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RESTRUCTURING THE ECONOMIC SYSTEMS ON THE WAY TO AN ADDITIVE ECONOMY

Abstract

The additive economy should be the productive basis toward which the national economies aspire. This paper aims to deepen the theoretical issues of the additive economy forming and its key components: additive technology and additive manufacturing. Additive technology is defined as a set of methods and tools based on which the production of products occurs by adding only the useful part of natural substances to the final commodity and creating no waste. Additive manufacturing is a system of interconnected processes of transforming natural substances into finished products based on additive technology. The additive economy is a system of trade and industries based on additive manufacturing. The study analyzes competitive advantages (direct prototyping, saving materials and energy, the ability to work without human participation, dematerialization of transportation and storage of products) and challenges of the additive economy (building an organizational network of production systems; forming solidarity economy; developing new social institutions; social development of a person). The paper formulates the key directions of economic systems restructuring to an additive economy formation, including restructuring energy production types, energy networks, and interface sphere and change of the structure of primary resources. The general debatable problem of the economic systems restructuring to the additive economy is the formation of new social institutions capable of providing necessary solutions.

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INTRODUCTION

Currently, humanity is experiencing a transition of industrial organizations and institutions to a new socio-economic formation. The reason for this is the impossibility of solving global and local environmental challenges within the existing production methods. The appropriate accumulated problems have appeared from the relationship between human and nature, which can conventionally be called subtractive. It means that a person uses usefully only a small part of the substances that are removed from nature. According to Melnyk et al. (2022) and Sineviciene et al. (2021), the valuable share does not exceed 10%, and the rest is returned to nature in the form of wastes (in a much more toxic and harmful state for humans and natural ecosystems). These are subtractive principles of obtaining energy and materials that have partially led to the modern global ecological crisis and the massive destruction of local ecological systems.

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This problem can be solved by switching to fundamentally different principles of using natural substances. The approach built on such principles can be conventionally called additive, which is extracting from nature only the amount of matter that is close to that which is usefully used. The basis of additive manufacturing methods is renewable energy sources, processing of materials using 3D printers, IT production, and industrial methods in agriculture.

This transition is a complex socio-economic phenomenon occurring during three industrial revolutions: 3.0, 4.0, and 5.0. Each of them solves special tasks. In particular, Industry 3.0 aims to find and implement nature-friendly means of production. Rifkin (2013, 2015) formulates the essential context and key features of Industry 3.0. According to Shahan (2020), U.S. Energy Information Administration (2020), Cockburn (2020), and EMBER (2020), the problems of transition to renewable energy sources are of critical urgency. Industry 4.0 is aimed at the complete transition of production complexes to cyber-physical systems that can provide solutions to Industry 3.0 tasks through automated systems. Schwab (2016) and Schwab and Davis (2018) formulated the context of the Fourth Industrial Revolution. Later, Skinner (2018) analyzed the problems of man's adaptation to the digital world.

Industry 5.0 aims to find a place for human in the cyberized world of production. Vollmer (2018) studied possible instruments of Industry 5.0. Elder (2019), Zennaro (2017) and Dobrowolski (2021) study the issues of Internet of Things formation, an essential precondition of additive economy forming.

Today, the concepts of "additive technology" and "additive manufacturing" are widely researched and discussed in the scientific literature. Much less attention is paid to the idea of "additive economy," which logically continues the line of the mentioned conceptual framework.

1. LITERATURE REVIEW

In recent years, additive manufacturing (AM) has attracted considerable attention from scientists and specialists. In particular, the object of research of many authors is the development of AM tools (Jones, n.d.). The problems of the development of materials for additive manufacturing are studied by Zelinski (2023), while the advantages and disadvantages of AM are analyzed by May (2022), Tavares et al. (2023), and Melnyk et al. (2022). Many researchers consider AM a necessary component of the circular economy (Ferreira et al., 2023; Tavares et al., 2023), with a clear economic aspect (Ruport, n.d.; Bierdel et al., 2023).

Several generalizations can be drawn by analyzing the general picture of publications on additive economy. First, most authors state that the concept of additive economy is limited only to the operations of technological processes of material processing; that is, it is understood as additive technologies. As a rule, additive technologies are limited only to 3D printing methods; however, the additive economy is much broader. Even when the idea of the additive economy goes beyond 3D printing (processes of creating informational images, designs, software, and printing materials), scientists are not talking about a fundamental change in the content of economic systems.

It should be noted that the evolution of the production of materials for 3D printing is currently taking place precisely through the search for materials that will allow the application of additive technology processes also at the stages of obtaining materials from primary natural resources. It could be materials from cellulose, ceramics, sand, and secondary resources, which minimize waste at the processing stages of primary raw materials (Zelinski, 2023). Considering the entire production cycle, alternative energy production processes are closer to additive manufacturing criteria than 3D printing operations.

Additive technologies (AT), on which the corresponding production and economy are based, have several advantages that allow them to defeat traditional production methods in many industrial sectors. Following the literature review, this study summarizes the competitive advantages of additive technologies compared to the traditional technological base and offers some features that can complicate their implementation in production practice (Dobrowolski et al., 2021a; May, 2022; Jones, n.d.; Bromberger et al., 2022; Zelinsky, 2023).

The advantages of the AT include:

- fast and direct prototyping (design materialization);
- high accuracy;
- reduction of material waste;
- energy saving cost reduction for small series/runs of production;
- reducing the need for additional equipment;
- environmental friendliness;
- possibility of fast materialization of unique designs;
- ability to work without direct human involvement;
- the ability to change the plan at the "last moment";
- ensuring the possibility of transportation and storage of products in an information form.
- The list of possible obstacles that complicate the implementation of the AT are:
- problems of obtaining the necessary materials;
- relatively high production price for large series compared to traditional production processes;
- high cost of entry; additive technologies have a flaw (like most other innovative technologies) associated with their introduction into the existing production system;
- the need to rebuild the enterprise's infrastructure;
- the need to rebuild relations (including suppliers and consumers) of the enterprise caused by the transition to new technologies and types of products.

Next, the study offers the main directions for using additive technologies in various activities, such as 3D printing. Currently, the asset manufacturing sector for the work of additive technologies in part 3D printing shows a highly dynamic growth rate of 22 percent per year. Annual sales of the sector's products are approaching 15 billion euros. More than 200 leading companies compete to develop critical components that enable 3D printing (Bromberger et al., 2022). The world is experiencing many transformations to achieve additive production, facing the triad of factors that form the socio-economic system: material, informational, and synergistic. Production is only the upper part of the systemic phenomenon of the economy. Its lower part is formed by the components of society (primarily social institutions), which ensure the functioning of the economy and the people whose needs it satisfies. By transforming all the social system components, it is possible to create the prerequisites for the transition to an additive economy. To effectively manage the transition, it is necessary to predict the specifics of the transformation process and see the opportunities of current industries' transformation. The diversity of economies in the investment process should also be considered using appropriate financial models and ratios (Dobrowolski et al., 2022).

Thus, this study aims to formulate the additive economy's conceptual foundations as a new economic system built on a fundamentally innovative nature-friendly production complex. Objectives include describing the additive economy's basic components and analyzing key transformational to it.

2. RESULTS AND DISCUSSION

The current paper proposes a fundamentally new concept of "additive economy," which means a complete economic system in all spheres of activity and economic relations, which functions on a fundamentally different production attitude to nature. This principle is: "Remove from nature only what is necessary and do not take extra." The additive economy includes additive manufacturing and additive technologies as its component subsystems.

The mutual relationship between the specified categories (from the narrow concept of "additive technology" to the broader concept of "additive

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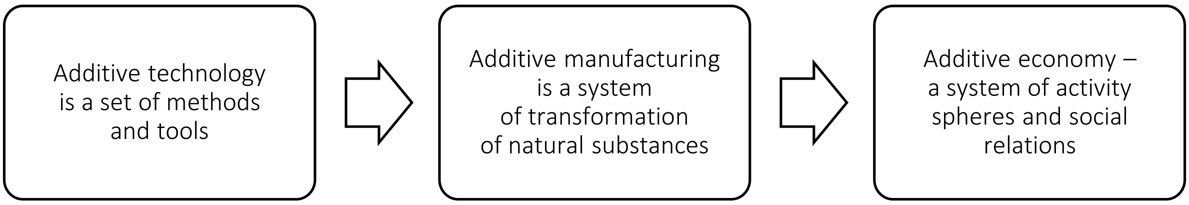

Figure 1. Conditional scheme of mutual connection of additive technology, additive production, and additive economy

economy") can be traced on a conventional diagram (Figure 1). Table 1 shows the definitions of the specified categories.

Table 1. Definition of additive technology, additive production, and additive economy

Category	Definition
Additive economy	A system of economic activity (including production and consumption of products), as well as a set of social relations (regarding production, distribution, exchange and consumption), which are based on the processes of additive production
Additive manufacturing	A system of interconnected processes of sequential transformation of natural substances into finished products, at the center of which is an additive technology
Additive technology	A set of methods and tools based on which the production of products takes place through extraction from nature and successive addition to the object of work of only the valuable part of natural substances (energy and materials) with a minimum of waste generation.

Additive technology is an alternative to subtractive technology, which it replaces. Until recently, humanity used mainly subtractive types of technologies in its production activities. They are built on cutting off unnecessary components from substances extracted from nature while manufacturing useful products. Such processes, in particular, are used in metallurgy, where only the metal component is extracted from the total volume of metal ore, and in metal processing, where a significant part of the primary metal becomes waste. Similar processes are used in thermal energy, where only the carbon contained in the fuel is burned, and the rest of the resource is turned into waste. The chemical industry, which uses only a small part of primary natural resources, works on a similar principle, as well as many other sectors of the economy.

In contrast to subtractive technologies, additive methods form the object of work not by cutting off unnecessary substances but by sequentially adding useful components. It is no accident that the concepts of additive technology and even additive manufacturing are equated with 3D printing.

3D printing belongs to the category of additive technologies. However, the latter is wider than 3D methods of printing. The concept of additive technologies should also include other modes of production, which are based on the principle of forming objects of work mainly by adding natural substances.

In particular, processes of obtaining energy from renewable sources are inherently additive technologies. For example, solar and wind energy are obtained directly from nature without returning to nature the primary substances previously extracted from it, as is the case in thermal energy based on burning coal, gas, and oil. Additive technology can also transport products using the remote transmission of their digital duplicates with the subsequent materialization of products on 3D printers.

Additive production involves the integration of additive technologies into an integrated production system to transform natural substances throughout the entire production cycle, from the extraction of natural resources to the production of the finished product and waste disposal. As one can see, "additive manufacturing" is broader than "additive technology" because it includes many more system components. With this in mind, even productions in the final stages of 3D operations printing cannot be fully classified as additive. Depending on the type of materials used, a large part of such productions use not additive but subtractive processes, particularly those related to obtaining the necessary materials.

An additive economy is a system concept since additive production is provided by a holistic system of human activity and social relations, summarized by the economic concept. The entire structure of processes in the economic system must be rebuilt to increase the share of additive operations. First of all, in the cycles of production and consumption of products. In particular, an essential step in constructing an additive economy and developing the additive output can be the transition to the principles of circular resource use, facilitated by the formation of cyber-physical systems within Industry 4.0, the introduction of the Internet of Things, and the transition to new forms of relations between producers and consumers of products.

Economic subsystem restructuring is an inevitable part of the additive economy transition. The transformational processes require solving complex issues to ensure the implementation of the corresponding future changes. Only by imagining the content, forms, and specificity of individual phenomena, as well as the cause-and-effect relationships of their occurrence, it is possible to reasonably determine the direction of public resources spending, effectively plan economic activity, and purposefully prepare human capital for solving future tasks.

One of the key factors on which the implementation of strategic planning is based is predictive assessments of expected changes in the components of economic systems, which is called restructuring. In general, the picture of the additive economy formation through the restructuring of the socio-economic subsystems is shown in Figure 2.

Restructuring energy production is essential in humankind's transition to renewable energy sources. It is based on extracting only the valuable part of the energy from nature with minimal waste accompanying this process (mainly at the stages of obtaining production assets and their disposal after the end of their service life). Thus, renewable energy mainly adds natural substances to finished products (energy received by humanity). Moreover, renewable energy can be considered a unique product of human labor. After all, the total amount of thermal energy on the planet does

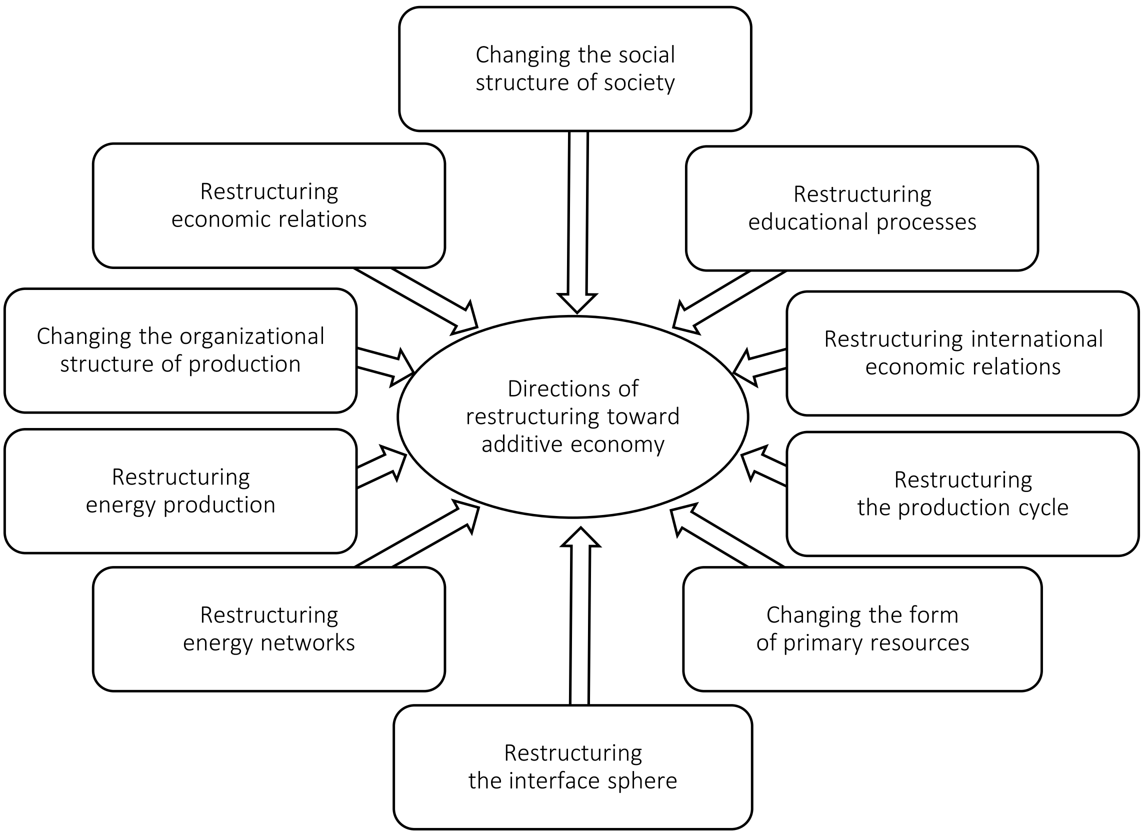

Figure 2. Direction of the additive economy formation through the restructuring of the constituent economic systems

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not increase during its production. The energy that the Earth receives from external space sources is only distributed in directions useful for humans. From 2022 to 2025, the share of renewable energy is forecast to increase globally from 29% to 35%. By 2025, 90% of the increase in energy production will be provided precisely at the expense of renewable energy (Ellerbeck, 2023a). The International Renewable Energy Agency (Hall, 2022) predicts that by 2050, 90% of electricity production will be provided by renewable sources. As of 2022, hydropower, solar, and wind energy plants provided nearly 85% of all renewable electricity production. A significant increase in renewable electricity production will specifically require bioenergy that has considerable potential and can significantly contribute to achieving that goal (Kurbatova et al., 2019; Kurbatova et al., 2021).

Analysis of energy sector restructuring provides an opportunity to draw several important conclusions regarding forming strategic directions for the public distribution of resources. Renewable energy development in 2022 made it possible to reduce CO_2 emissions from global energy production processes. Thus, this direction becomes one of the most promising from the point of view of preserving the planet's climate. There is a significant redistribution of jobs favoring the renewable energy sector. Moreover, Bertrand and Etienne (2022) found that a 1% increase in renewable energy usage in the manufacturing industry in Cameroon leads to a 9.27% increase in labor productivity. According to the IRENA agency, about 12.7 million people currently work in this sector worldwide (Ellerbeck, 2023b).

It is crucial to create a dynamic model of the use of tools (technological, economic, social) necessary for introducing, supporting and further exploiting alternative energy sources. This model should be dynamic and flexible, providing mechanisms for adjusting the tools depending on the conditions that arise in society. In particular, the practice has shown that "green" tariffs, which were relevant at the initial stages of the development of renewable energy, should be mixed with other instruments and accompanied by tools for balancing energy production and developing energy storage systems (Kurbatova et al., 2019, 2021; Sotnyk et al., 2020).

In restructuring energy networks, there is a need for a new concept of energy infrastructure creation. Regarding the EU, one can talk about a figure of hundreds of millions. This value measures the infrastructure expected to obtain renewable sources (solar, wind, biogas, and energy obtained with the help of heat pumps). In addition, numerous technical, organizational, and financial issues regarding production, acquisition, transformation, storage, transportation, and energy consumption need attention. For this, a unique electrical network (EnerNet) infrastructure is required.

It is necessary to consider that such systems must ensure a two-way exchange of electricity and information flows because the producer and consumer of energy (and they can be ordinary households located in different territories) can constantly change roles. And the person who was producing energy just a few minutes ago can become a consumer due to specific reasons (weather conditions, work mode, etc.). Naturally, the reverse transition should be just as easy. It is about the fact that all objects of the energy network should be transformed from passive to active. Active energy networks, able to quickly adapt to the changing needs of interested parties (owners, consumers, sellers), are considered today a vital element of the infrastructure of "smart" energy systems of the future. Another critical task that EnerNet is designed to solve is integration into the operation of other "smart" networks (smart grids) created today at the level of enterprises, territories, and countries. EnerNet is a form of one of such "smart" networks, which allows it to organically fit into the general picture of the formation of the global information space. Smart information and energy networks can boost energy production and consumption processes and ensure the quality of energy supply and the stability of the whole system. Finally, the transition to "smart" energy systems will give impetus to developing new products and services and forming new markets.

Construction of relations between the state, producers, and the management of networks with a highly complex construction system is crucial. In particular, it is necessary to consider the entire range of incentives and mechanisms for financing renewable energy and managing its state. For example, they are public-private partnerships, cooperatives and energy communities, new mechanisms for the development of alternative energy, such as net metering of energy consumption and bilateral purchase agreements of electricity, which provide certainty and stability for both producers and long-term consumers of clean energy.

Restructuring the interface sphere relies on the emergence and development of additive technologies and additive manufacturing, which create prerequisites for the interface field's operations changes. The latter connects separate economic entities into single functional systems. The interface sphere usually includes processes of transportation and storage of products, as well as trade operations (Ievsieieva et al., 2021; Tsypkin et al., 2020).

Additive manufacturing also fundamentally changes the structure of trade operations. The appearance of cheap and easy-to-use 3D equipment (printers, scanners, pens) can significantly affect the relationship between the manufacturer and the consumer of products. In particular, this makes at least two things a reality: firstly, the possibility of manufacturing products to individual customer orders; secondly, the implementation of direct financial relations between the producer and the consumer of products, that is, without an intermediary in the form of trading entities.

A debatable issue is the developing technologies capable of self-reproducing their capabilities and the regulatory systems capable of supporting innovation activities (Koblianska & Kalachevska, 2019; Hrytsenko et al., 2021). At the same time, research searches for new transportation forms in additive economy. Another problematic issue is direct communication between the producer and the consumer of products and the production of products to the individual order of the latter (Kurbatova et al., 2019; Sotnyk et al., 2014, 2022).

The transition to additive manufacturing will undoubtedly affect the structure of primary resources. 3D printers require materials to have completely different properties than those used in subtractive technologies. The main materials used in a 3D printer are polymers, metals, composites, ceramics, sand, organic raw materials, and bioactive materials.

Based on Zelinski (2023), Venhuizen (2020), Andreassen (n.d.), critical directions along which the properties of materials used in 3D printing are:

- achieving technical characteristics (physical properties) necessary for work in certain physical and chemical conditions (high or low temperatures, high or low pressure, shock loads, aggressive environments, intense friction, etc.);
- ensuring the possibility of working as "ink" for 3D printing;
- ensuring high accuracy in design, i.e., when calculating, forecasting, and achieving specified properties and characteristics;
- achieving flexible changes in properties and features with minimal expenditure of labor, time and money;
- achieving the ability to convert one form of energy into another;
- achieving suitability for implantation in biological organisms;
- achieving acceptability for the metabolism of ecosystems and the need for circular resource use;
- ensuring sufficient cheapness of acquisition, operation, and disposal.

Each listed material property provides the appropriate direction for directing society's resources, including funds, material assets, and human capital. It is seen that additive technologies are directly related to innovations. According to Koilo et al. (2022), a 1% increase in innovation leads to a 0.27% increase in energy efficiency. According to Koilo (2021), R&D expenditures and turnover from product innovations significantly affect value-added; moreover, R&D activities contribute to the maritime industry's sustainable transition. A debatable issue is the formation of single scientific complexes capable of ensuring the synergistic unity of the three components of additive manufacturing: hardware, software, and materials. The arrival of artificial intelligence in the specified

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sphere of activity could ensure the dynamism of choosing optimal materials at a specific time for specific tasks.

Manufacturers now strive to shift the center of production gravity (and, accordingly, costs) from the replication of products to their design. Future products should be evaluated according to their properties, functions, and parameters. Shortly, what is now commonly called production will begin to perform the functions currently performed by an ordinary 2D printer; it just needs to be produced in material form and, if necessary, replicate the results of information production at the previous stages of the production cycle.

The primary type of products in business is not products and services but startups, and more precisely, innovations, the production of which these startups are focused on. Moreover, the range of innovations startups produces is extensive and concerns all spheres of life. According to Ivanová and Žárská (2023), R&D expenditures and the aggregate innovation index in all V4 countries positively correlated from 2014 to 2021. It is possible to name even more precisely the type of items sold in the form of a startup – these are various forms of increasing the efficiency of human life support processes.

Additive manufacturing is expected to undergo significant structural transformations. This is primarily because networks of small units should replace massive production facilities. They can only become a real productive force by being united in integral network systems.

The specifics of the additive economy and the additive energy and additive processing industry operating within it require fundamentally transforming the synergistic (communication) basis. Moreover, with such transformations, both additive economy and additive energy will be able to be fully realized. Unlike traditional energy, which is based on large-scale processing capacities, additive animation uses a considerable number (hundreds of millions of units are planned in the EU alone) of small generating plants. This is due to the significant deconcentration of energy sources. Every family, remaining an energy consumer, turns into its producer. Such deconcentrated energy sources can become a real productive force only if combined into single system complexes and informationally organized.

Similar processes are taking place in the divisions of the additive processing industry, where networks of economic subjects will inevitably emerge to unite producers of informational components of future images (designs, models, images) and capacities capable of printing them on 3D printers.

Another area where additive technologies are gaining intensive development is agricultural production, based on hydroponics, vertical farms, and systems for growing meat from a test tube. Each of these types of products has signs of additive technologies because it is carried out with a minimum involvement of natural factors and is implemented by adding only the necessary components to the work items.

It should be noted that horizontal production organizations are close in their form to ecosystem hierarchical structures, which can be characterized simply by the formula: the center is everywhere, and the periphery is nowhere. In such structures, the driving impulse of activity in the form of a decision is at the level of a specific performer, depending on the situation. The information signal is transmitted from the bottom up to the upper levels. The latter's function is to coordinate the actions of individual actors, distribute system-wide resources, create an optimal environment, and identify its prospects.

The specificity of additive manufacturing creates prerequisites for the remote integration of economic entities in a single production process. Enterprises separated in space can combine their production operations in single periods. Thanks to the creation of production networks, enterprises located in different spatial conditions – often in different corners of the globe – can integrate their activities into single production cycles. Today, on the global market, a business can choose as a partner any complementary enterprise that will independently provide its logistics, personnel, and technical policy, as well as solve all production and marketing issues for all other segments of its activity.

Research also widely discusses the problems of harmonizing issues related to the difference in the national conditions (social, ethical, legislative, and economic) within the international virtual enterprises.

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The formation of horizontal production networks is accompanied by an increased number of producers (for example, alternative energy generators, 3-D printers or personal computers that work in conjunction with the latter). There is mass socialization in the economy when the means of production pass to a large part of the population. At the beginning of the 2020s, in Ukraine, there were nearly 50 thousand private solar power plants (most installed in the last five years). In Germany, this indicator already reaches more than half a million units.

There are conditions for forming a social and solidarity economy because the formal owners of the means of production are, at the same time, their actual users. This forces them to actively manage the economic systems (networks).

Today the world is on the threshold of creating new social and solidarity economy forms. Discussion issues in each of the production communities are a wide range of issues: from ensuring the consistency of the work of individual co-executors to payment systems, taxation, and relations with local and central authorities. A separate issue is a search for ways to implement the sustainability principle: "Think globally – act locally." The specified direction of social restructuring is one of the most discussed and relevant in social development issues.

Restructuring of educational processes prepares human capital for life in a new reality and activity in new production conditions. The transformational processes associated with the transition to the additive economy objectively cause a fundamental change in the structure of educational processes.

In terms of content, this change requires new nomenclature of professions and specialties, which the additive economy brings. It is also possible to predict a specific change in the forms of educational processes following changes in living conditions and the specifics of production processes. These changes can be summarized as follows:

- from skills and knowledge of material means to innovative information tools;
- from training with standard knowledge and skills to the formation of the individual potential of the producer necessary for the production of a creative product;
- from living in a local environment to the shape of a worldview, knowledge, and skills for activities in the global space;
- from consuming material products to using information goods and services;
- from consuming non-renewable natural resources to using renewable natural factors and activities in the circular economy;
- from linear thinking to non-linear thinking.

It identified only a hypothetical range of directions for restructuring economic systems and their possible direction in the space of advancement toward an additive economy. For each of the directions, a topical range of discussion issues regarding its implementation was determined. The primary vector for the education sphere to adjust to life in the changing conditions of the additive economy will be the transition from learning with accumulated data to searching for new knowledge independently. The search for the forms and content of the implementation of this transition is today the most discussed problem in the scientific literature. Thus, according to Spivakovsky et al. (2023), digitalization and social communications were vital for survival during the Kherson State University (Ukraine) displacement. Porkuian et al. (2023) shared similar results considering two displacement of the Volodymyr Dahl East Ukrainian National University, stressing high importance of forming shared values and reputation. However, this also needs introducing an advanced educational system organization (Mishenin & Koblianska, 2015).

The specified forecast makes it possible to carry out the appropriate restructuring of educational processes for the preparation of human capital with fundamentally new knowledge and work skills. Arfara and Samanta (2023) found that "green" intellectual capital can be enhanced by internal marketing practices.

Additive manufacturing is converted into a production system that follows the guiding principle: "take what is necessary from nature, and not cut off the excess from the resources extracted from it." Thus, the category of additive manufacturing should in-

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clude various types of activity where the specified principle is implemented according to the nature of the production activity. These include, in particular, renewable energy, IT production, various industrial, agricultural production, intellectual sectors of the economy, etc. Additive manufacturing is called to improve the EU energy situation and reduce CO_2 emissions (Kuzior et al., 2023).

A substantial reduction in the cost of additive manufacturing facilitates significant progress in developing the renewable energy production sector and circular economy promotion. Thus, an additive economy could benefit economically and environmentally allocating exchange-traded futures on recycled resources (Dobrowolski et al., 2021b; Moore et al., 2022).

This is expected to accelerate developing countries' transition to alternative energy sources and the restructuring of the corresponding investments. For 31 EU members, environmental protection investments do not influence Environmental Performance Index (Vorontsova et al., 2022). Therefore, not all investments are suitable for ecological efficiency improvements. Also, different market expectations could exist concerning the political situation (Bielykh et al., 2021).

The specified transition to the additive economy also creates prerequisites for the spread of the concept of "additive" to the scale of the economic system because the transition to additive manufacturing inevitably changes the entire system of production organization, economic relations, social institutions, and human factors that accompany the functioning of production. This concept of "additive economy" fundamentally differs from those currently found in the scientific literature, where "additive" is used only at the level of direct production processes. The legality of using the specified approach is the critical debatable issue of the paper.

A significant factor in improving production is its integration with design generation. The latter provides for optimizing production processes using the connection of cloud computing and artificial intelligence, which makes it possible to consider essential production factors: permissible load, restrictions, and safety characteristics (McClintock, 2023). Moreover, additive technologies allow the customization of the products, and each client could receive a personal offer, significantly improving satisfaction with the product. According to Dewarani and Alversia (2023), when customers show good involvement, this enhances cooperation with service providers, increasing customer satisfaction. Additive and digital technologies contribute to the development of digital tourism, thus making it sustainable (Luo et al., 2022).

Applying the "additive economy" concept opens up horizons for further research in the specified direction. In contrast to the development of the technological tools of additive manufacturing, this must be solved during the transition to the additive economy. The key challenges of additive economy development are related to the radical restructuring of the organizational base (in particular, the growth to a network organization of production systems), a revolutionary change in economic relations (in particular, the formation of a solidarity economy), the creation of new social institutions that would ensure the functioning of new industries, the priority of social development of a person, and accordingly, the formation of new consumption models based on energy accountability (Sułkowski & Dobrowolski, 2021).

The perspectives for future research should include determining priority areas of financial resources spending, effectively planning economic activity, and purposefully preparing human capital for additive economy fostering.

CONCLUSION

This study aimed to deepen the essence of the additive economy and its key components: additive technology and additive manufacturing. The additive economy is a new phenomenon that includes spheres of management and economic relations based on additive manufacturing. The key competitive advantages of the additive economy are direct prototyping, material and energy saving, the ability to work without human participation, dematerialization production, transportation, and storage of products.

Since additive manufacturing adds only the necessary amount of natural substances during production, it significantly reduces the generated waste volume and the burden on ecosystems.

Additive technologies inevitably lead to economic system restructuring. The critical areas of restructuring economic systems during the transition to an additive economy are restructuring energy production types, energy networks, the interface sphere, the production cycle, and economic relations, changing the social structure, and restructuring educational processes. The expected and debatable issues of additive economy fostering are the determination of new social institutions capable of providing solutions for long-run sustainable economic development. Therefore, new jobs and skills would be needed in the labor market to meet the challenges of additive economy formation.

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