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TABLE OF CONTENTS

SECTION 8. INNOVATIVE ECONOMY

8.1 Disruptive technologies for green economy formation in conditions of the fourth industrial revolution: the EU experience

Disruptive technologies create the prerequisites for the decrease in demand of a resource or substituting one resource by another, which is more effective from an economic or ecological point of view. In this context economy can increase along with several pathways: 1). Increase in the efficiency of production or consumption without the substitution of critical resources (in this case, the production process's efficiency increases, the use of raw materials, and the demand for energy decreases). 2). Substitution of less effective resources by more effective ones. 3). Less effective resources are substituted by more effective social demand.

By green economy we understand a phase transition to new energy; new communications; new settlements, new economic relations; a new lifestyle; new needs; and a new man. The green economy includes sectors and types of activities, which help reduce a load of production and consumption processes (goods and services) on the environment and man's biological nature and create conditions for personal difference human development.

The essential characteristics of the green economy are continuous self-optimization (self-adjustment) of technical systems, continuous improvement, environmental limits, conservation of biodiversity and ecosystems; the priority of the reproduction of human personality basis.

The Fourth Industrial Revolution (known as "Industry 4.0") introduces cyber physical systems in production processes. It is foreseen that cyber-physical systems will combine into a single network with the formation of particular local "ecosystems" serving for the maintenance of a specific house, company, or city.

The Third and Fourth Industrial Revolutions facilitate achieving sustainable development. We can expect two critical transformations in socio-economic activity:

1. Changes in consumption: transition from creation and production of different products and services to systemic complexes for creating comfortable

conditions for human biological needs, development of social needs, and the realization of human creativity.

2. Changes in production: transition from "torn" production cycles to the formation of nature-friendly labor, production, and consumption organized according to closed processes.

Based on the analysis of publications (Schwab, 2017; Melnyk et al. 2019a; Melnyk et al. 2019b; Melnyk et al. 2020), the authors formulated the most important functions of cyber-physical systems carried out without any human participation: information exchange (a kind of a "dialogue") in real-time; control of external and internal parameters; self-activation and stop under specific information signals; self-tuning for optimal operating conditions; forecasted (anticipatory, preventive) systems self-service; interaction with produced goods (production systems case); adaptation to the new needs of consumers; definition of the needed equipment to make the required products or meet new demands; self-learning of new work methods.

The EU experience of a green economy is based on a fundamentally new type of technology and economic relations. On the one hand, this is due to the need to transition to sustainable development, which allows overcoming the threat of a global environmental catastrophe and ensuring the transition to social (personal) development priorities. On the other hand, the achieved scientific and technical level of society at the present stage creates prerequisites for solving various corresponding problems.

The green economy is the mainstream worldwide nowadays, a new economic model without harmful pressure on the environment. Industry 4.0 is the bridge for transforming the economy to green energy systems based on renewable energy sources (RES), green technology based on additive methods and 3D printers; new materials based on progressive characteristics (10 times lighter than aluminum and ten times more potent than steel) and are environmentally friendly. As a result of innovation activities in conditions of the Third and Fourth Industrial Revolutions, the variety of technological principles for implementing energy, working on renewable sources, has dramatically increased. Whole clusters are successfully developing today in each of their components (solar, wind, biogas, geothermal, etc.).

The main areas of energy systems' development are development of new principles for RES implementation; improvement of technological solutions (efficiency increase) within the framework of the research; efficiency increase of energy storage processes; optimization of spatial solutions for RES placement; formation of information systems optimizing RES operation and related infrastructure; the formation of communication systems that integrate the operation of certain RES into integrated energy systems.

Successful implementation of renewable energy projects depends mainly on the efficiency of the appropriate methods of obtaining energy. In this case, the efficiency should be understood as the ratio between the assimilated amount of energy and maximally reaching the source. This indicator is an analog of the efficiency coefficient used in the energy industry and other technical spheres.

RES installations' efficiency entirely depends on other indicators – economic characteristics, showing the profitability of using these generators compared with other obtaining energy methods. The fact is that for forty years, the cost of getting a unit of solar energy has dropped by 150 times. In terms of cheapness, it goes ahead of traditional power. It means that the efficiency of solar energy installations is hugely increasing.

The report of the International Council on the Agenda for the Future of Software and Society, organized in the framework of the World Economic Forum, states that many disruptive technologies will reach a crucial point in their development by 2025 (Deep Shift, 2015). Society comes closer and faster near surprising technological innovations, as, e.g., quantum computer, the universal introduction of the blockchain, virtual reality, and developments based on artificial intelligence. Every year experts and scientists discuss the issues related to disruptive technologies, focusing on the positive sides for economic growth promotion. The other researchers are more skeptical of these positive effects and refer to the negative direct impacts and potential threats (Sotnyk et al., 2013).

The main direction of Industry 4.0 is the formation of cyber-physical systems and the Internet of Things (IoT). The Internet of Things is a concept of an information-

driven network of physical objects ("things") equipped with built-in technologies to interact with others or with the external environment. The formation of IoT can rebuild economic and social systems, contribute to personality development, and achieve sustainable development goals. IoT is closely related to sustainable development issues. First, it may significantly increase social systems' efficiency, dematerialize industrial metabolism, and reduce the ecological impact on nature (Karintseva, 2017). Second, it establishes conditions for the implementation of a circular economy. Third, disruptive technologies providing IoT (alternative energy, additive technologies, artificial intelligence, cloud technologies, etc.) are inherently sustainable phenomena. They provide a solution to economic, environmental, and social problems. As a rule, disruptive technologies are not realized as separate innovations but within a broad front (cluster) with other disruptive technologies. In one case, they serve as an auxiliary, providing the implementation of other disruptive technologies. In another example, they are the leading (essential) application of which other disruptive technologies work.

In particular, for the realization of every disruptive technology, three dates are provided. The first characterizes the critical event's implementation when an industrial sample is produced, and disruptive technology moves from the scientific sphere to an industrial application. The main event of the technology development period refers to the second date, which characterizes the technological maturity and its readiness for implementation within the Internet of Things. The last date shows the most specific event(s) related to the given technology's current state.

Without completing all disruptive technologies (Personal computer – PC, mobile phone, Internet, Wi-Fi, Renewable energy, 3D printing, digital technology, artificial intelligence, RFID tags, GPS, robot, cloud), the implementation of the Internet of Things would be impossible. Only the essential components of the necessary disruptive technologies are shown in the table. There are many more, as the production of new materials for the operation of 3D printers, the formation of energy storage systems necessary for the full service of renewable energy sources, and new disruptive technology, creating the conditions for implementing GPS.

PC, mobile phone, Internet, Wi-Fi, Renewable energy, 3D printing, digital technology, artificial intelligence, RFID tags, GPS, robot, cloud are the original "components" for assembling the IoT. Each of these phenomena is a landmark in the history of human civilization. The results of these innovations are called phenomena because of their scale and versatility. In particular, "mobile phones" or "3D printers" necessitate various objects and technologies that constantly change in space and time.

The Internet of Things could not appear before the production and use of each of the mentioned phenomena (from a personal computer to “cloud” technologies) reached industrial maturity. The latter involves at least two aspects: firstly, achieving cheapness, which ensures the profitability of mass production and uses; secondly, the success of the massive scales of the application.

Cisco analysts consider 2009 as the start of the era of the Internet of Things (IoT). By this time, the number of devices connected to the Internet has exceeded Earth's population. Thus, the global network began to serve people and the things themselves (Evans, 2011).

The formation of a green economy, especially the EU experience at this stage of civilizational development, becomes possible because the Third and Fourth Industrial Revolution form prerequisites for the transition to much more efficient technological solutions to produce and consume goods and services.

It is essential to see the logic of the events taking place when analyzing economic systems' behavior. It helps make reasonable decisions and avoid mistakes that could lead to negative consequences in the future.