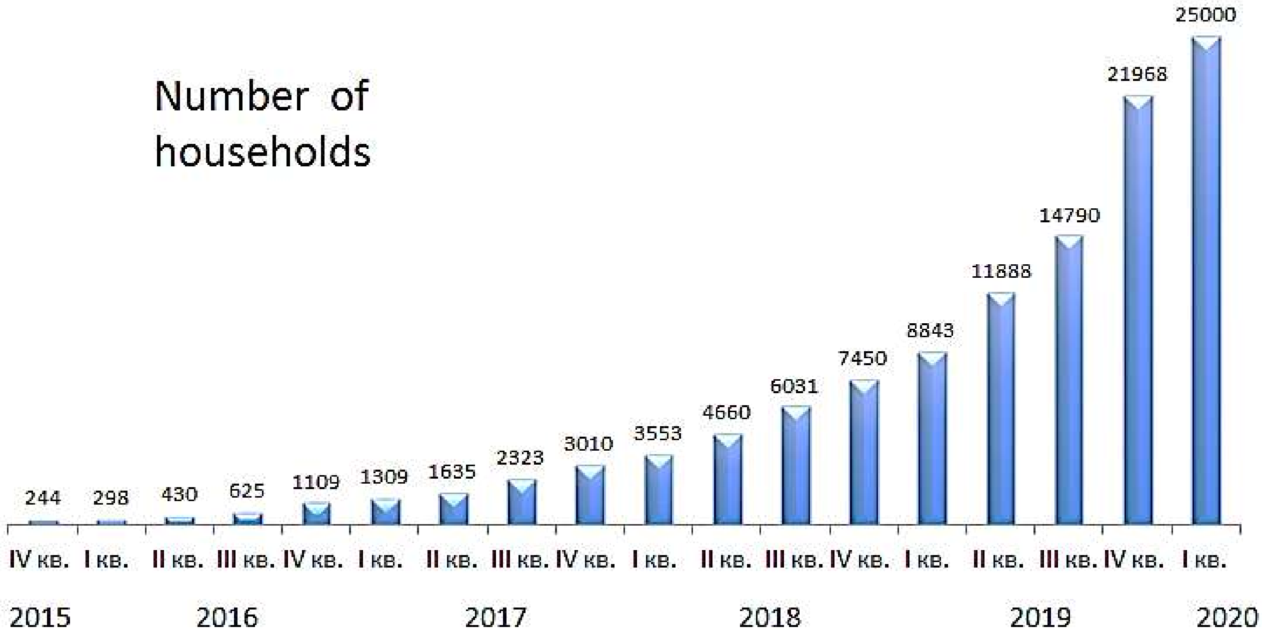
New language

Badge, pancake (new meaning – n.z.), blogger, blockchain, boyfriend, bonus, brand, background, gadget, girlfriend, glitch, developer, device, drive, road map, dress code, tin, google, skid (n.z.), hard, easy (from the English. “easy”), image, casting, cluster, call center, copywriter, creative, creative, cryptocurrency, cool, cache, leasing, lobby, logistics, low-cost, sucker, loser, mine, margin, minibus (marik), macho, nickname, “cloud”, online, rollback, paddy (entrance), parking, PR, pin code, prime time, price list, presentation, provider, promoter, profile, cut, resume, rating, reception, respect, realtor, retailer, site, soundtrack, selfie, slang, slogan, smiley, smartphone, sms, social networks, startup, supervisor, sale, second hand, talk show, tolerance, transfer, traffic, trend, training, tuning, file, fast food, facebook, feedback, flash drive, flashmob, freelancer, fake, face control, hype, sharing, shopping, shore CV, IT, HR, PC, PR, VIP, wi-fi, 3D printer

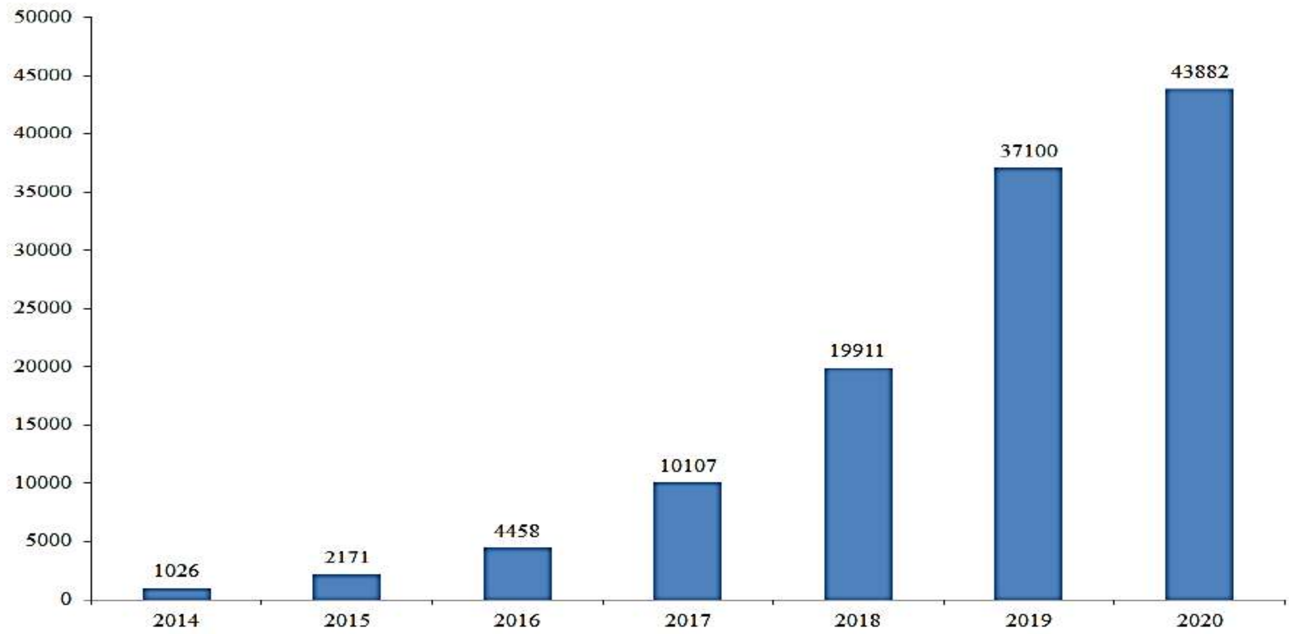
COVID-19 cases in Ukraine



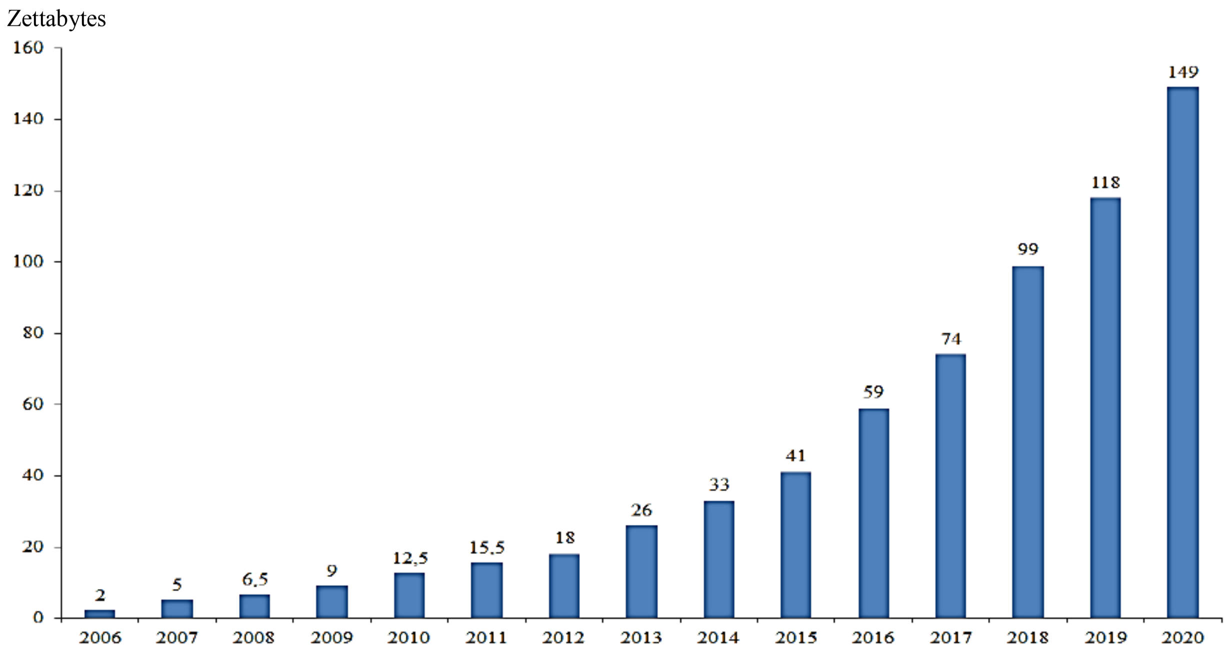
Viral nature of the spread of private SES in Ukraine



Number of electric cars in Ukraine



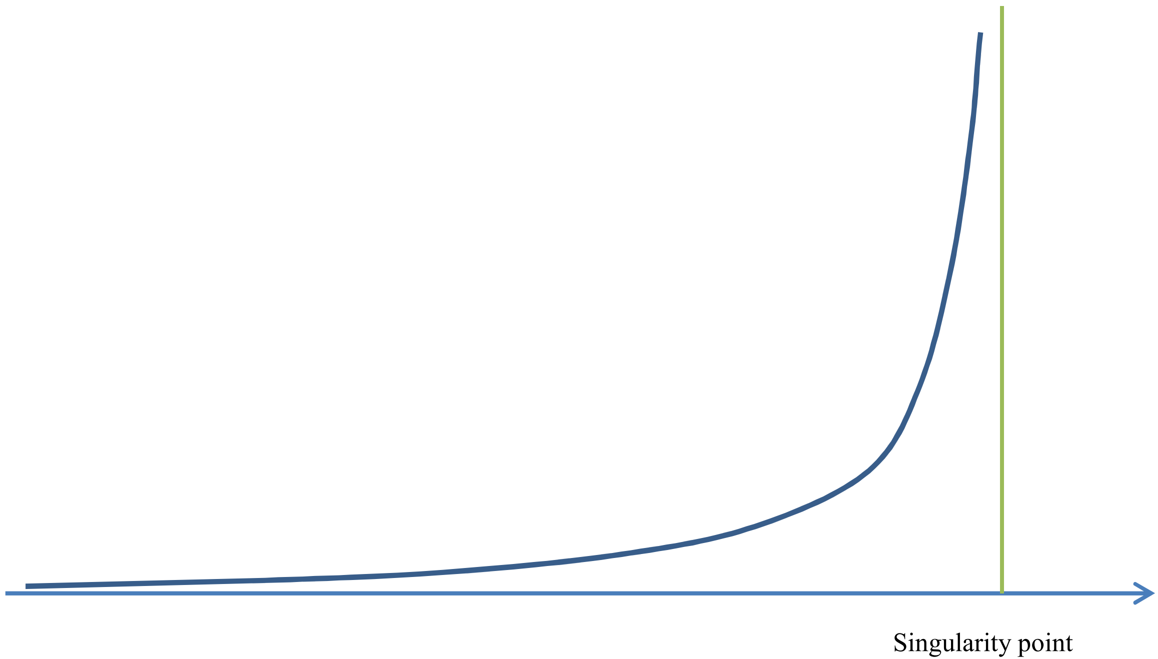
Information production graph



The viral nature of changes in the basic factors of civilization over 20 years

Index	Value	
	2000	2020
1. Number of personal computers, million units	140	7500 (about 100% of the population)
2. Number of mobile phones, million units	> 100	7800 (more than 100% of the world's population)
3. Number of Internet users, million units	80	4200 (55% of the world’s population)
4. The share of renewable energy,%	1	25
5. Number of 3D-printers, units.	1 (prototype)	More than 2000 additive systems
6. The share of digital information, %	< 50	99
7. The share of information generated by machines, %	10	50

Singularity graph



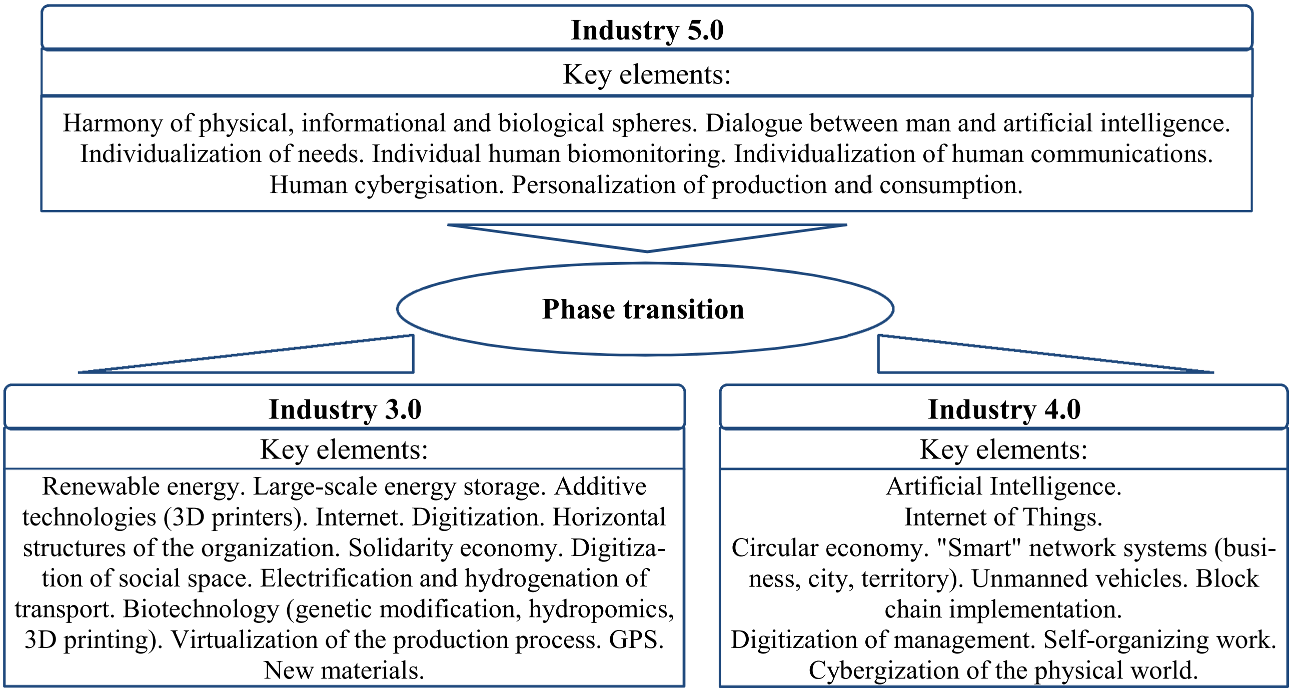
7. Industry 5.0

V Industrial Revolution (Industry 5.0)

Aimed at returning people to production and personalization of consumption:

- synergy of man and artificial intelligence;
- formation of emotional intelligence;
- creative functions of the person in production of use of potential of the person;
- from mass production of standard products to the consumption of goods for the individual;
- from efficiency goals to social development goals.

Key elements of modern industrial re



M. M. Neplyuyev among his first pupils. Photo 1887

Economic results in the labor Brotherhood

- Crop yields are 3 times higher than the average in Chernihiv province and 5 times higher than in Yampil District.
- In the entire history of the Brotherhood (≈ 40 years) no crop failure.

Information heritage of the Chernenko family – apples, bred varieties, 2012

Lime alley in Vozdvizhensk Garden

Steps into the future of brotherhood members

- Advanced reproduction of personality
- Harmony of production and arts
- Synergy of natural forces and man
- Full material support
- Equality and democracy
- Freedom of self-realization

Summary

- Today the world is experiencing a phase **transition** to a new civilization.
- The basis of human life is the production and consumption of **information**.
- Daily **innovations** become a reality.
- Man faces the need for **transformation**.
- The transition to a new management model forces us to constantly solve new problems. Non-transition pushes the country to the periphery of public life.

Sustainization of the economy

Presentation materials

Lecture plan

1. The concept of the sustainable development and the sustainization of the economy
2. Ways to sustainable development
3. Transition to sustainable (green) economy
4. Smart systems
5. Social aspects

1. The concept of the sustainable development and the sustainization of the economy

Sustainable (“green”) economy and Sustainable development

- **Sustainable (“green”) economy** – is an economic system that ensures the achievement of sustainable development
- **Sustainable development** – Sustainable Development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs.” (Rio de Janeiro, 1992)

Sustainability and Sustainization

- **Sustainability** is ability to maintain or support a process over time.
  In business and policy contexts, sustainability seeks to prevent the depletion of natural or physical resources, so that they will remain available for the long time.

- **Sustainization** is the process of transforming economic systems in a direction that brings closer the achievement of sustainable development (sustainable development goals).

Sustainable development measures

1987 “Our Common Future” Report of the Bruntland Commission

1992 «Agenda 21» The Rio Earth Summit

2002 The Rio + 10 Earth Summit

2012 The Rio +20 Earth Summit

2015 United Nations Climate Change Conference

2019 United Nations Climate Change Conference #COP25

2021 United Nations Climate Change Conference #COP26

2022 United Nations Climate Change Conference #COP27

What next???

Agenda 21

- **Agenda 21** is the Rio Declaration (plan of actions) on Environment and Development, and the Statement of principle for sustainable development achievement.
- F.e.: Think globally act locally Agenda is not the document, but the process

The process of Local Agenda-21 implementation

Sustainable development goals

Sustainable development goals

The basic theory

- Everything in the world – **open stationary systems.**
- Any system can exist only by supporting its metabolism – *a dynamic flow of matter-energy-information*.
- The system supports stationarity – narrow range of its parameters (*homeostasis*).

A balanced state of the three systems

Disbalanced state of the three systems

Global problems

- Climate change and global warming;
- Depletion of the ozone layer, formation of ozone holes;
- Lack of resources;
- Energy use;
- Biodiversity loss and extinction of certain plant and animal species;
- Water pollution;
- Air pollution;
- Land pollution;
- Increase in the number of people

Global problems

- Urbanization and the environment;
- Depletion of water resources;
- The problem of hunger;
- Deforestation and forest degradation;
- Desertification and land degradation (soil erosion);
- Toxic chemistry;
- Disposal and storage of waste (including hazardous waste);
- Noise pollution;
- Precipitation and acid rain;
- Social inequality and social exclusion;
- Ethnic disagreements

Human impact on the environment

We use the living world as

- a resource for food supply
- an energy source
- a source for recreation
- a major source of medicines
- natural resources for industrial products

The basic problem of the economy

How to make the best use of limited resources to meet people's unlimited wishes?

2. Ways to sustainable development

Objectives of sustainable development

A principal goal
is predominantly infinite existence
of human civilization and its
evolutionary development

Providing objectives are:
1) preservation of biosphere in a very narrow sense
when a human biological nature can exist;
2) preservation of the entire natural landscapes as
the information basis for development of a personality
(a social human being)

Supporting objectives
are aimed at reproduction of conditions when the components of biosphere
(ecosystems) can exist

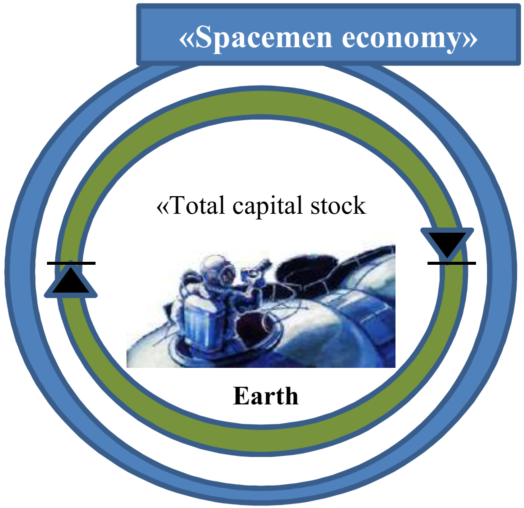
The image of sustainable development

Social
personality
development

Termitary

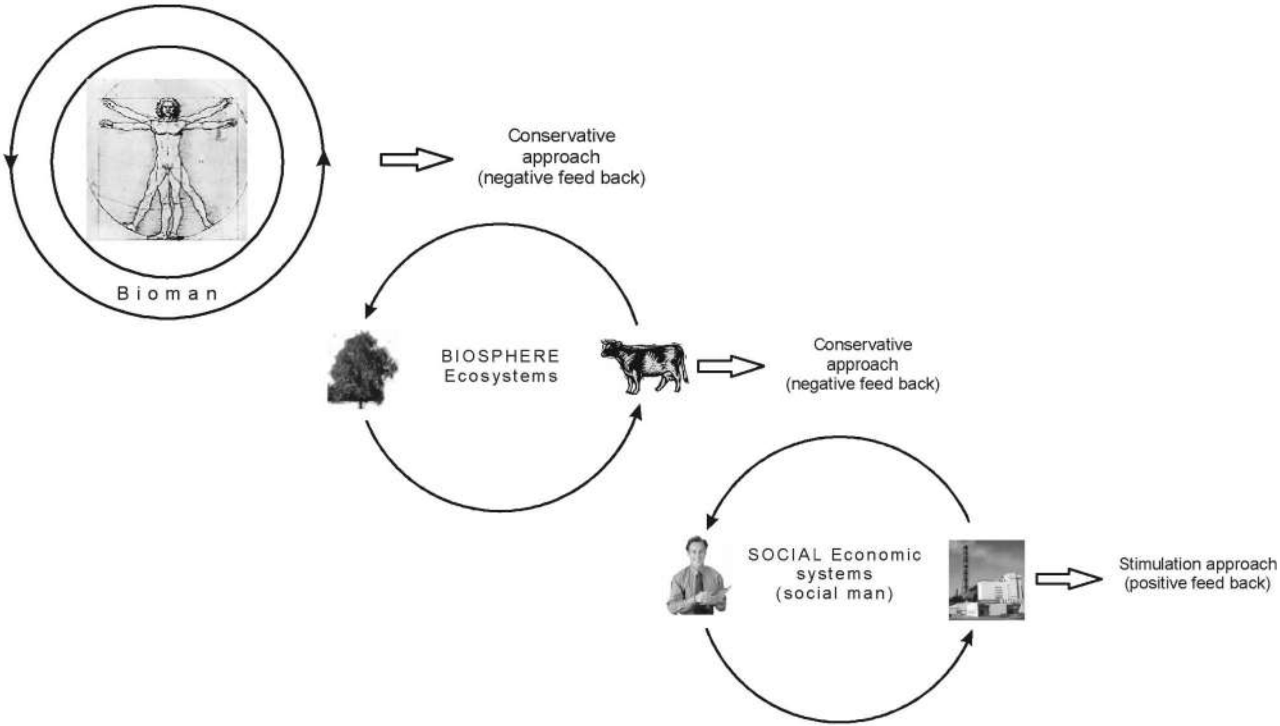
“Forward to nature!”

“Spacemen economy”



- Renewable resources.
- Closed cycles.
- Stable material metabolism.

Formation of instruments



The main methods of solving environmental problems

- Economic instruments – taxes, levies, reform of subsidies for environmentally harmful activities, etc. c.
- Regulation of activities – standards, licenses, restrictions
- Voluntary commitments – agreements, unilateral commitments (GRI, ISO 14000)
- Technology development, research support
- Dissemination and education – education, eco-labels, educational films
- Other instruments – spatial planning, infrastructure development, etc.

3. Transition to sustainable (green) economy

Phase transition

"Green" economy – a phase transition to:

- new energy
- new communications
- new settlements
- new economic relations
- a new lifestyle
- new needs
- new man

The characteristics of green economy

- The use of renewable resources
- The closed cycle of resource use
- The material components fit harmoniously into the ecosystem
- Stable volume of industrial metabolism
- Dematerialization of metabolism (in times!)
- Effective energy storage

The characteristics of green economy

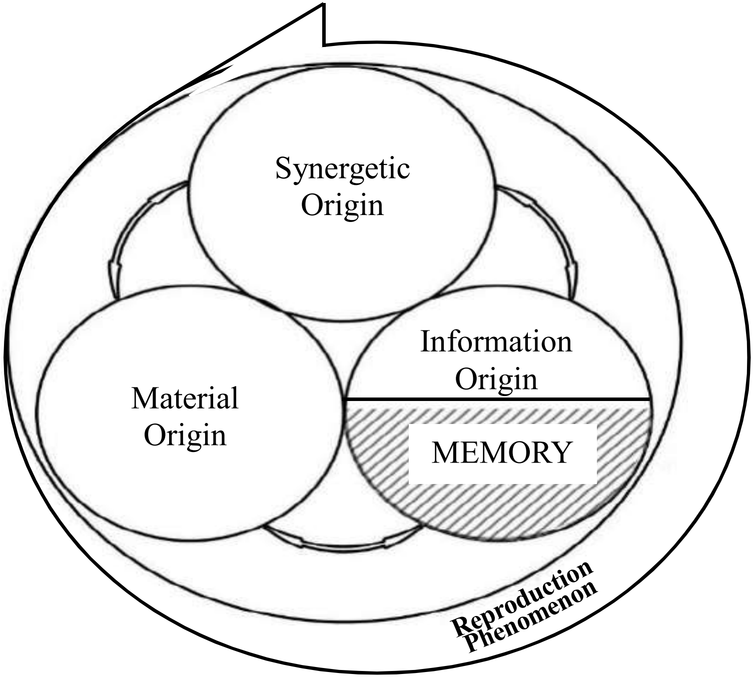
- Continuous self-optimization (self-adjustment) of technical systems
- Continuous improvement
- Not exceedance of environmental limits
- Conservation of biodiversity and ecosystems
- The priority of the reproduction of human personality basis

The basic theoretical principles

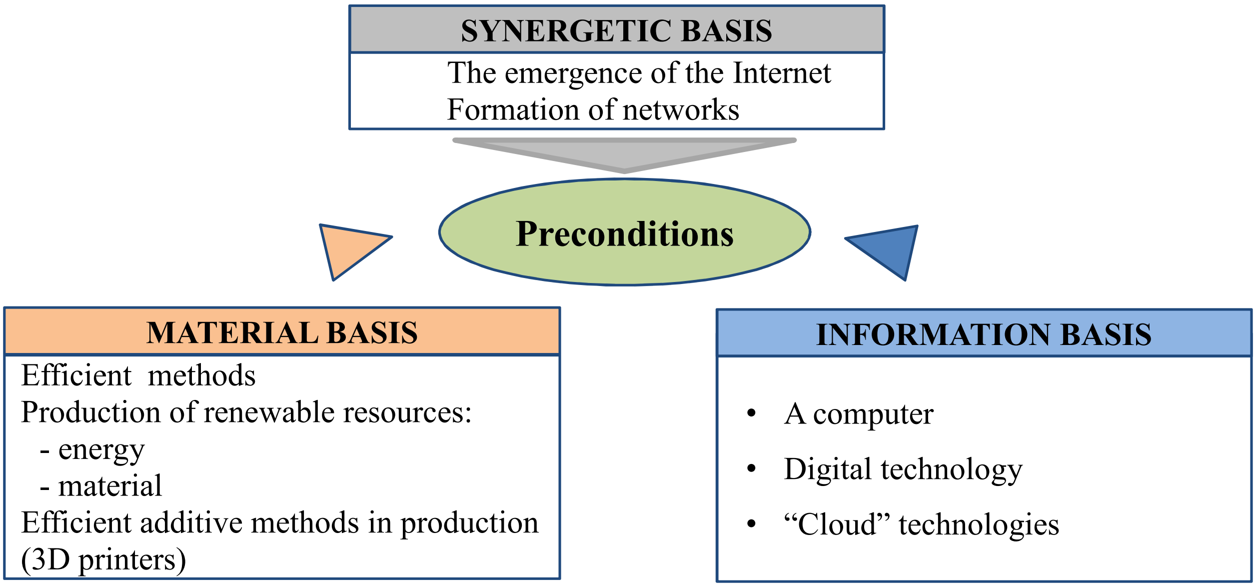
The system is formed by the natural trinity origins:

- **Material** – drives
- **Information** – guides
- **Synergetic** – unites

The essential basis for systems formation



The basic preconditions for the start of the Third Industrial Revolution



The resulting forms of the Third Industrial Revolution

- Horizontally distributed structure of “production-consumption”.
- The priority of renewable energy sources.
- EnerNet.
- 3D printers and additive technology.
- Switching to renewable resources and closed technologies.
- Electrification of transport.
- Hydrogen technologies.
- Dematerialization of transport operations.
- “Smart” structure (production, factory, city, region, country).
- Large-scale energy storage.
- Mass introduction of cyborgs.

Phase transition

Industry 5.0

Harmony of the physical, informational and biological spheres. Dialogue of human and artificial intelligence. Individualization of needs. Individualization of human biomonitoring. Individualization of human communication. Cyberization of man. Personalization of production and consumption

Phase transition

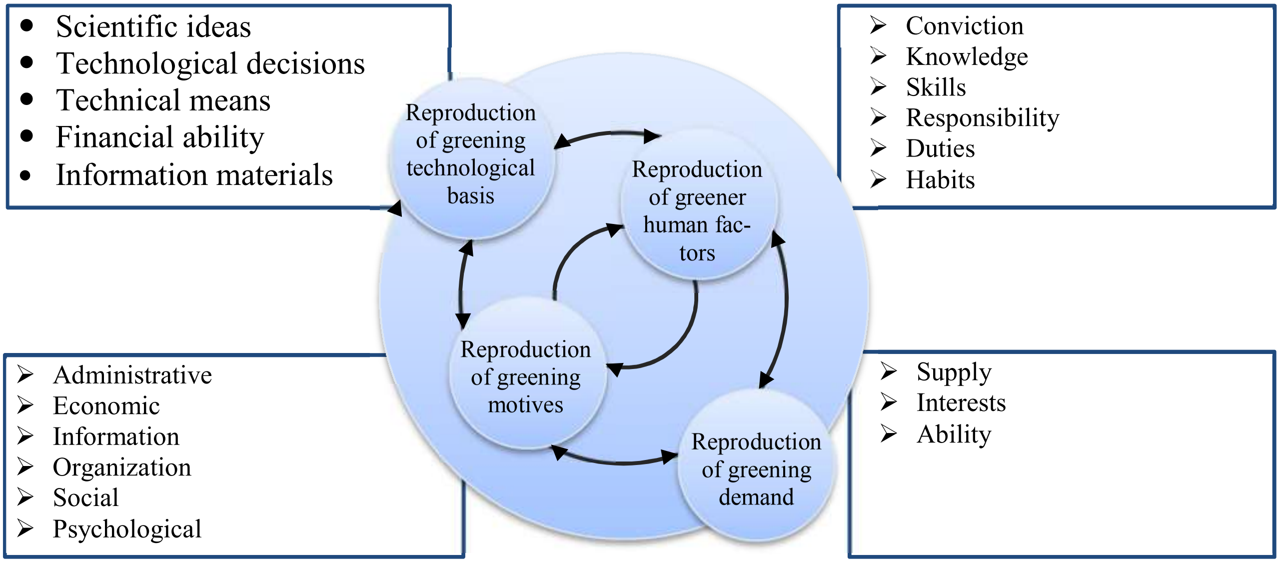
Industry 3.0

Renewable energy. Large-scale energy storage. Additive technologies (3D printers). The internet. Digital information systems. The horizontal structure of the organization. Joint economy. Digitalization of social space. Electrification and hydrogenation of transport. Biotechnology (gene modification, hydroponics, 3D printing). Virtualization of the production environment. GPS new materials

Industry 4.0

Artificial intelligence. Internet of things. The circulation economy. Cloud technologies. Smart systems (enterprise, city, territory). "The Internet of pipes and trees". Self-driving vehicles. Implementation of blockchain technologies. Digitalization of management. Self-organizing robots. Cyberization of the physical world

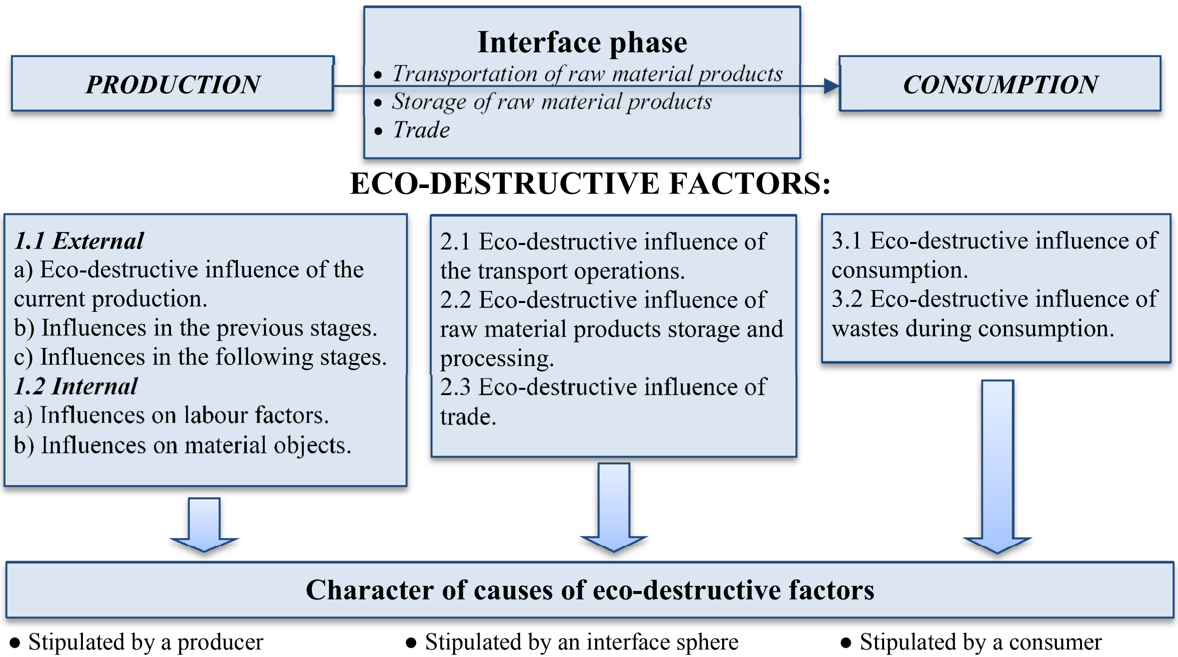
Mechanism of sustainization of the economy



Direction of sustainization of the economy

• throughput economy	→	• ecologically managed material flows
• wasting material	→	• material productivity
• wasting energy	→	• energy efficiency
• towards orientation products	→	• orientation towards function
• reactive environmental protection	→	• preventive environment protection
• (over-) exploitation of natural resource	→	• sustainable use of natural stock
• control of natural processes	→	• orientation towards natural processes
• throw-away mentality	→	• mentality of esteem

Strategies of sustainization of the economy



European strategy for Industry 3.0

1) “Green” energy.

2) Every building – as a source of energy.

3) Efficient accumulation of energy.

4) EnerNet Formation – smart grid.

5) Electrification of transport

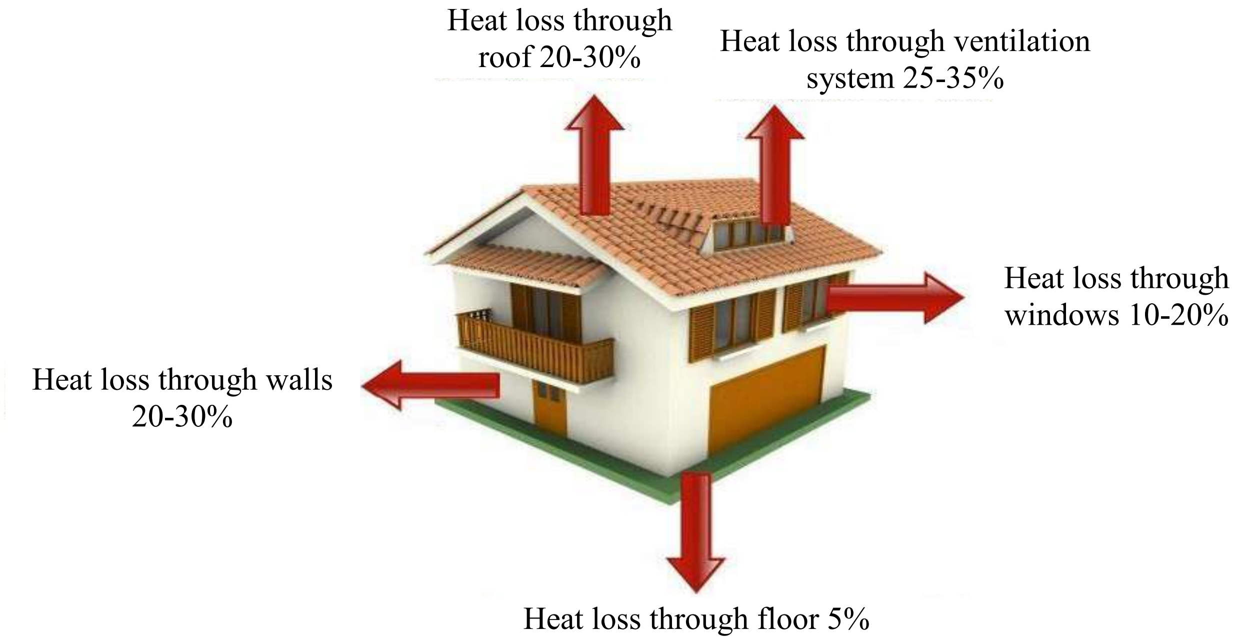
European strategy for Industry 3.0

1) “Green” energy.

2) Every building – as a source of energy.

- every building in the EU is becoming a source of energy.
- EU 191 million buildings: on the roofs and in the windows – solar panels; facades – wind generators; in the basement – underground heat; in the kitchen – biogas plants.

Ratio of heat loss in a house



Autonomous buses in the Netherlands

- In November 2015, the Netherlands opened the first route. Passengers will be transported by autonomous buses WEpod EZ-10.

Wireless car charging

- Electric re-charging lane. Electrical cables beneath the road surface creates an electromagnetic field, which is converted into electricity and charges the electric vehicle. Successfully tested in the UK

4. Smart systems

Smart factors of additive production

- unlimited design possibilities;
- *free* provision of complexity;
- *free* provision of variability;
- minimal waste;
- production for individual demand;
- exclusion assembly step;
- direct materialization of information

Smart materials

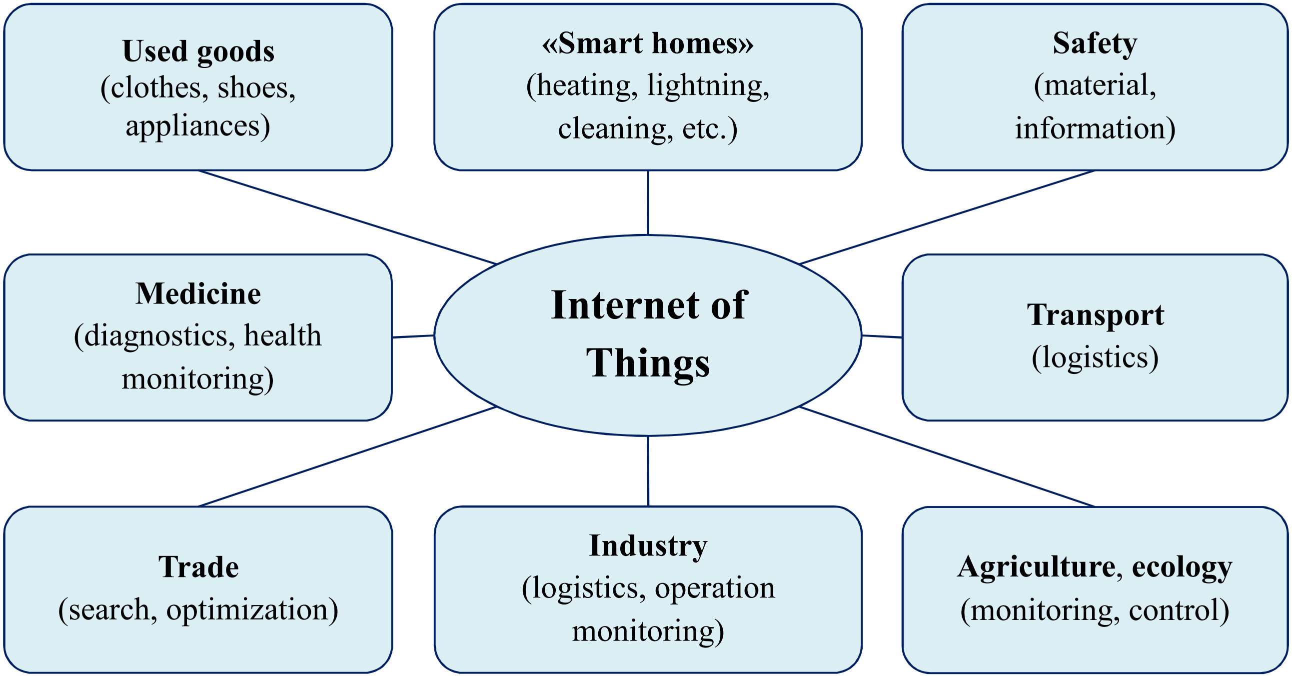
- materials with controlled properties;
- material becomes construction;
- it is constructed directly in the material during manufacture of the product

3D-technology for multiple materials

Functions cyberphysics systems (performed without human participation)

- Information exchange;
- Control of the environment parameters;
- Self-activization and stop;
- Self-tuning to the optimal mode;
- Projected (anticipatory) self-service;
- Interaction with manufactured goods;
- Adapting to new needs;
- Identifying hardware for self-reproduction
- Self-learning

Applications of Internet of Things



Virtual enterprises

- Creating virtual enterprises.
- Horizontal distribution system.
- CISCO-system is the company that controls 50% of the production of computer equipment and operation of 38 enterprises worldwide. Only 2 of the enterprises directly belong to it. Today, you can choose any company in the market that is complementary to you i.e., adds to your opportunities

China began planning 500 “smart” cities

Features:

- trucking;
- logistics;
- fleet management
- transport;
- Internet of Things;
- new vending machines
- generation;
- smart storage;

- food delivery;
- CCTV;
- monitoring

Cognitive technologies opportunities

Today there are programs that have

- self-written
- self-learning
- self-improvement potential

Factory in a Day

- Since 2015 several US companies engaged in the production of robots and 3D-printers started selling flexible plants (with software). They can be built in in 24 hours.
- The plant is sold as smartphone or tablet

Fable Manufacturing (Founder – Massachusetts Institute of Technology, Boston, USA)

- Using existing equipment the plant is able to finish building itself and to expand the existing functionality itself

5. Social aspects

Solidary economy

Formation of bases of a new type economic relations – *solidarity economy*.

Solidarity economy is based on:

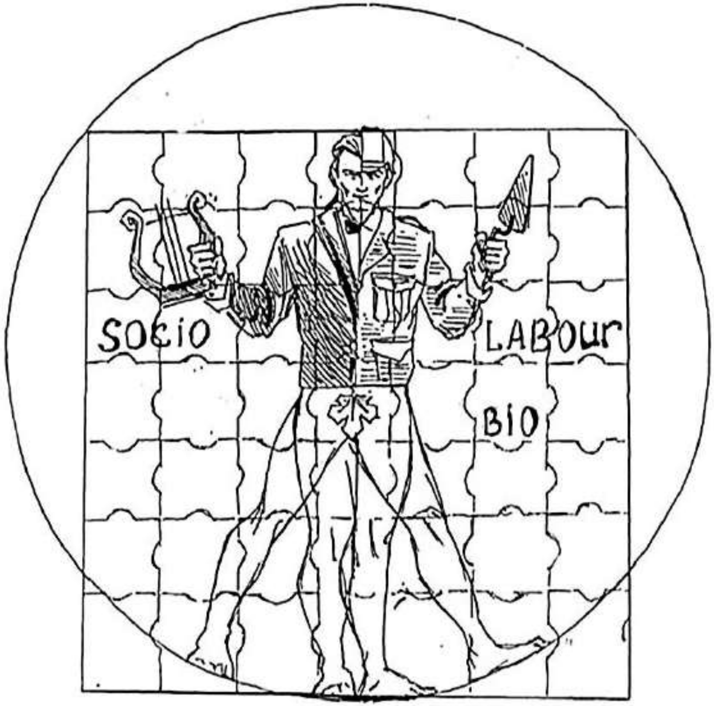
a) individual or cooperative ownership of means of production;

b) voluntary entry into the production systems;

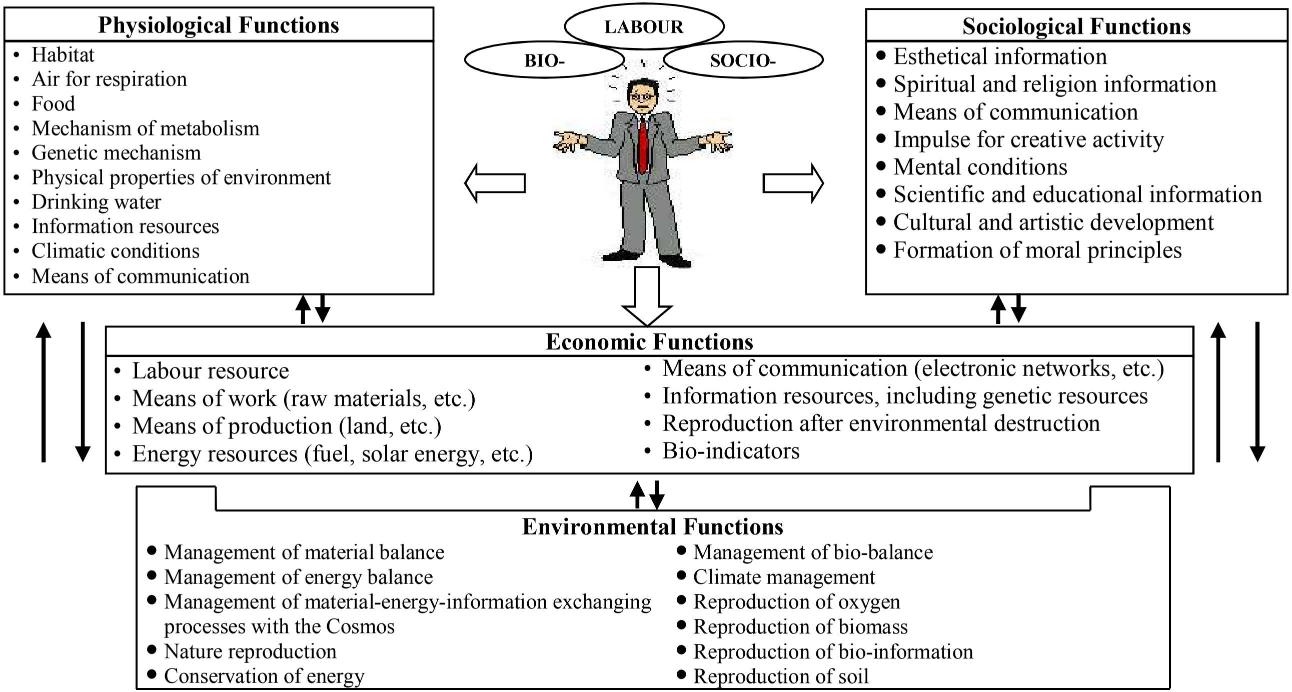
c) public participation in management;

d) public distribution of labor results

Trialectic nature of man



Functions of nature



Human being transformation changes

- economy of personality reproduction;
- from the consumption of material goods to the consumption of information ones;
- from the consumption of information goods to personality designing;
- the reproduction of the net human.

A green yard in Japan

Colorful carp in the fountains of Japan

Japanese “green yard”

Japanese “green yard”

Japanese “green yard”

A river running in a circle (pumps return water to its sources)

“Green standards” in Japanese construction

Flowers and trees in flower gardens (Japan)

Japan. Waste storage pit

Sustainization of energy sector

Presentation materials

Lecture plan

1. Economic conditions of sustainization of the energy sector: EU experience
2. Development of alternative energy in the EU and in the leading countries of the world
3. Energy storage
4. Direction of RE development

1. Economic conditions of sustainization of the energy sector: EU experience

An example of the economic instability of the traditional energy

2007
A jump in oil prices
→ **30-40$ per barrel** → **120$/b**

A jump in commodity prices and a slowdown in economic activity

2008
A new jump
→ **120$** → **147$**

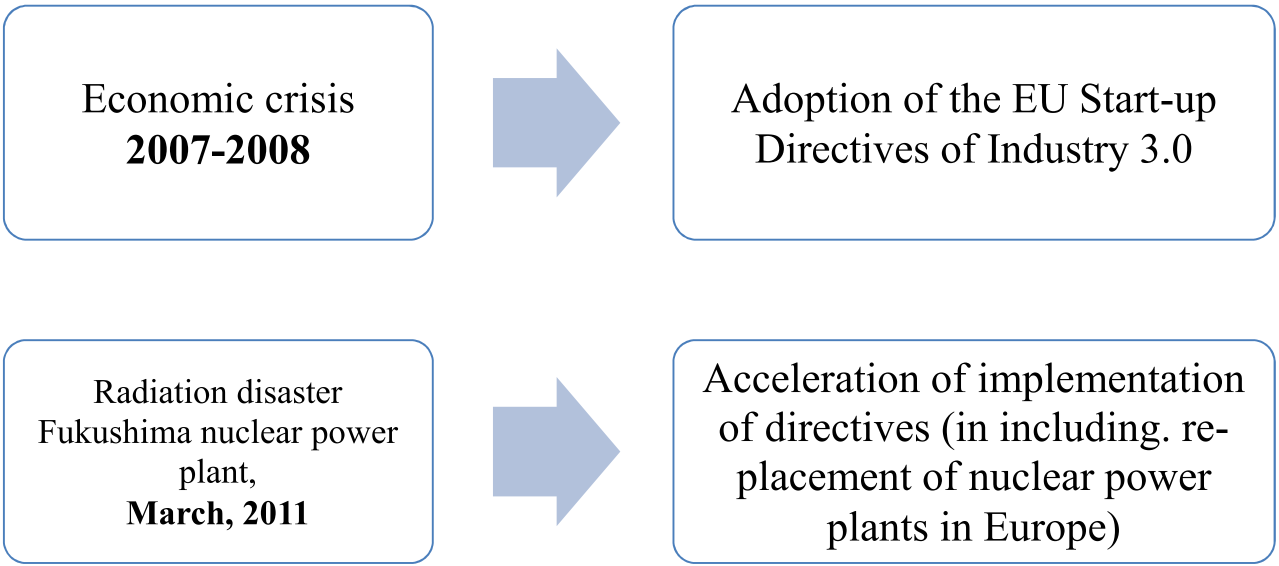
Financial crisis and stoppage of economic activity

2009
Falling oil prices
→ **147$** → **30$**

Activation of economic activity

2012
Increase in oil prices
→ **30$** → **120$**

Events that affected the start of Industry 3.0



Achieving electricity price parity in traditional and alternative energy (2020)

Type of production capacity	Full adjusted cost (USD/MWh)
Off shore VES	138.0
Coal fuels with 30% residual content CO_2	130.1
Coal fuels with 90% residual content CO_2	119.1
Biomass power plants	95.3
Modern nuclear power plants	92.6

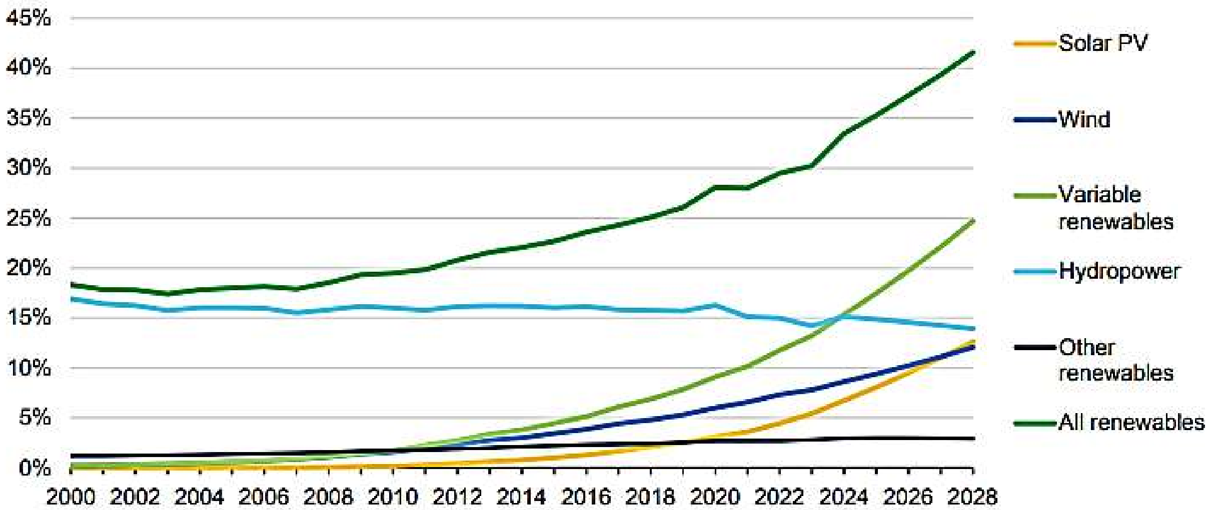
Achieving electricity price parity in traditional and alternative energy (2020)

Type of production capacity	Full adjusted cost (USD/MWh)
Gas e/s (with capture CO_2)	74.9
Photovoltaic(PV)SES	63.2
HPP	61.7
On the ground VES	59.1
Gas (without capture CO_2)	50.1
Geothermal	44.6

2. Development of alternative energy in the EU and in the leading countries of the world

Energy generation by technologies, 2000-2028

Electricity generation by technology, 2000-2028



IEA. CC BY 4.0.

Energy generation in the EU in 2023, %

- Renewable – 44
  - VES – 18
  - HES – 12
  - SES – 9
  - Bio – 5
- Gas – 17
- Coal – 12
- Reduction of energy consumption 3.4% to 2022
  6.4% until 2021

Renewable energy (RE) generation in China, 2023

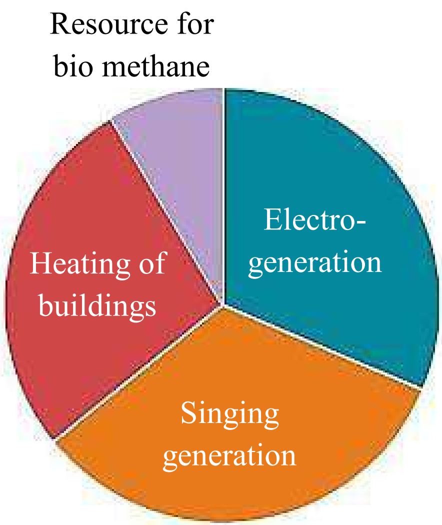
• Renewable energy capacity	1,320	Gwt	
• Renewable energy share			49%
➢ Hydro	418	Gwt	(32%)
➢ Wind	390	Gwt	(30%)
➢ Solar	471	Gwt	(36%)
➢ Bio	43	Gwt	(3%)

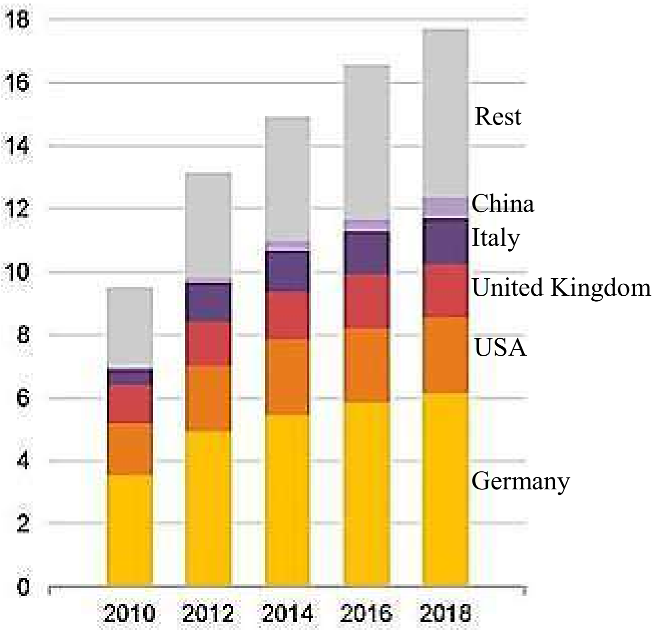
- Growth of RE in 2023 is 20% to 2022

The average world cost of energy (LCOE), 2020 USD/kWh

- VES (coastal) 0.045
- SES (pv) 0.048
- SES (thermal) 0.073
- VES (offshore) 0.108
- Bio fuels 0.050 – 0.250
- TPP on fossil fuel (new) 0.050 – 0.150

The largest biogas producers and raw materials in 2019

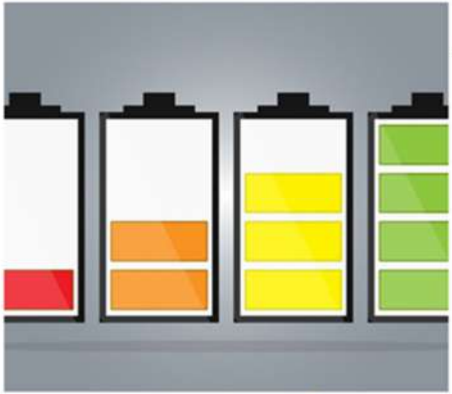




Geothermal power plants in the world

Country	Power, MW	Share in the energy balance, %
USA	4,400	0.3
Philippines	1 904	27
Indonesia	1,200	4
Mexico	1,000	3
Italy	843	0.5
New Zealand	628	10
Iceland	580	30
Japan	536	0.1
Salvador	204	14
Kenya	170	12
Costa Rica	166	14
Nicaragua	88	10

Underground heat/cooling pipes



3. Energy storage

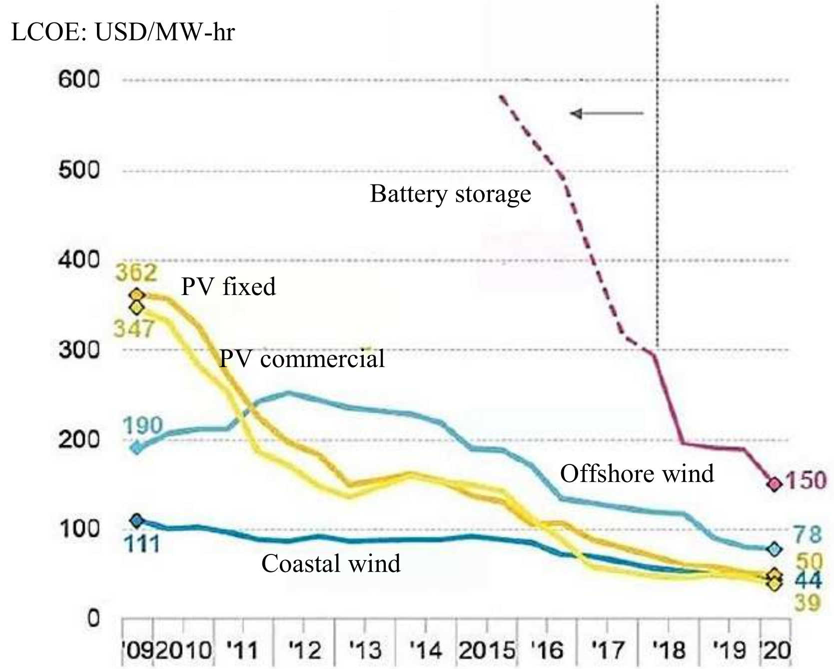
Directions of energy accumulation

- Hydro-.
- Electro-.
- Hydrogen technologies.
- Thermal.
- Chemical.

Accumulation news

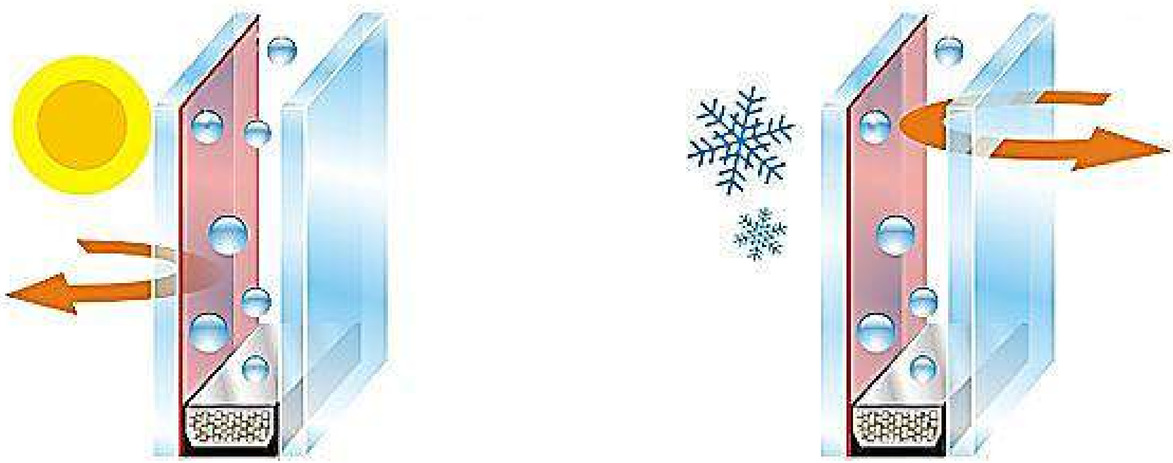
- There are already 10 large-scale storage systems (CAS) in the world (Australia, China, USA, Canada)
- In Ukraine, a 1 MW CAS should be put into operation by the end of 2020.

Dynamics of specific costs (for the entire technological cycle – LCOE) for the production and storage of one kWh of electricity



4. Directions of RE development

“Window-SPP”



Solar batteries in the windows

Solar panels are so cheap that they are used as fences

A light well at a subway station in Berlin

The upper part

lower part

Solar thermal power plant, 6,300 acres (China)

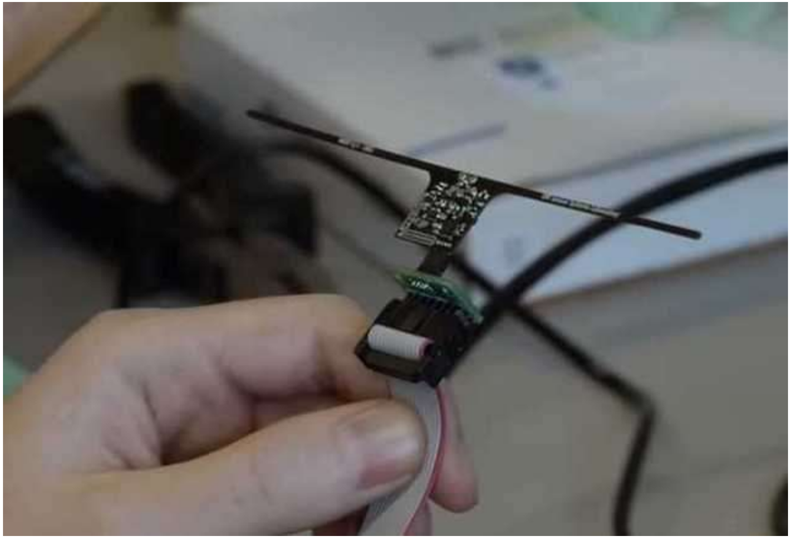
Hybrid solar and hydroelectric plant in the Atacama desert (South America, between the Andes and the Pacific Ocean)

Solar thermal power plant, 6,300 acres (China)

Wind turbine from electrostatic “straws” (Sweden, Stockholm)

Power plant based WISP (Wireless Internet Service Provider) and the use of electromagnetic wave energy

- Wireless WISP technology (based on Bluetooth) allows you to capture radio waves and convert them into electricity



Solar panels balconies in Germany

- These are 400 000 solar systems on balconies in Germany. They are connected to the electric network
- Balcony panels has much less problems than panels on roofs (cheaper installation, permissions are not required).

Sustainability of transport

Presentation materials

Lecture plan

1. Basics of transport sustainization.
2. Electrification of transport
3. Hydrogenation of transport
4. High-speed transport
5. Light individual transport
6. Driverless transport

1. Basis of transport sustainization

The role of transport

1) Transport is a link connecting economic subjects

2) Participates in most transactions

3) Participates in intra-economic activities of subjects

4) Provides social communications

Directions of sustainization of transport

- electrification of transport;
- use of new energy sources (primarily hydrogen);
- the use of new types of vehicles and their hybridization;
- robotization of vehicles;
- replacing material transfers with information transfers;
- improvement of transport logistics.

2. Electrification of transport

Electric car, built Thomas Parker (photo 1895)

Share of electric car in the world, %

- 2019 р. 2,5
- 2020 р. 3,2
- 2023 р. 7,0
- 2040 р. 31,0

Traffic in the city of Sumy at the beginning XX Century

Share of electric car in the world, %

- Speed up to 600 km/h

Unmanned mini-electric bass

- The range is 530 km, the speed is 180 km/h, it can be charged to 80% in 30 minutes. Solar panels are on the roof.

Chinese electric bus

- Range 288 km. Capacity – 120 passengers

Hybrid truck Nikola One

- Power reserve – 240 km In addition, it is equipped with a turbine with that can work on any fuel. When fully refueled/charged, the range is 1,900 km.

Electric truck Urban eTruck (Mercedes-Benz)

- Range – 200 km. Load capacity – 18–26 t.

Slovenian electric plane Panthera Electro

- The flight range is 400 km, the possibility of parachute descent if the charge runs out

2-domestic electric air craft Airbus E-FAN companies Airbus

- In the series piece since 2017. Maximum speed – 220 km/h, cruising speed – 160 km/h.
- The duration of the flight is 1 hour.
- The cost of 1 hour is 19 USD instead of 55 USD on a gasoline plane.

The first multi-seater in the world electric liner Alice Israeli companies Evasion Aircraft

- Designed for 6–9 passengers. Flight range on one charge is 965 km.
- Made of composite materials, it is 300 times more efficient than an ordinary airplane.
- Cruising speed – 450 km/h. Altitude – 3000 m.
- In 2017, it was presented at the air show in Le Bourget.

Planet Solar Türanor– a German catamaran

- Length – 31 m, width – 15 m, height – 6 m.
- The price is 14 million euros.
- The area of solar panels is 527 sq.m, 38000 btary.
- The average speed is 7 knots (13 km/h), the maximum speed is 14 knots.

Circumnavigation route Planet Solar Türanor

- Carried out in 2010-2011.
- International crew of 6 people
- Duration of crossing the Atlantic 22 days 12 hours 32 minutes

3. Hydrogenation of transport

New hydrogen Toyota Mirai

- Range – 650 km. Refueling time – 5 minutes.
- In 2021, 1,500 will be released piece, in 2022 – 2,000 pcs.
- Price – 60 – 80 thousand dollars.

Hydrogen truck Nikola One(USA)

- The range is almost 2000 km. Hydrogen for refueling (300 stations) is produced by 50 SES (water electrolysis). Refueling time 15-20 minutes.

Car on compressed air Tata One

Car on compressed air Tata One

- Range at a speed of up to 100 km/h – 90 km, at a speed of up to 80 km/h – 130 km. The price is 5-8 thousand dollars. Download at a special station – 3-4 minutes. “Inflating” with the help of a mini-compressor – 3-4 hours.

- According to the value equivalent of the need for “fuel” – 1 liter per 100 km of travel. Minimum maintenance costs: oil – 1 liter per 50,000 mileage, for regular ones – up to 30 liters.

4. High-speed transport

Maglev

- ***Maglev*** **–** from words *magnetic levitation*–train on *magnetic pad*. Moves, steers and brakes with the help of a magnetic field.

Shanghai Maglev

- Shanghai – airport – 430 km/h
- It is planned Beijing – Shanghai – 1200 km
- Tokyo – Nagoya – 500 km/h

5. Light individual transport

Doubleround skate

One-wheeled skate

Suitcase Scooter

Segway-scooter

Gyroscooter

6. Driverless transport

Unmanned 6-domestic bus in Wageningen, the Netherlands

- Operated since 2015.

Unmanned 15-domestic electric bass in Lyo

The company's unmanned truck Otto-Uber

The company's unmanned truck Otto-Uber

- The first flight was made in 2016 in the state of Colorado, USA. I drove 120 miles (193 km).
- The average speed of the truck was 90 km/h.
- The driver, however, was in it, but he, having driven the truck out of the city, moved to a sleeping place in the back of the cabin.
- The drone's first cargo was the company's beverages Anheuser Busch. Regular commercial flights were planned to start in 2017.

Drones

Spheres using

- Geology, archeology, infrastructure management.
- Insurance business.
- Management construction
- Medical help
- Scientific activity
- Space tools stations
- Formation of the structure Internet
- Service NS.

Drones

Spheres using

- Postal Service and Service delivery
- Sanitary and epidemiological service
- Restaurant business
- Patrol service
- Agricultural production and forestry household
- Sporty activity
- Journalism and cinematography
- Wildlife protection nature
- Entertainment and show business

Sustainization of settlements

Presentation materials

Lecture plan

1. Think globally – act locally
2. Environmental standard
3. Biotopes
4. Social development of a human
5. Eco-construction
6. Sustainable construction of econom-class
7. Modern urban planning

1. Think globally – act locally

Purposes of the formation of sustain settlements

- Provision of conditions for social development of a person (informational contact with primary natural ecosystems).
- Provision of conditions for human recreation and maintenance of health (healthy environment)
- Provision of conditions for the functioning of economic systems (resources and containers for waste).
- Ensuring the reproductive potential of ecosystems.

Ecopolis

- A settlement during the planning, design and construction of which conditions are created for the personal development of a person and his creative work, the satisfaction of the ecological needs of a person (including, its informational contact with ecosystems), implementation of economic activity and the steady state of environmental components.

Criteria for residential complex

- criteria and standards of material well-being (material objects to satisfy material needs);
- criteria and standards for provision of material objects intended for social (personal) development;
- biosphere criteria and standards (guarantee a stable equilibrium state of the ecosystem);
- hygienic criteria and standards (guarantee the safety of exposure to the human body);
- criteria and standards for providing a person with informational contact with natural systems.

2. Environmental standard

Environmental standard

- Firstly, due to the normalization of the possibility of human contact with elements of the natural environment (green areas, water bodies, birds and animals) within the limits of the human residential zone (this is the way they follow in Japan).
- Second, normalizing the possibility of human contact with natural landscapes (forest, field, mountains) outside the residential area, but within the maximum reach, in particular with the help of public transport (a similar approach is developed in Germany).

Landscaping standards in Japan

- There is a scale of greening indices.
- Territories that do not have green spaces receive the value of the index – 1; farms, meadows, grass lawns, fields, gardens have an index from 2 to 4; thickets of bushes and bamboo – 5; tree planting – 6; young secondary forest – 7, old secondary forest – 8, primary forest – 9, especially valuable primary forest – 10.
- After the completion of the construction of the object, the average index of the developed territory should be at least 6. Therefore, to compensate for the areas filled with asphalt, the builders should plant “adult” trees.

Planting of “adult” trees on a construction site in Japan

Standard for the presence of living beings

- In Japan, there is also a standard for the presence of living representatives of nature in the human habitat. Therefore, you can observe in the fountains color fishes, and deeres in parks.

Standard of harmony

- There is a universal phrase in the standards: “The object must be in harmony with the environment”

An artificial river in Nagoya

3. Biotopes

Landscape design of the backyard of a Japanese house

Biotopes are one form of green architecture

- Japanese green yard

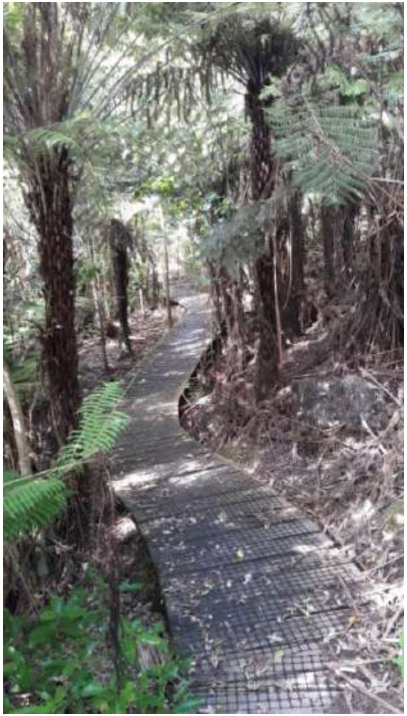
Biotopes are one form of green architecture

Flowers and trees in flower gardens (Japan)

Biotope in the courtyard of the hotel “Adina”, Sydney, Australia

Biotope in the courtyard of the hotel “Adina”, Sydney, Australia

Jungle biotope in one of the schools Auckland, New Zealand



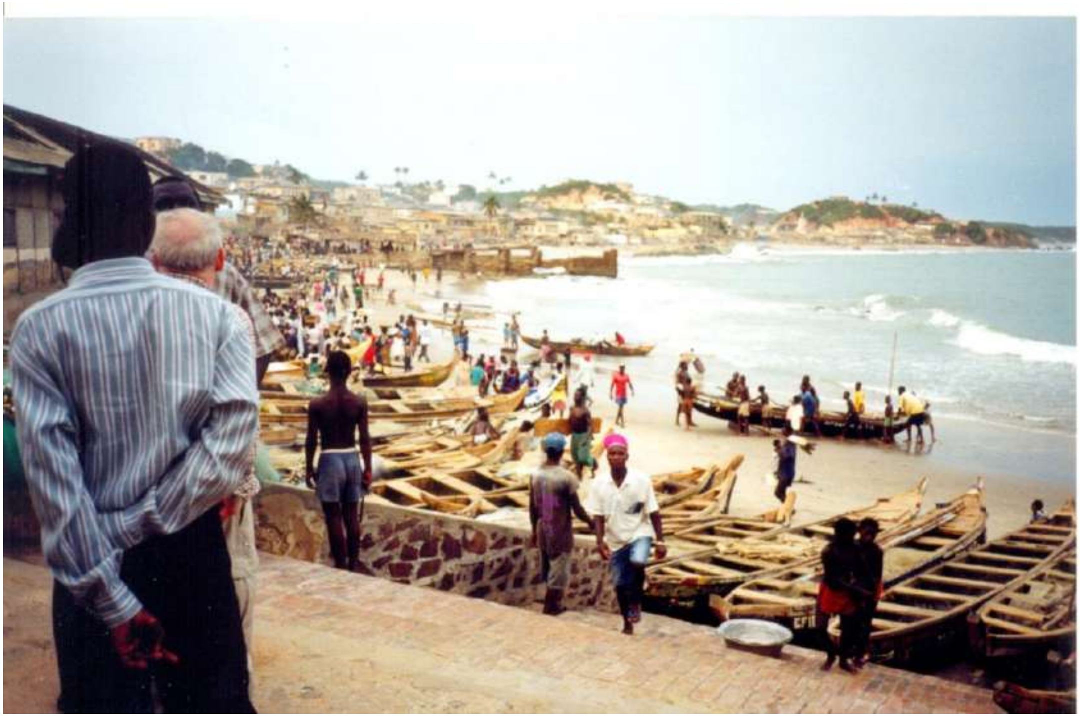
“Vertical Forest” in Milan (Sky scraper Bosco vertical)

Green wall on the house Caixa Forum in Madrid

Sustainable district in West Hurbury, Malmö, Sweden

Ghana. Residential complex on the ocean in Ghana

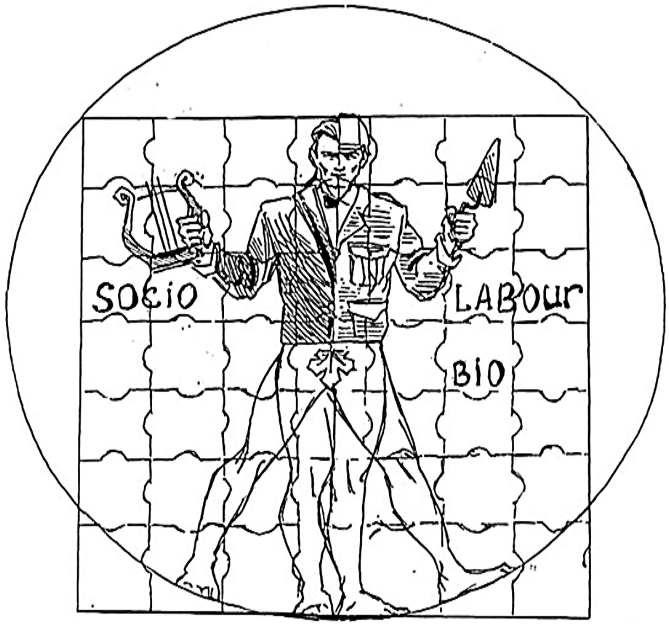
Ghana. The ocean shore is next to the residential area



4. Social development of a human

Trialectic nature of a human

- “Green” economy is an economy that mainly satisfies the informational needs of the individual



“Meadow” on the roof of the Research Institute of Gardens on the Roof in Malmö, Sweden

Gardens with “lawns” on the roof of a shopping center in Heislingen, Germany

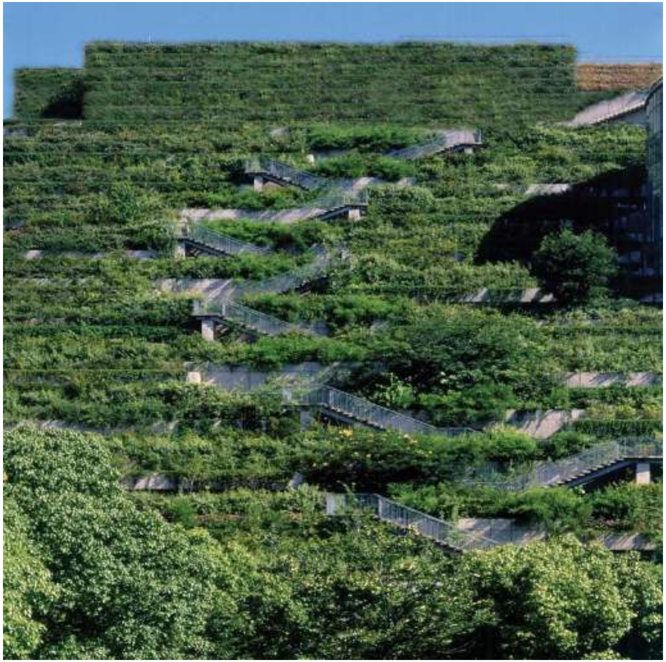
A garden with a flowerbed on the roof of an insurance company WGV-Versicherungen in the city Stuttgart, Germany

The green roof above the Adina Hotel in Sydney, Australia

Shrubs with a lawn on the roof of the Villa Olympia building in Dnipro, Ukraine

General view of the business center ACROS Fukuoka Prefectural International

Green “outfit” of the facade of the business center ACROS in the city of Fukuoka



5. Eco-construction

Development directions of sustain construction

Conditionally, several main directions of development of sustain construction can be identified:

- ***ecological modernization***, when sustainization is carried out in previously constructed buildings (most often these are century-old buildings and even older ones);
- ***eco-tech*** – "green" construction using the most advanced technologies and materials, as a rule, quite expensive, which also affects the price of the constructed objects;
- ***"green" economy class construction*** (eko-lautek) – construction designed for less solvent segments of the population; as a rule, the sizes of the objects under construction are optimized; inexpensive materials are used, usually of local origin.

“Smart” eco-house Sun house 360° that rotates behind the sun

Building One Angel Square in Manchester (England)

Business center ASTARTA in Kyiv

Project of different states of a rotating skyscraper Dynamic Tower in Dubai

Sun Rock, a building completely covered with solar panels (Taiwan)

Artificial “bones” and “egg” shell

- Artificial bones are 50% mineral and 50% protein.
- Artificial scrambled eggs for 95% of minerals and on 50% – from squirrel.
- This makes the material strong and resistant to damage.

6. Sustainable construction of econom-class

“Smart” house in Stuttgart

Passive house “Solar farm”, USA

Mini-house on wheels

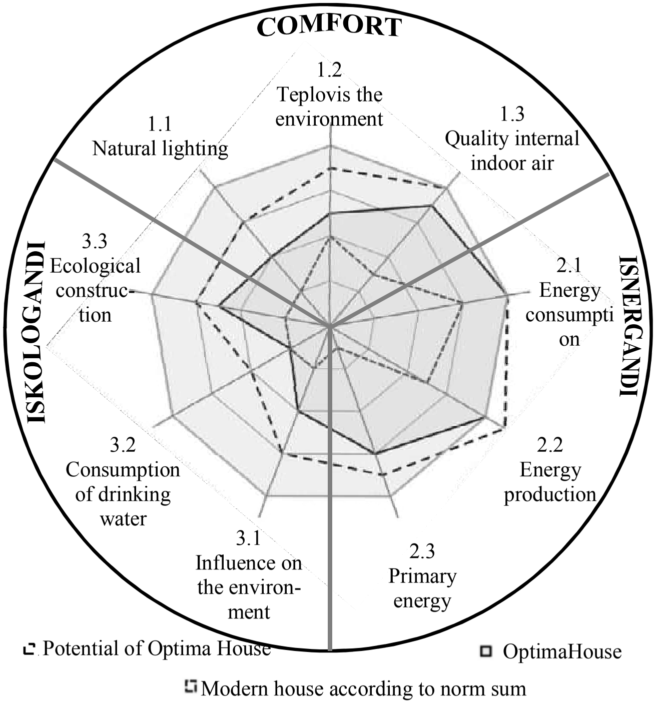
Geo-house under the glass dome (Norway)

The living quarters of the building are under a glass dome

PassiveDom: “smart” eco-house, printed on 3D-printers

Multi-comfortable house Optima House

Chart


COMFORT
ISNERGANDI
ISKOLOGANDI
1.1
Natural lighting
1.2
Teplovis the environment
1.3
Quality internal indoor air
2.1
Energy consumpti on
2.2
Energy production
2.3
Primary energy
3.1
Influence on the environ-ment
3.2
Consumption of drinking water
3.3
Ecological construc-tion
Potential of Optima House
OptimaHouse
Modern house according to norm sum

“Smart” modular house

“Straw House” in Zaporizhzhia

“Straw House” under construction

7. Modern urban planning

The most important directions of the formation of sustain complexes

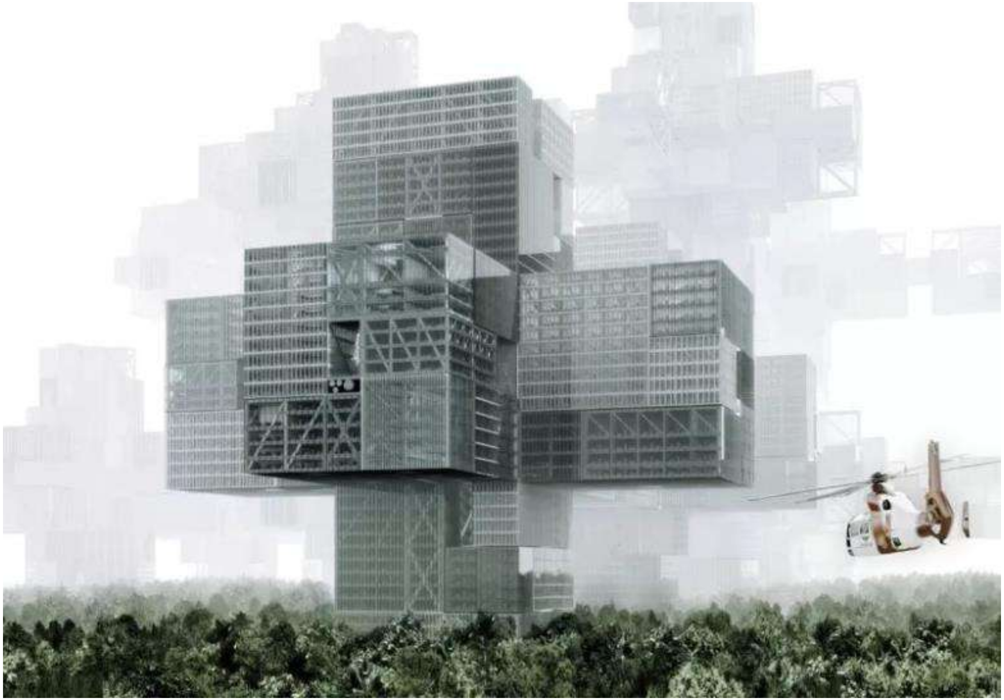
- Relative autonomy in terms of resource use.
- Green spaces in the city.
- Minimization of motor vehicles
- City for people
- “Smart city”.

The Belgian project of the city on the water

Green areas around Great City

Green areas in the middle Great City

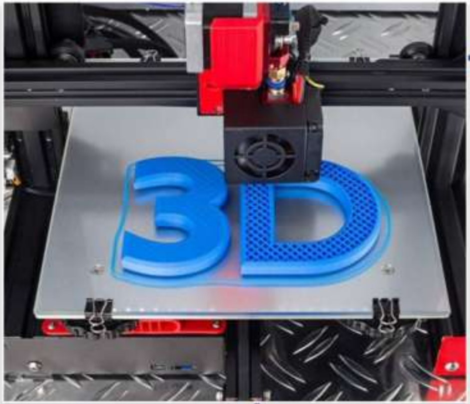
3D-city



The project of “green” modernization Gothenburg (Sweden)

“Smart city”

- Artificial intelligence should come to town (AI), which will manage the life processes of the city, ensuring the economic and ecological efficiency of its functioning.
- Task, which will decide AI, will be constantly get complicated: from rational use of resources and optimization of functioning modes to help in finding a life partner, choosing a profession and preventing criminal offenses.
- AI should become the backbone of all innovations that change the face of cities.



Sustainization of technologies

Presentation materials

Lecture plan

1. Basis of additive technologies
2. Development of 3D-printers
3. Sustainization of agriculture
4. Self-reproducing production systems
5. Convergence and miniaturization

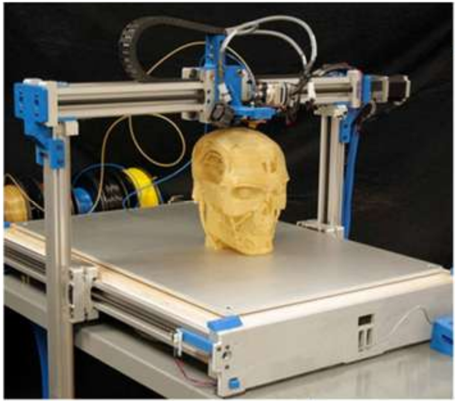
1. Basis of additive technologies

Additive manufacturing (AM)

- Additive manufacturing (AM) is the construction of a three-dimensional object from a CAD model or a digital 3D model. It can be done in a variety of processes in which material is deposited, joined or solidified under computer control, with the material being added together (such as plastics, liquids or powder grains being fused), typically layer by layer.

History

1981	**Hideo Kodama, Nagoya, Japan**
1984	Alain Le Mehaute, Olivier de Witte Jean Claude Andre, France
1984	Chuck Hull, USA
1995	Two students of the Massachusetts Institute of Technology (Boston, USA) called the device a 3D printer



2. Development of 3D-printer

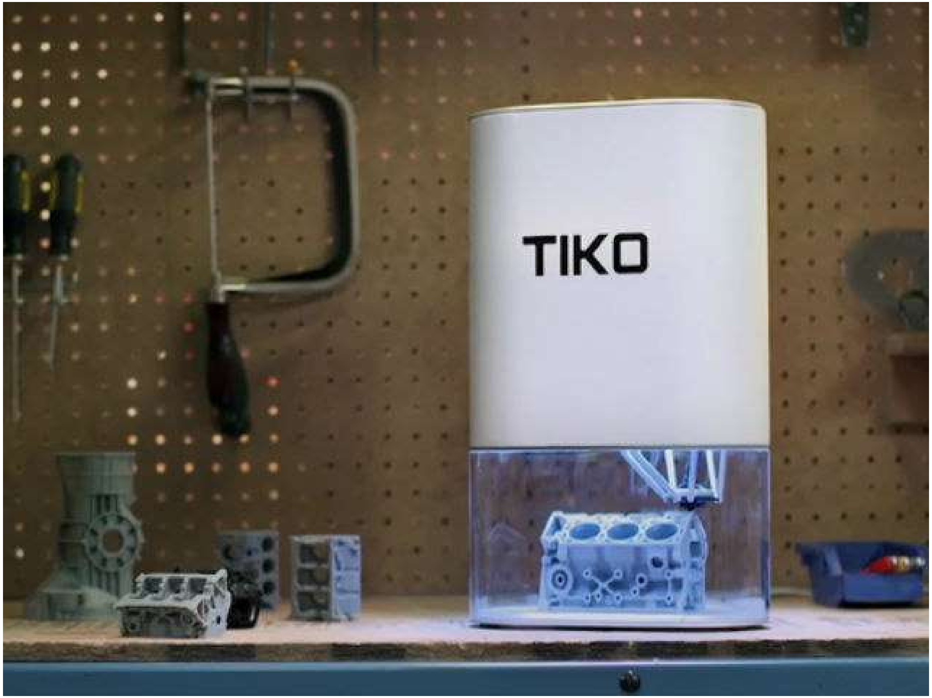
Task, which 3D-printing provides

1) increasing the complexity and variety of products;
2) ensuring flexible variability, that is, the ability to quickly and with minimal costs change the properties of materials;
3) greening of the material basis of the materials used due to their maximum closing to the natural basis;
4) maximum reduction of the cost of materials and the cost of equipment working with these materials

The 3D printer works with 10 materials

- *Massachusetts Institute of Technology:*
- The device works with **ten** different materials at once.
- Uses the technique of
- ***3D scanning***.

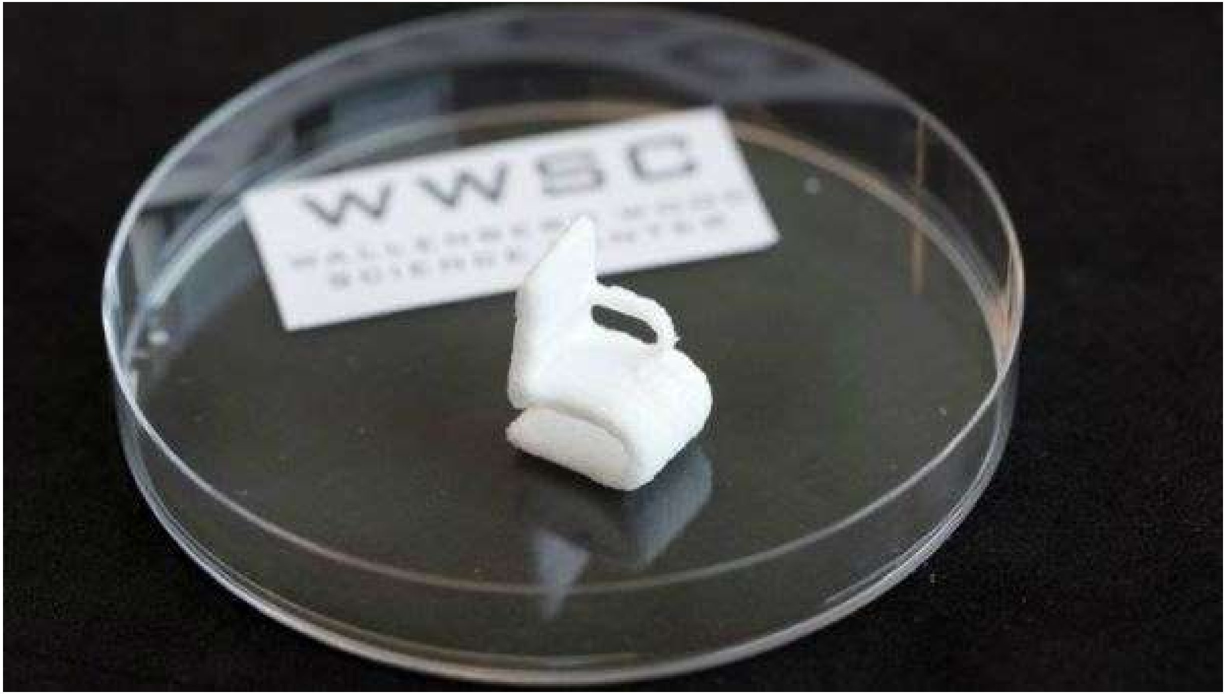
3D printer that costs as much as a refrigerator ($179)



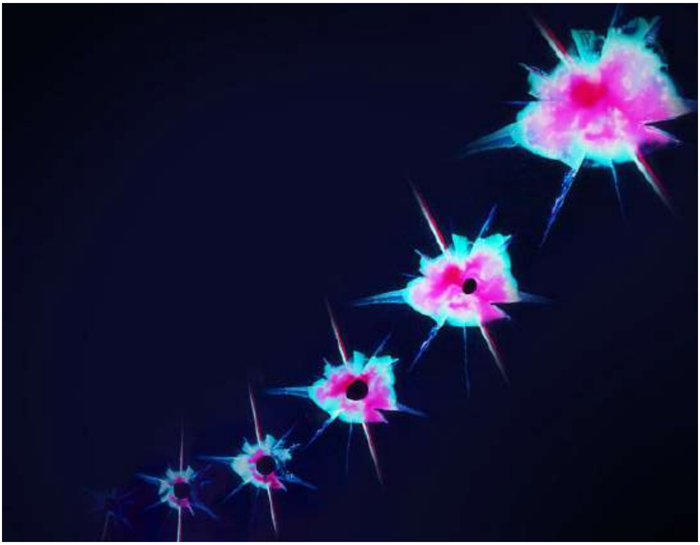
The bio-printer printed a human organ

- The 3D printer printed the mouse's thyroid gland.
- After the transplant, the organ worked

“Ink” for the 3D printer from cellulose



4D printing (self-restoring plastic)



Products printed on 3D-printers

- We also print: smartphone cases, LED lamps, fiber optic cables, shoes, cakes and much more

Printing houses

- House printed on 3D-printers by a Shanghai company

The first in Belgium “printed” on 3D printers two-story

The world's largest city printed on 3D-printers

- The length of the bridge is 25 m, the width is 3.6 m. Before printing, a copy was made on a scale of 1: 4 for strength testing

3D bridge print

- The bridge was printed in Shanghai by two robotic systems 3D-printing in 450 hours (almost 20 days)

- The bridge is equipped with a monitoring system that collects data on the load and deformation of the bridge in real time. This allows you to monitor the properties of materials for further work.

3D-printing of decorative and food products

- Figures from ice and chocolate, printed on 3D- print

3D-shoe printing

3D-printing of biological objects

- Since 2013 year Chinese scientists printed ***ear fragments, liver and kidneys***. Printing of finished organs is expected after 2025.
- In 2015, a new jaw was printed in Belgium for an 83-year-old Belgian woman.
- IN in 2016 printed thyroid gland, which was implanted in laboratory mouse. After the transplant, the organ started to work and began to secrete hormones.

Bandages with skin cells astronauts

3D-printing city layouts

- A historical layout of the central part of Poltava has been printed. The layout features more than 450 buildings with lights and more than 1,500 glowing lanterns.

3D-pens (3D pens)

Decorative objects produced using 3D-pen

Art with help 3D-pen

3. Sustainization of agriculture

Lab –Grown Meat

Cultured meat, cultivated meat, artificial meat

- Cultured meat is grown from real animal cells.
- But this meat was never part of an animal that lived its life
- Cultivated meat now is produced in countries: Australia, Belgium, France, Israel, Singapore, Japan, USA

Lab –Grown Meat

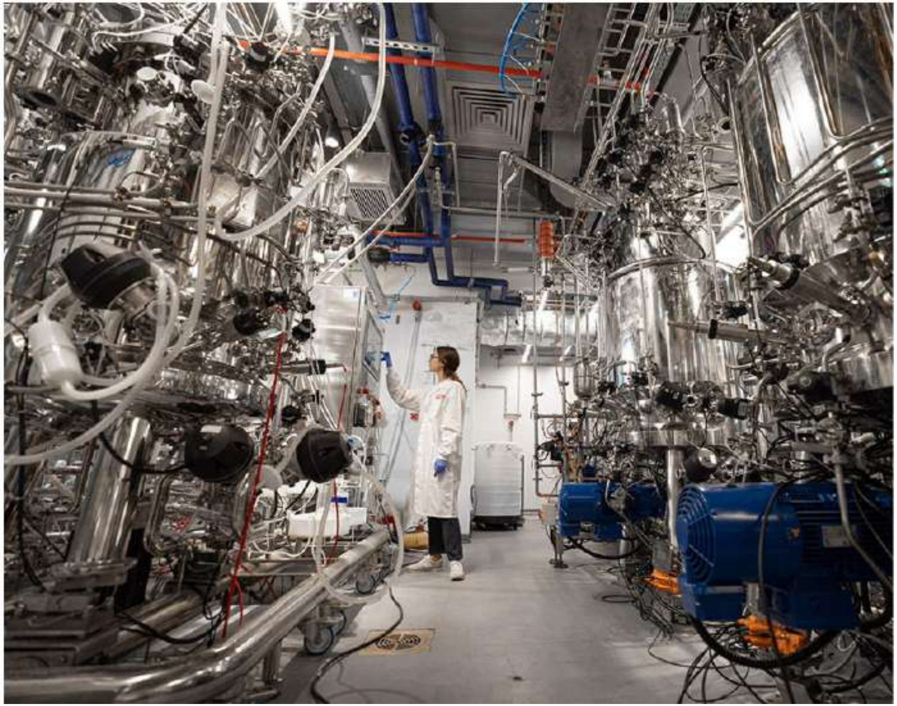
History of cultivated meat

- Winston Churchill once said that it is not advisable to raise a whole chicken in order to eat only the breast or wing from it.
- In 2000-s, his idea became a reality

History of cultivated meat

1971	Professor of patology Rassel Poss (USA) produced muscle fibers for the guinea pig aorta
1991	John Wayne (USA) received a patent for the production of artificial meat for human food
2001	Vit Westerhof, Willvan Koten and Will van Eilen (the Netherlan) received a patent for the production of cultivated meat. They used a collagen matrix which was seeded with muscle cells. Befor researchers try to created artificial skin

The process of meat cultivation



The process of meat cultivation

Methods:

- From collagen matrix, animal cells (biopsy) and protein solution in a bioreactor.
- From vegetable proteins, fats and natural dyes. The 3D printer simulates the layers of Lamb, pork, and beef of a typical piece of meat. It looks tastes, and smells like meat
- Meat from insects: roaches, cockroaches, etc. They are grown, processed, dried, turned into flour. The final stage is meat.

Cultivated meat

Cultivated meat

- Primary animals for meat cultivation were: fish, chicken, guinea pig, turkey, frog, sheep, other.

- The following types of artificial meat are currently being produced: chicken, goose, Lamb, pork, beef, kangaroo, zebra, rabbit, turtle, fish, seafood.

Sustainable importance of cultivated meat

Lab-grown meat is free from:

- Heavy metals
- Other pollutions
- Microplastic
- Parasites
- Antibiotics
- Necessity of extra land
- Necessity of extra water
- Necessity of environmental pollution (≈15% CO_2)

Sustainable importance of cultivated meat

Positives:

- Opportunity of balancing useful components: proteins, fats, vitamins, trace elements, etc.
- Production of cultivated milk began.

Evolution of cost for cultivated meat

2013	One burger	$325 000
2019	One burger	$100
2021	One burger	$3
2021	One chicken breast	$7.50
2023	One chicken breast	$1.70
	One pound of a chicken (453 g)	$7.70

Sustainable Technologies in plant growing

Hydroponics – aggregato-ponics (solid materials), chemoponics (organics), aeroponics

- Soil conservation
- Space saving

Sustainable issues

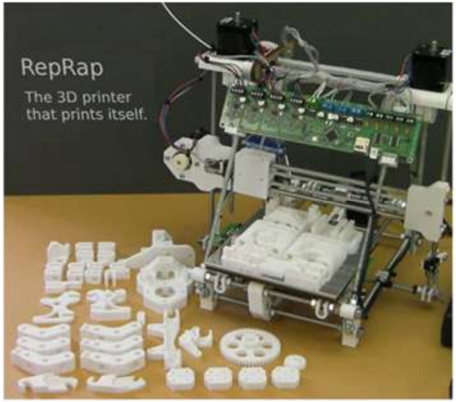
- Water saving
- Protection from insects and rodents
- Protection from weeds
- Cultivation whole year round

Radish

Strawberry

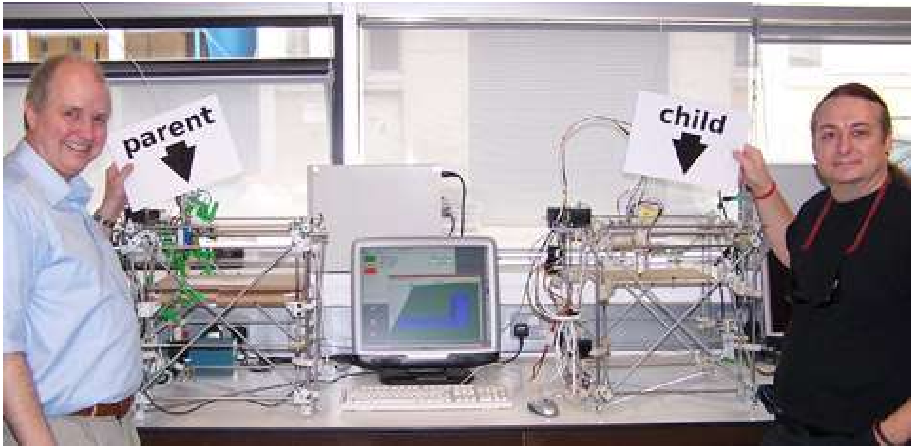
Vertical farms

Vertical farms



4. Self-reproducing production systems

RepRap



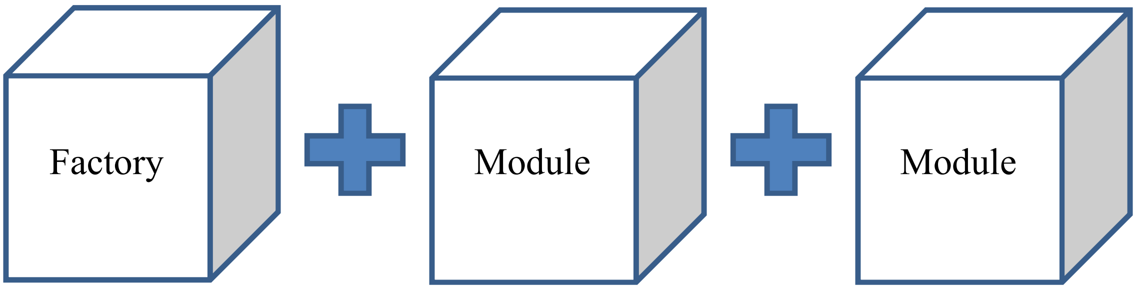
- Adrian Bower(left) and his partner Vic Oliver (Vik Oliver) along with RepRap-“father” (assembled from parts created on a regular 3D-printers) and the first fully completed and operational device RepRap-a “child” who already a few minutes after his “birth” created the first part of his “son”, that is, the “grandson” of the first car.

Factory in a day

- The project "**Factory-in-a-one day**" was initiated in European countries.
- Companies that produce 3D printers and robots sell flexible factories that can be set up in 1 day. These factories are based on software and artificial intelligence.
- The problem only is: How to teach and train workers to make products

Self-building of an additional module

- Massachusetts Institute developed the technology of self-building (self completion) of an additional module
- Using the existing equipment and 3D printers, a plant (factory, itself can complete and expand the necessary production modules)



5. Convergence and miniaturization

An example of convergence

Some functions of a modern mobile phone (iPhone)

Function	Function
➢ Phone	➢ Notebook
➢ Computer	➢ Clock
➢ Camera	➢ Timer
➢ Slide scope	➢ Flashlight
➢ Video camera	➢ Calendar
➢ Dictionary	➢ TV-receiver
➢ Library	➢ Radio
➢ Dictaphone	➢ Transmitter
➢ Calculator	➢ Player
➢ Directory	➢ Printer
➢ Remote control	➢ Corrector
	➢ Navigator (GPS)

Топ 10 Emerging Technologies of 2023-2024

Flexible batteries, 2023

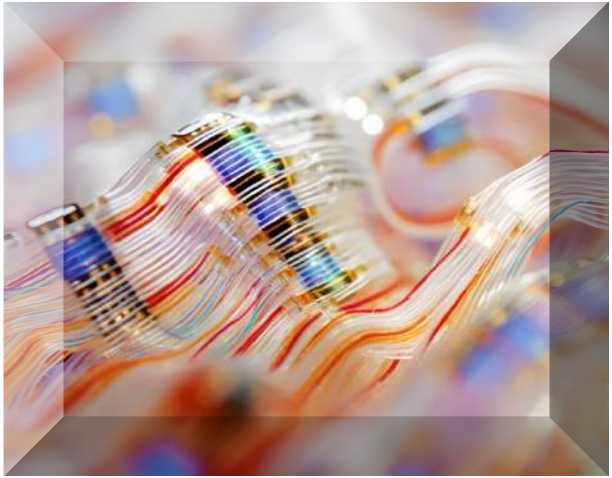
Powering wearable technologies for healthcare and e-textiles

- Powering wearable technologies for healthcare and e-textiles

Flexible neural electronics, 2023

Better engineered circuits to interface with the nervous system

- Researchers have recently developed brain interfacing circuits on biocompatible materials that are soft and flexible

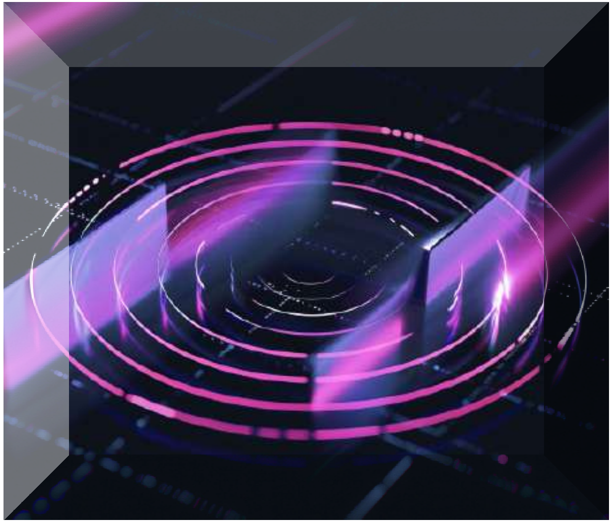


Flexible neural electronics, 2023

- Flexible circuits can conform to the brain, reducing scarring and sensor drift, and they can be packed with enough sensors to stimulate millions of brain cells at once, vastly outperforming the scale and timeframe of hard probes

Reconfigurable intelligent surfaces (RIS), 2024

Transforming wireless connectivity with smart mirrors



- RIS enable the precision focusing control of electromagnetic waves, reducing interference and the need for high transmission power. Equally, RIS are highly adaptive and can dynamically adjust configurations according to real-time demands. This adaptability enables efficient use of resources and enhances energy efficiency in wireless networks

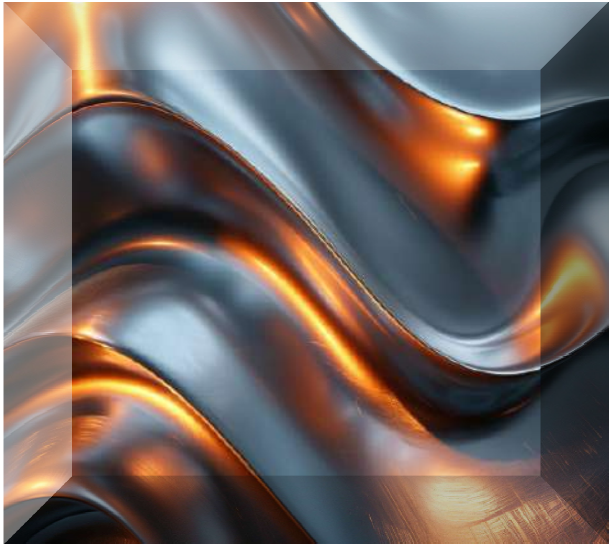
Reconfigurable intelligent surfaces (RIS), 2024

- For example, tailored radio wave propagation in smart factories can ensure reliable communication in a highly complex environment. RIS allow sensors to transmit data with minimal power for the internet of things (IoT), which demands considerable energy.
- For vehicular networks, RIS enhance safety by enabling robust communications between vehicles and infrastructure.
- To improve coverage in agricultural settings, RIS are a promising solution with low energy consumption and high-cost efficiency.

Elastocalorics, 2024

Powering heat systems to work like muscles

- Elastocaloric heat pumps are an innovative technology that can drastically reduce the energy required for heating and cooling several times over.



Elastocalorics, 2024

- The heart of this technology is elastocaloric materials, which emit heat when subjected to mechanical stress and cool down when the stress is relaxed. This allows them to operate on a continuous stress and relaxation cycle.
- The added benefit of elastocaloric heat pumps is that they do not rely on refrigerant gases, which are potentially damaging to the environment. Instead, they make use of widely available metals like nickel and titanium.
- Taken together, the environmental impact of catering to emerging energy requirements for temperate control can be significantly reduced by elastocaloric technology.

Wearable plant sensors, 2023

Revolutionizing agricultural data collection to feed the world

- These sensors are small, non-invasive devices that can be attached to crop plants for continuous monitoring of temperature, humidity, moisture and nutrient levels. Data from plant sensors can optimize yields, reduce water, fertilizer and pesticide use, and detect early signs of disease.

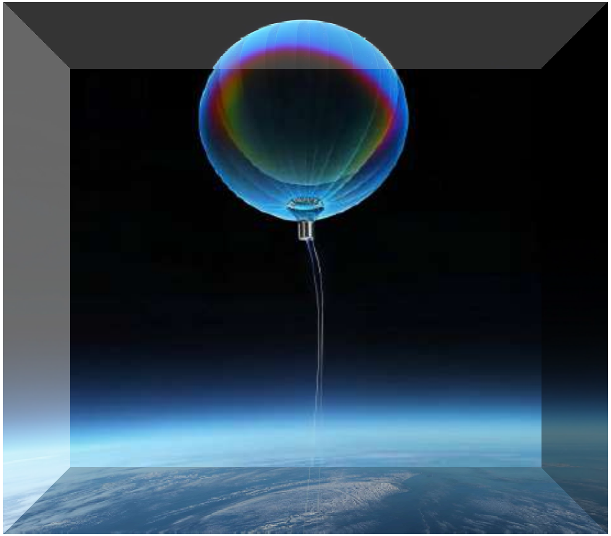
Wearable plant sensors, 2023

- Farmers can thus monitor crops in real time and perform precise interventions based on the specific demands of plants, such as adjusting irrigation or fertilizer application in response to moisture levels or nutrient data.

High altitude platform stations (HAPS), 2024

Bridging the internet divide from the stratosphere

- HAPS operate at stratospheric altitudes, approximately 20 kilometres above Earth. Typically taking the form of balloons, airships, or fixed-wing aircraft, they offer a stable platform for observation and communication and can operate for months.



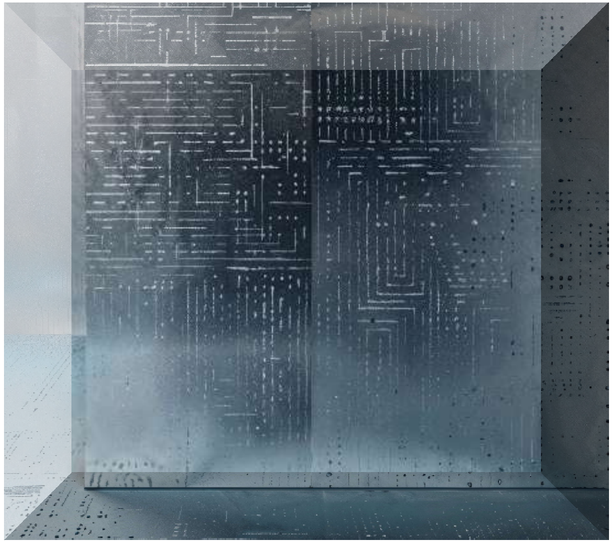
Designing and implementing net-zero-energy data centres

- Achieving net-zero-energy data centres will involve innovative approaches to integrating the above mentioned approaches with new electricity generation, storage and management technologies. Given the wave of innovation and investment in this area, there is reason to be optimistic about the years ahead.

Privacy-enhancing technologies, 2024

Empowering global collaboration at scale

- Powered by advances in AI, synthetic data removes many of the restrictions to working with sensitive data and opens new possibilities in global data sharing and collaborative research on biological phenomena, health-related studies, training AI models and more.



Integrated sensing and communication (ISAC), 2024

Building next-generation networks with digital awareness

- ISAC bring sensing and communication capabilities into a single system, facilitating simultaneous data collection and transmission. This integration optimizes hardware, energy and cost efficiency while also enabling novel applications beyond conventional communication paradigms.

Integrated sensing and communication (ISAC), 2024

- Examples of this include environmental monitoring systems that use sensors and data analytics to monitor air and water quality, soil moisture and weather conditions.
- These systems help in smart agriculture, environmental conservation and urban planning.
- Additionally, smart grids integrate sensors and communication technologies into power grids, enhancing efficiency and reliability while enabling the monitoring of electricity consumption and generation.

Generative artificial intelligence, 2023

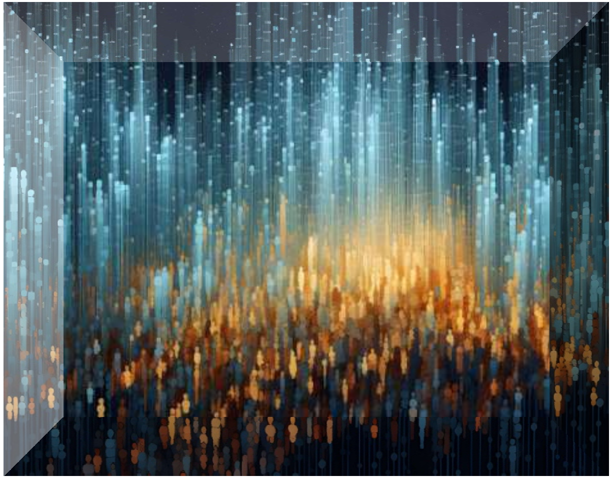
Expanding the boundaries of human endeavour

- Generative artificial intelligence (AI) is a powerful type of AI that can create new and original content by learning patterns in data, using complex algorithms and methods of learning inspired by the human brain

AI-facilitated healthcare, 2023

New technologies to improve the efficiency of healthcare systems

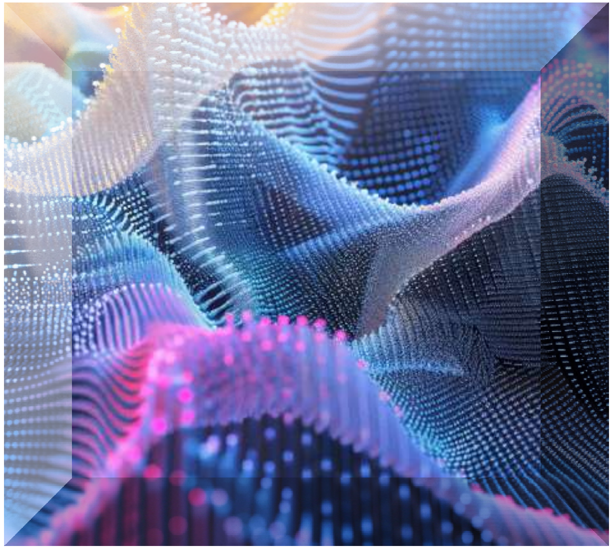
- In response, government-based and academic teams have been created to integrate AI and machine learning (ML) into healthcare – both to anticipate impending pandemics and to aid in effectively addressing them.



AI for scientific discovery, 2024

Pioneering new frontiers in knowledge

- AI is emerging as a transformative general-purpose technology in scientific research that can unearth discoveries that would have otherwise remained hidden.



Metaverse for mental health, 2023

Shared virtual spaces to improve mental health

- Excess screen time and social media can decrease psychological well-being, but they can also enhance well-being when used responsibly. Screen time spent building connections in shared virtual spaces might help combat the growing mental health crisis as opposed to contributing to it

Immersive technology for the built world, 2024

Laying new foundations for construction and maintenance

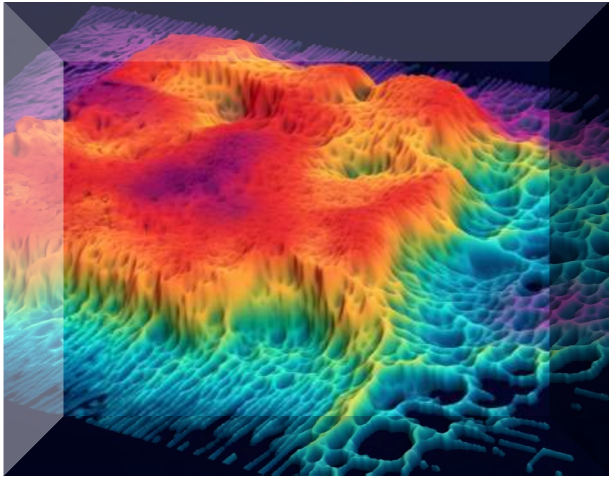
- Immersive and AI-driven immersive reality tools for the built world allow designers and construction professionals to check the congruence between the physical and digital, ensuring accuracy and safety and advancing sustainability.

Immersive technology for the built world, 2024

- Immersive design experiences help anticipate the challenges that could evolve during construction by testing hypotheses, identifying potential errors and providing solutions before construction starts.
- Virtual prototyping and experimentation increase accuracy.
- Digital twins could be used to simulate outcomes of far more complex proposals for urban development projects, better develop infrastructure and serve constituents, and allow greater efficiency and effectiveness.
- Crucially, this would streamline the construction process from design to implementation, allowing waste to be identified and eliminated, improving both efficiency and sustainability.

Spatial omics, 2023

Molecular-level mapping of biological processes to unlock life’s mysteries



- By combining advanced imaging techniques with the specificity and resolution of DNA sequencing, this emerging method enables the mapping of the what, where and when of biological processes at the molecular level
- Spatial omics allows previously unobservable cell architecture and biological events to be viewed in unprecedented detail.

Designer phages, 2023

Engineering viruses to augment human, animal and plant health

- Key to this engineering are phages – viruses that selectively infect specific types of bacteria. Upon infection, a phage injects its genetic information into the bacterium.

Virus (phage) engineering, 2023

- Using synthetic biology tools, the genetic information of phages can be reprogrammed so that infected bacteria execute a bioengineered set of genetic instructions. With bioengineered phages, scientists can change a bacterium’s functions, causing it to produce a therapeutic molecule or to become sensitive to a certain drug.
- For example. As phages generally only infect one type of bacteria, individual bacterial species within the complex microbiome can be targeted.

Carbon-capturing microbes, 2024

Engineering organisms to convert emissions into valuable products

- Microorganisms are being used to capture greenhouse gases from air or exhaust gases and convert them into high-value products. To drive this process, the organisms use sunlight or chemical energy such as hydrogen.

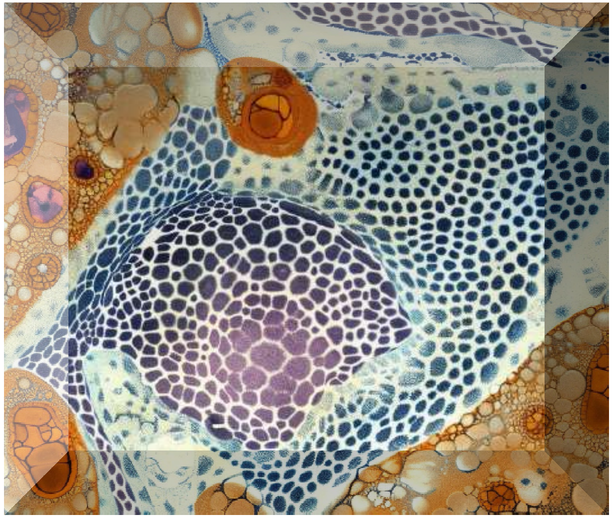
Carbon-capturing microbes, 2024

- There are two main designs for microbial carbon capture. The first, photobioreactors, use photosynthetic organisms like cyanobacteria and microalgae to capture CO_2, employing sunlight to process CO_2-laden gas bubbled through a bath containing such organisms.
- The second is when microorganisms capture CO_2 by using energy from sources like hydrogen, organic waste streams or other chemicals derived from CO_2 using renewable energy.
- Regardless of whether they use sunlight or chemicals for energy, both systems modify organisms to convert CO_2 into new products, such as biodiesel or protein-rich animal feed.

Genomics for transplants, 2024

Gene-editing organs for transplantation advancements

- The ability to understand and precisely edit the genome has enabled the first successful transplantation of a non-human (pig) kidney into a living human recipient in March 2024



Sustainable aviation fuel, 2023

Moving the aviation industry towards net-zero carbon emissions

- Enter a solution that does not require largescale changes to current aviation infrastructure and equipment: sustainable aviation fuel (SAF), produced from biological (e.g. biomass) and nonbiological (e.g. CO_2) resources.

Alternative livestock feeds, 2024

Revolutionizing animal nutrition for sustainability

- These feeds, sourced from insects, single-cell proteins, algae and food waste, provide viable alternatives to traditional ingredients like soy, maize and wheat.
- Transitioning to alternative livestock feeds could promote more environmentally sustainable practices in animal agriculture.

Informatization of economic systems

Presentation materials

Lecture plan

1. Signs for informatization of economic systems
2. Concept of information
3. The role of information in the economy and business
4. Features and content of information goods
5. Unique properties of information goods
6. Trends in socio-economic development during

1. Signs for informatization of society

Modern information trends

From:

- ***information dimension of the material entity***

to:

- ***information dimension of the information entity***

- ***Reason:*** increasing modes (speed, pressure, temperature, aggressiveness, pace of life) of equipment operation and prices of failure and errors

Information measurement indicator

- **Quality** is an indicator of information measurement.
- ***Particles*** play a primary role in it : *millimicrons, milligrams, milliseconds, hundredths of a degree*
- Key features: ***reliability, accuracy, long term*** etc.
- Names companies are the indicators of a class: *“Sony”, “Bosch”, “Nokia”, “Adidas”, “Mercedes”, “Toyota”, “IBM”.*

2. Concept of information

The role of information

- **Information**, along with matter, is the basis of the formation and development of natural and social systems.
- Any of them carries both a material and informational principle, mutually conditioning and mutually forming one other

Functional signs of information

- In the works of scientists (Brillouin, Winer, Reimers, Ursula, Shannon, Ashby) are formulated the functional characteristics of information

  - message;
  - measure of probability and uncertainty;
  - display form;
  - the reality that forms matter;
  - development program;
  - organizing principle;
  - natural resource;
  - criteria of difference;
  - degree of diversity;
  - degree of heterogeneity;
  - choice of alternative;
  - degree of choice;
  - measure of arrangement.

Definition of information

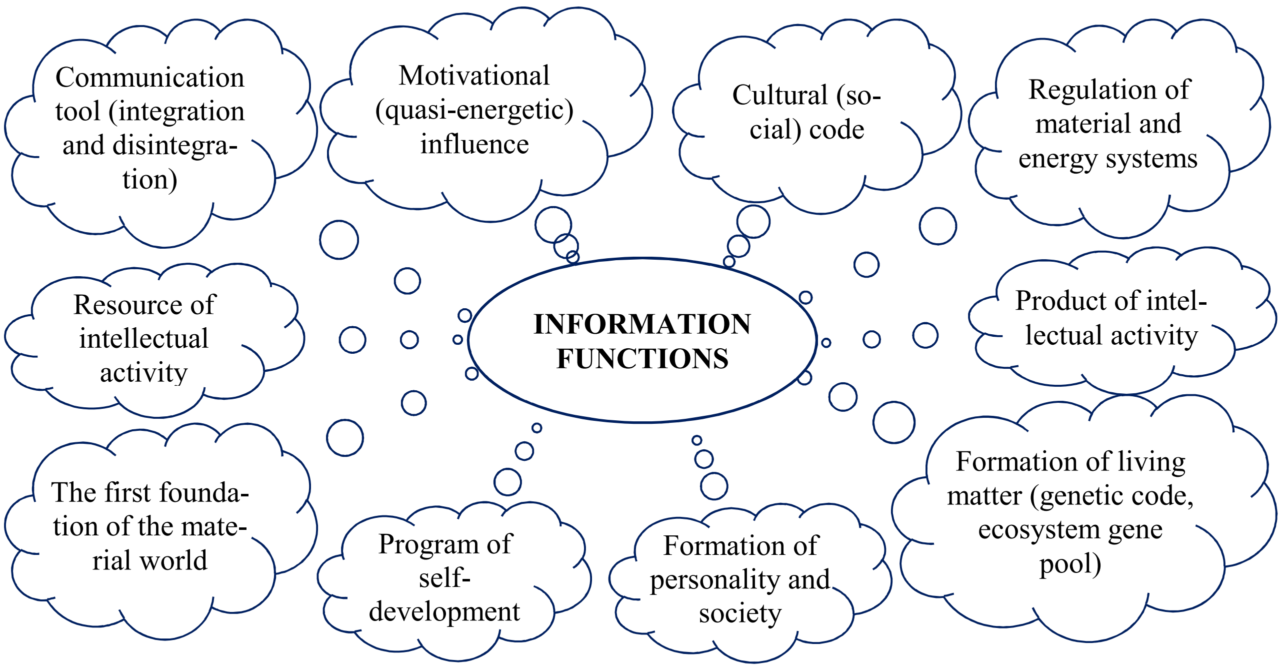
Information

- is a natural reality that carries the characteristic features of objects and natural phenomena that manifest in space and time

Material status of information

- ***Information is intangible***. It does not have the two main characteristics of material objects – charge and mass.
- However material objects are the carrier of information.
- It is formed with the help of energy potential differences fixed in the system's memory (between the elements inside the system and between the system and the external environment).
- They determine the ability of the system to change in space and time.

Functions of information



Human information products

- emotions;
- knowledge;
- artistic images;
- ideas;
- constructive principles;
- technological solutions;
- decisions made;
- commands to action.

Information products

Information products can be in the form of:

- ***blanks*** (for example, collected and analyzed facts),
- ***semi-finished products*** (ideas),
- ***finished products*** (information services, for example, consultations) or ***information goods***
- "***information nodes***" (of artistic samples) and
- ***complex systems*** (technological solutions).

3. The role of information in the economy and business

Economic functions of information

- ***raw;***
- ***means of labor;***
- ***subject of work;***
- ***final product;***
- ***means of consumption;***
- ***capital*** (source of income);
- ***goods*** (object of purchase and sell);
- ***object of ownership;***
- ***means of protection.***

Reasons for increasing the role of information

1) Acceleration of development rates:

- in the second half XIX Art. the average period of technology change is 50 years;
- in the first half XX Art. – 15-30 years old;
- in the second half XX Art. – 5-10 years;
- Early XXI Art. – 1-2 years, and in some industries several months.

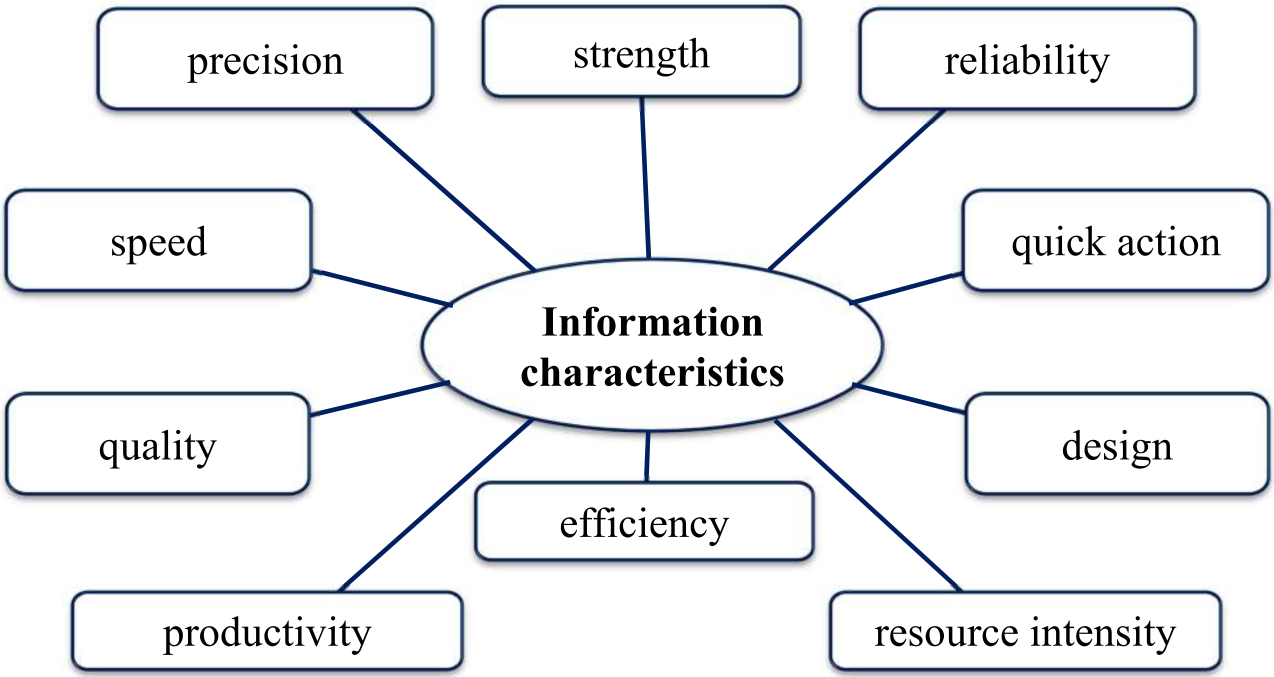
Reasons for increasing the role of information

2) Only information allows you to answer the questions: "What to produce?", "How to produce?", "For whom to produce?"

3) Expansion of technical capabilities – allows to involve ordinary and cheap materials in production (orientation not on material, but on function).

4) Increasing requirements for information characteristics (accuracy, reliability, energy efficiency, etc.)

Information as a subject of work



Information as a tool

Information plays a leading role in the performance of production functions

Information has a predominant share in the cost of production assets (up to 80-90%)

Information as goods. The top ten richest people, 2025

1. Elon Musk

- CEO of Tesla (electric car), SpaceX (space technology) and company X (social media), xAI (the AI firm), Boring Co

2. Jeff Bezos

- The founder of Amazon (the world's largest online store), the company Blue Origin (private space flights)

3. Larry Allison

- Chairman and Chief Technology Officer company Oracle (software)

4. Mark Zuckerberg

- Founder and CEO of Meta Platforms, which owns Facebook, Instagram and WhatsApp (social networks and technology)

Information as goods. The top ten richest people, 2025

5. Bernard Arnault

- CEO and chairman of LVMH (moda and luxury goods)

6. Larry Page

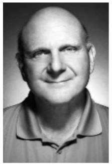
- Co-founder of Google (Internet technologies)

7. Sergey Brin

- Co-founder of Google (computer engineering, information technology)

8. Warren Buffett

- Chairman and CEO of Berkshire Hathaway (investments and finance)



9. Steve Ballmer

- Former CEO of Microsoft (2000-2014); investor in Social Solutions (production of software for non-profit organizations and government institutions)

10. Jensen Huang

- Co-founder of Nvidia (production of graphics processing units (GPUs) and artificial intelligence hardware)

4. Features and content of information goods

Functions of means of production

- ***raw*** (databases, statistical and analytical information, expert assessments, etc.);
- ***means of labor*** (computer programs, technological solutions, management technologies, etc.); including, information can even perform the role of a "working body" when affecting material objects (such, for example, are means of protection: in particular, anti-virus computer programs, insect repellants, etc.);

Functions of means of production

- ***items of labor or semi-finished products*** (genetic information, manuscripts and variants of artistic works, etc.);
- ***products of labor*** (advice, recommendations, information services of intermediaries, etc.);
- ***communication tools*** (example, means communication);
- ***labor factors*** (knowledge, skills, outlook, beliefs, ability to work in a team, etc.).

Consumer goods

- ***production purpose*** (for example, manuals for running a subsidiary farm, auxiliary materials for self-training, etc.);
- ***household purpose*** (for example, humidity or temperature control systems);
- ***ecological purpose*** (monitoring systems);
- ***means of reproduction of the human condition as a biological organism*** (recreational services and equipment);

Consumer goods

- ***means of satisfying human social needs*** (cultural and artistic works, tourist, cultural and sports services, spectacles, etc.);
- ***means for forming personal characteristics of a person*** (education, training, etc.);
- ***means for performing socially determined functions*** (legislation, state and territorial administration, social protection etc.).

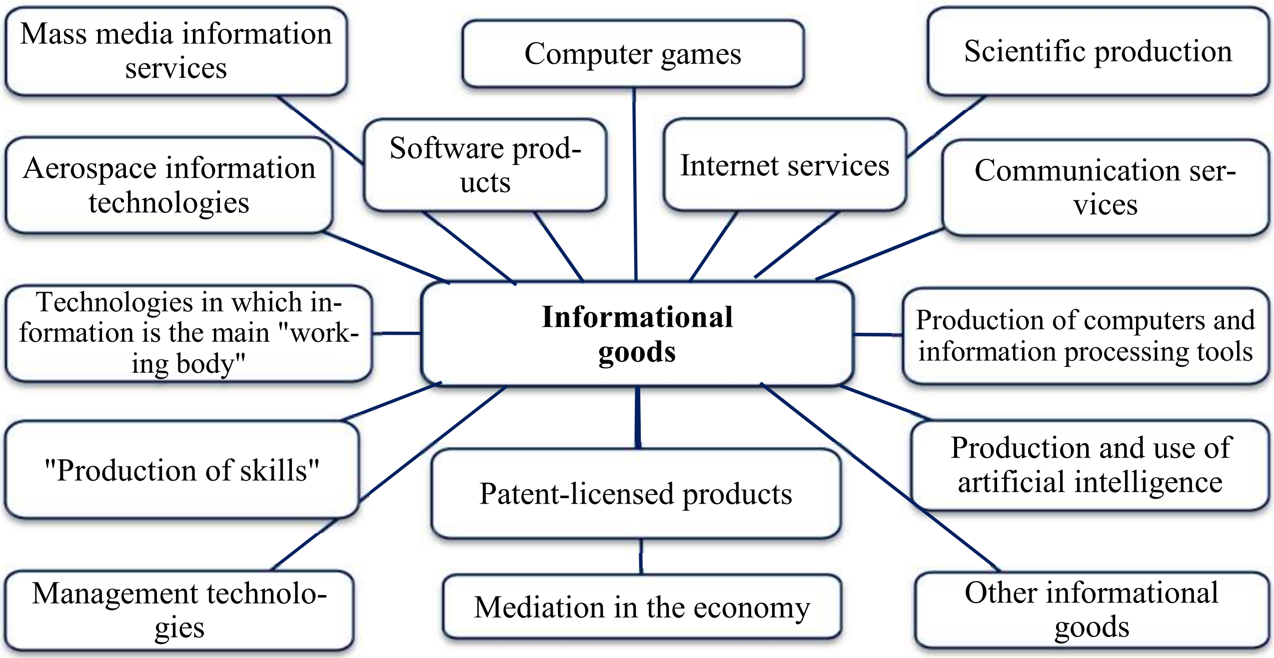
Information status

- ***goods materializing information***(science-intensive products and services);
- ***goods intended to influence information***(computers, memory devices);
- ***goods that use information in production*** as a “working subject” (genetic engineering, educational technologies);
- ***goods that use information as an object of consumption*** (tourism, perfumery);
- ***goods that are themselves information***(computer programs, virtual services).

Traditional information services

- education;
- medicine;
- arts;
- cultures;
- show business;
- tourism;
- sports;
- recreation;
- architecture;
- advocacy;
- politics and much more.

New types of information goods



5. Unique properties of information goods

Unique properties of information goods

- Any computer program, design idea or technological “know-how” can be used simultaneously by all the inhabitants of the Earth.
- The appearance of each of the replicated programs does not mean the disappearance of “something” (in the sense of a material and energetic substance); copies of programs appear with the click of a button.
- After any selling software or video products, it does not disappear from the seller.

Unique properties of information goods

- Buyer, having barely purchased an information product, at the same time gets the technical opportunity to reproduce it himself, and therefore sell it.
- Information products (unlike material goods) are not consumed, but used – because they cannot be “consumed” (meaning used without remainder); no matter how much you use them, it does not become less.
- Information products do not wear out physically (unlike their material carriers; they can wear out only morally, in particular, become obsolete).

The role of information in the development of economic systems

- Providing people with resources does not depend on the number of explored resources, but on ***information technology development*** (including: extraction and use of resources and satisfaction of one's needs).

The role of information in the development of economic systems

- Systems (social and economic) that are better able to ***accumulate***, ***fasten*** and ***use*** information
- Progress is an increase in the degree of informativeness of systems.
- Information becomes the basis ***means of production*** and the main ***consumer product***.

6. Trends of socio-economic development during the transition to the information society

A key trend

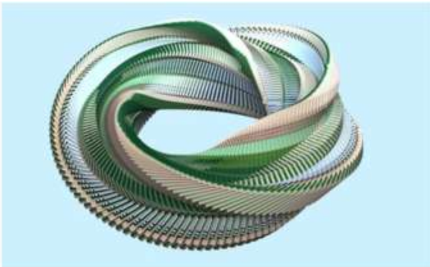
- The key transformation must take place in the person. In trend "bio-labor-socio" the personal essence of a person should take the leading position – his "social"
- Digital technologies significantly change the social life and business landscape, making it more "human-centred"

Business Digital Transformation

- Digital transformation is a fundamental transformation of the way the organisation operates.

- The goal of digital transformation should be to create a competitive advantage through the continuous deployment of technology at scale to improve customer experience and lower costs.

McKinsey & Company



McKinsey Explainers

What is digital transformation?

Digital transformation is the rewiring of an organization, with the goal of creating value by continuously deploying tech at scale.

What we mean by digital and AI transformation

Global Innovation Tracker Dashboard 2023

Science and innovation investment

	Scientific publications	R&D investments		Venture capital		International patent filings
		Global total	Top corporate R&D spenders	Deal numbers	Deal values	
Short term	1.5% 2021 → 2022	5.2% 2020 → 2021	7.4% 2021 → 2022	17.6% 2021 → 2022	−37.8% 2021 → 2022	0.3% 2021 → 2022
Long term (annual growth)	4.9% 2012 → 2022	4.8% 2011 → 2021	n.a.	9.9% 2012 → 2022	20.6% 2012 → 2022	3.6% 2012 → 2022

Global Innovation Tracker Dashboard 2023

Technological progress

	Computing power		Costs of renewable energy		Electric battery price	Cost of genome sequencing	Drug approvals
	Moore's Law	Green supercomputers	Solar photovoltaic	Wind			
Short term	54.6% 2021 → 2022	54.3% 2021 → 2022	−12.8% 2020 → 2021	−13.2% 2020 → 2021	7.1% 2021 → 2022	−23.3%* 2021 → 2022	−26.0% 2021 → 2022
Long term (annual growth)	43.7% 2012 → 2022	35.4% 2013 → 2022	−17.0% 2011 → 2021	−9.6% 2011 → 2021	−15.3% 2012 → 2022	−22.3%* 2012 → 2022	−0.5% 2012 → 2022

Global Innovation Tracker Dashboard 2023

Technology adoption

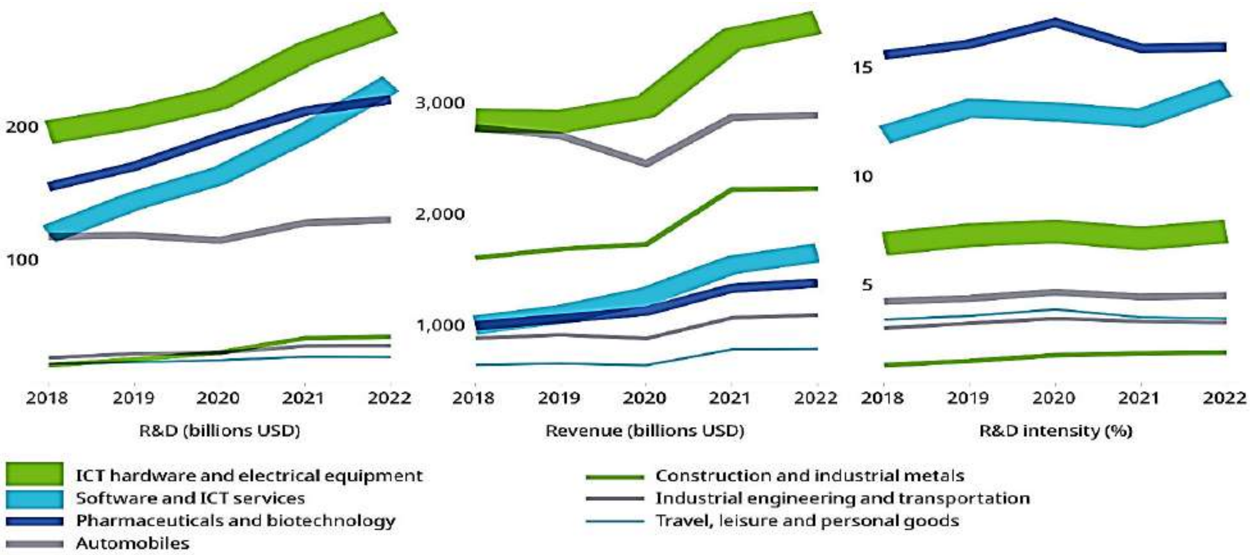
	Safe sanitation	Connectivity: Fixed broadband	Connectivity: Mobile broadband	Robots	Electric vehicles	Cancer radiotherapy
Short term	1.4% 2021 → 2022	4.8% 2021 → 2022	6.0% 2021 → 2022	14.6% 2020 → 2021	59.9% 2021 → 2022	−1.4% 2020 → 2022
Long term (annual growth)	2.4% 2012 → 2022	6.7% 2012 → 2022	14.8% 2012 → 2022	11.7% 2011 → 2021	63.5% 2012 → 2022	−1.3% 2012 → 2022
Penetration	57 of 100 inhabitants in 2022 (45 in 2012)	17.6 per 100 inhabitants in 2022 (16.8 in 2021)	86.9 per 100 inhabitants in 2022 (82.0 in 2021)	n.a.	2.1 of 100 cars in 2022 (1.3 in 2021)	20.9 of 100 countries in 2022 (21.5 in 2020)

Global Innovation Tracker Dashboard 2023: technology impacts

Socioeconomic impact

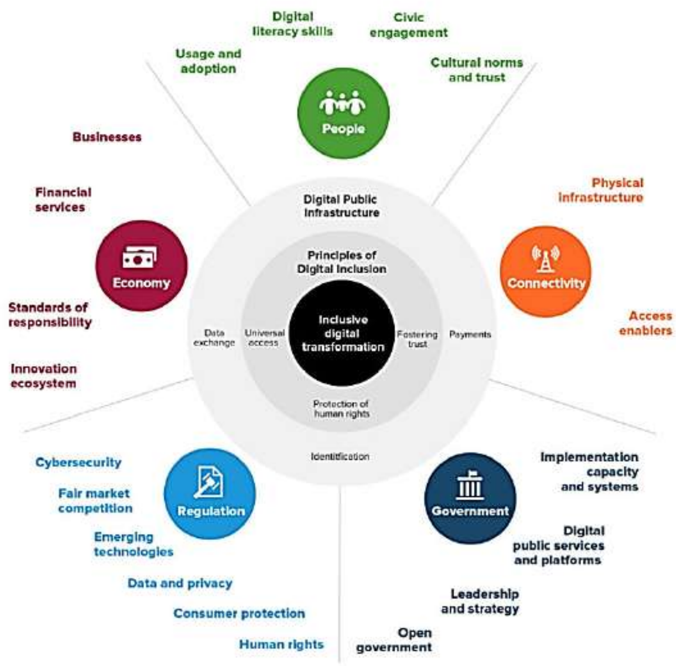
	Labor productivity	Life expectancy	Carbon dioxide emissions	
Short term	0.0% 2021 → 2022	−1.3% 2020 → 2021	5.3% 2020 → 2021	1.7%* 2021 → 2022
Long term (annual growth)	2.2% 2012 → 2022	0.0% 2011 → 2021		0.7% 2011 → 2021

R&D expenditure and revenue totals of top global corporate R&D spenders, by industry and year, 2018-2022

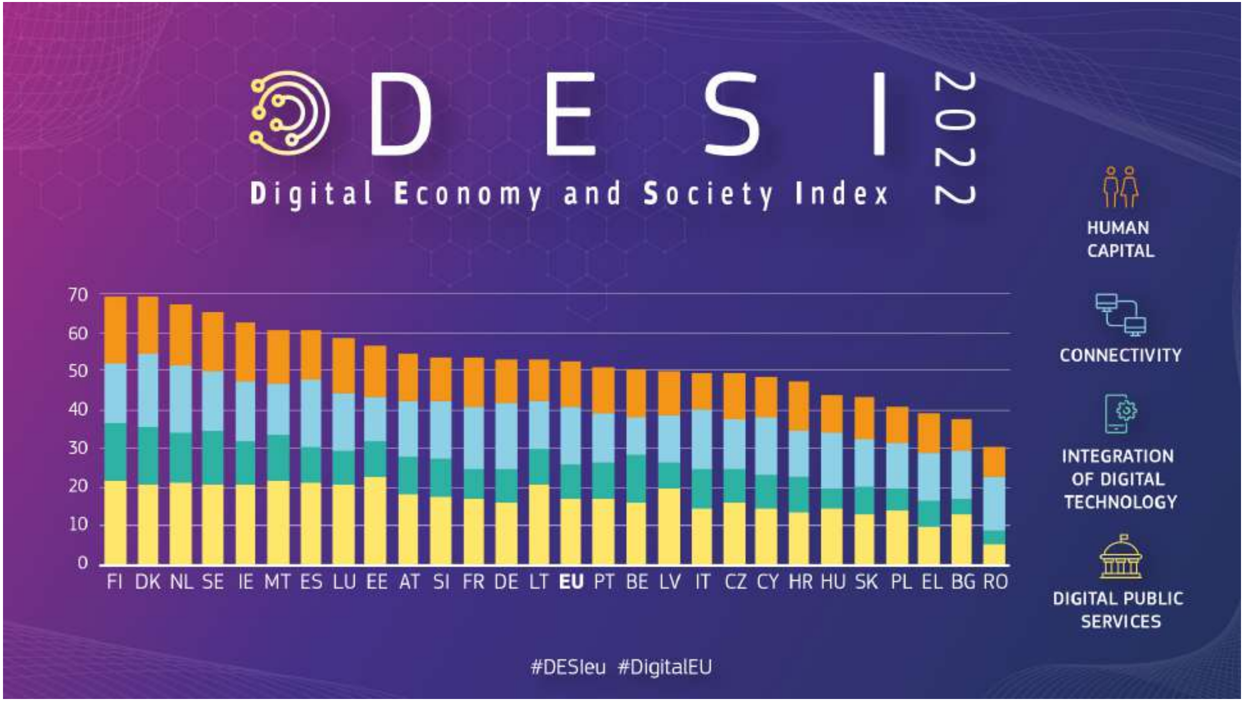


Source: WIPO, based on BvD Orbis database.

UNDP Digital Transformation Framework



The Digital Economy and Society Index (DESI)



The content of current trends of socio-economic development

Presentation materials

Lecture plan

1. Concept of trend
2. Types and content of socio-economic trends
3. Characteristics of megatrends
4. Characteristics of metatrends

1. Concept of trend

Trend definition (broad context)

Trend, tendency
(in a broad context)

- is relatively stable (sustainable) direction of development of a certain phenomenon

Trend definition (broad context)

In economic systems, the trend is implemented through dynamics of:

- sets of relationships (between some parts of systems);
- properties (inherent in systems);
- indicators of income and costs;
- supply and demand;
- user preferences;
- parameters of the technological base, etc.

The influence of the trend on the future

Mark Esposito (Professor of Harvard University):

> "Socio-economic trend is the trajectory of events that occur today, but affects future changes (in particular, demographic or natural resource nature), as well as the possibilities of solving problems in the future (for example, climatic or social)"

Trend definition (narrow context)

Trend

- is compliance with normative features or dynamic characteristics of a certain period of time (in particular, this can be observed on the example of the phrase "to be on trend")

Characteristic features of the trend (tendencies)

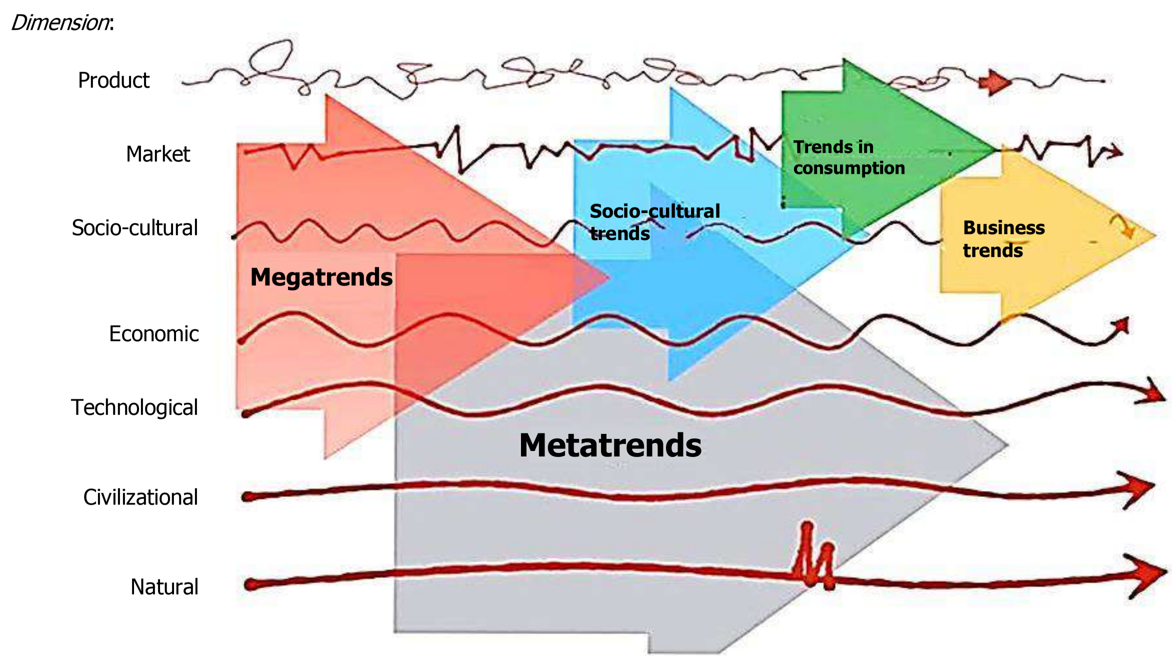
- They characterize the dynamics of processes (that is, phenomena that occur over time);
- Determine the direction of their actions in the conditional socio-economic space.

Similar terms

- direction/direction;
- direction;
- vector;
- trajectory;
- attractor;
- mainstream.

2. Types and content of socio-economic trends

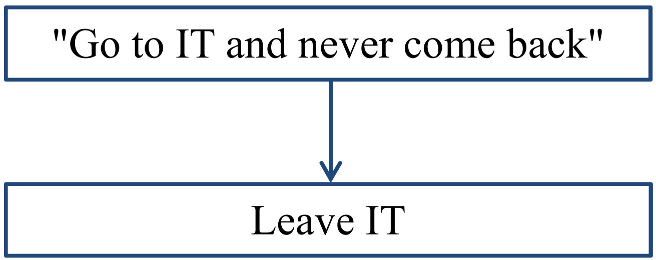
Relationship between socio-economic trends



Characteristic features of trends

- Turbulent nature
- Wave character
- Spiral character (in every trend there is an anti-trend)

Example



Characteristics of socio-economic trends

- ***Socio-cultural trend*** – products find their supporters among the population and entrepreneurs;
- ***Trend in consumption*** – consumers are beginning to massively switch to new types of products;
- ***Business trend*** – the use of new technologies for the production of a new type of product turns into a profitable business platform.

Characteristics of socio-economic trends

- ***Product trend*** – the new product begins to take on the characteristics of a profitable commercial product;
- ***Market t.*** – new products begin to compete on the market with their analogues;
- ***Technological t.*** – the disruptive technology finds areas of its application in practical activities;
- ***Civilizational t.*** – defines people way of life;
- ***Natural t.*** – defines the relationship between man and nature

3. Characteristics of megatrends

Characteristics of megatrends

- **A megatrend** is a large-scale long-term trend of social development, which determines the change in the qualitative parameters of socio-economic systems.
- Z. Efrat concretizes the concept of a megatrend and defines it as global sustainable macroeconomic forces of development that affect business, economy, society, culture and personal life, thereby determining our future world and the pace of its development.

Examples of megatrends

- *combination in disjunction*, in other words, joint actions in individual isolation. The effect of this trend has especially intensified in the context of the latest COVID-19 pandemic;
- *spread of artificial intelligence* in all spheres of life;
- *increase in capacity (in gigabytes) of individual connection of information systems* both someone and something with a constant decrease in the specific cost of such a connection;

Examples of megatrends

- *the spread of the "instant economy of things"* and modes of "instant fulfillment" of orders, which can be carried out by drones, robots or even young people on bicycles or scooters;
- *development of cellular agricultural production*, which would provide high-quality and healthy protein;
- *sensory revolution*, which means a significant increase in the sensitivity of devices and the use of new opportunities in various fields of activity (in trade, in particular, it may mean the transition from card payments to "face" payments);
- *transition to resourceful and flexible marketing management*.

Increasing the efficiency of technical systems over 35 years

Technical means/process	Multiplicity of changes, times
The processor in the computer	10000
Sensor and RFID tag	1000
Execution of one conditional operation on an automatic device	1000
Video surveillance	500
Reduction of the production cost of 1 kWh. electricity on a solar battery	150

Meat from a test tube (from stem cells)

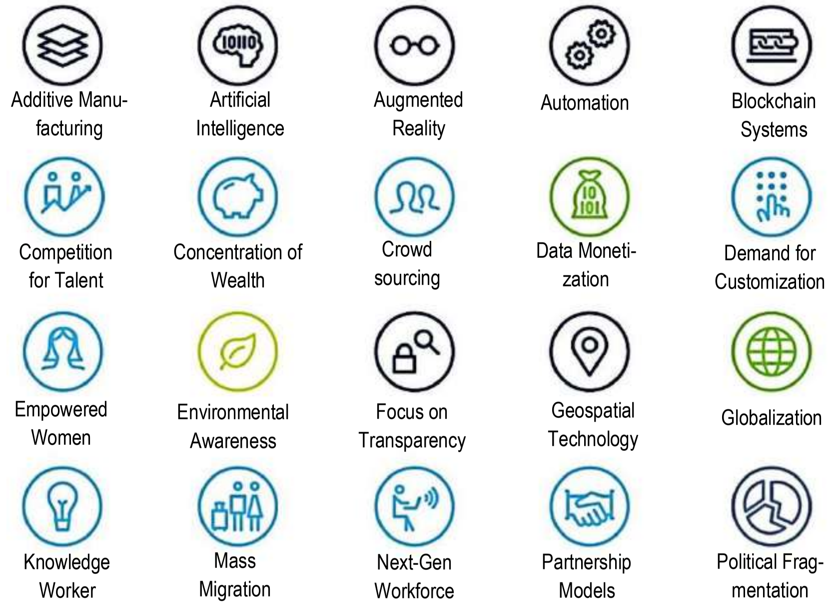
In 2013	the world's first test-tube meat burger cost	$ 325 000
By 2017	the cost price was reduced by	30,000(!) times
In 2017	1 kg of meat cost	$80
In 2017	1 burger is	$ 11
In 2020	prices for natural and stem meat have leveled off	

- But there are legal and administrative problems. The competitor is vegetable meat.
- Kosher artificial meat, synthetic protein, and dairy products are also produced.
- Colossal ecological effect! (2,500 liters of water are needed to produce one hamburger from natural meat).

Ultra-fast delivery by mail in Kyiv in 5 hours

The Meest system guarantees the delivery of goods up to 10 kg in Kyiv in 5 hours through post offices

Conventional names and symbolic images of different megatrends



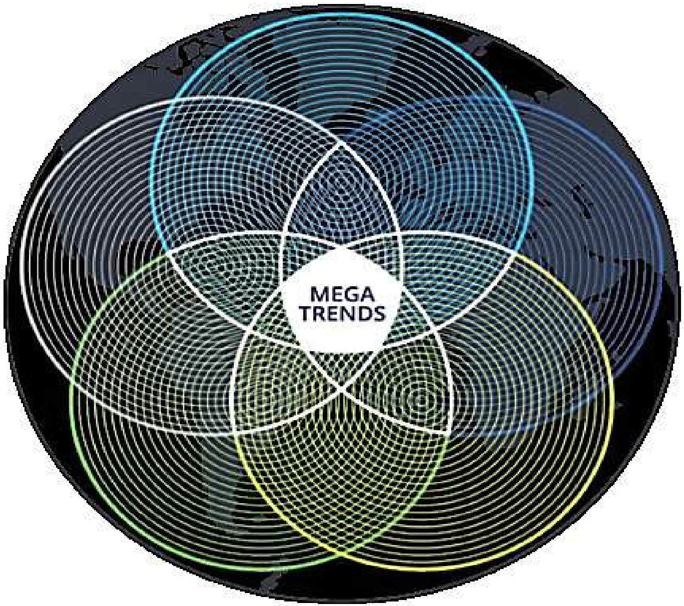
Conventional names and symbolic images of different megatrends

Formation of megatrends

- ***Megatrends***, resembles situation when rivers formed from streams, start from breakthrough technologies, and then, combining with other trends, gain the power of megatrends.

  Examples:
  - *electrification,*
  - *motorization,*
  - *telephoning,*
  - *installation of radio,*
  - *computerization,*
  - *development of GPS,*
  - *development of additive technologies (3D printing)*.

Conventional scheme of formation of megatrends



4. Characteristics of metatrends

Characteristics of metatrends

- *Metatrends* have a more significant scale. They cover the relationship between man and nature and lead to civilizational transformations in society.

- Jeff Norton:

  > “Metatrends are macro forces that shape our future and are phenomena that affect all aspects of human life through economic, social and environmental spheres”.

Demographic trend

- Dynamics of the Earth's population, billion people

Year	Number of population, billion people
1976	4.13
2016	7.43
2050 (forecast)	9.72

Birth rate per 1 person

- Germany and Japan – 1.4;
- China, Canada, Russia – 1.6;
- Austria and Brazil – 1.8;
- Great Britain – 1.9;
- USA – 2.0;
- India – 2.5;
- Malawi – 5.8;
- Zambia – 5.9;
- Burkina Faso and Uganda – 6.0;
- Somalia and Burundi – 6.1;
- Niger – 6.9

Average age of the population, years

	2010	2050 (forecast)
Asia	29	40
Africa	19	25
Latin America	27	41
North America	37	41
Europe	40	46
Oceania	32	37

The size of the middle class

Year	2009	2020	2030
Population, billion people	6.8	7.7	8.3
Number of middle class (m.c.), billion	1.8	3.2	4.9
Share of m.c.,%	26	42	60

Literacy among the adult population, %

Region	1990	2015
The world as a whole	76	86
Europe	97	98
Central Asia	98	100
East Asia and Oceania	82	95
Latin America	86	93
Africa	50	66

Share of the population living in cities, %

- Dynamics of the share world urban population %

Year	Share of the population
1960	34
1993	44
2014	54
2050 (forecast)	66

Interconnection of megatrends and metatrends

- Metatrends are born from megatrends, lagging behind them. But after being born, the metatrend begins to influence the megatrends, thereby dictating its requirements.
- In particular, in the metatrend of the development of additive technologies, the needs of 3D printers are beginning to determine the requirements for the development of the necessary computer programs, properties of new materials, digital platforms, etc.

Рецензенти:
Т. М. Степура – д.е.н., професорка кафедри економіки підприємства та інвестицій Львівського Національного університету «Львівська політехніка», м. Львів;
Л. Л. Калініченко – д.е.н., професорка, завідувачка кафедри економіки та бізнесу, Харківський національний університет будівництва та архітектури, м. Харків;
В. М. Тарасевич – д.е.н., професор, член-кореспондент НАН України, завідувач кафедри міжнародної економіки і соціально-гуманітарних дисциплін, Український державний університет науки і технологій, м. Дніпро

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Навчальний посібник знайомить з однією з найбільш актуальних категорій сучасності, як сталий розвиток соціально-економічних систем. Характеризуються ознаки, взаємні відношення та процеси еволюції різних секторів економік в напрямку сестейнізації виробництва. Показані особливості формування сучасних трендів у різних сферах діяльності: сестейнізації, інформатизації, цифровізації, кіборгізації економіки та її галузей, розвитку технологічної основи, нових матеріалів, Інтернету речей. Особлива увага приділяється сучасним промисловим революціям (Industries 3.0; 4.0; 5.0) та фазовому переходу до нової соціально-економічної формації.

Призначений для викладачів і студентів навчальних закладів, а також для наукових працівників, фахівців підприємств, спеціалістів місцевих органів адміністрації.

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