Eulalia Skawińska, Romuald I. Zalewski

CONTEMPORARY CHALLENGES FOR SUSTAINABLE DEVELOPMENT

LINEAR VERSUS CIRCULAR ECONOMY

PTE Polish Economic Society

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She is a member of international organizations: EAAE, COPE, IIIS, scholarship holder of the Universities of Anges, Padua, Stockholm, Humboldt Berlin, Glasgow and Edinburgh financed among others by TEMPUS and ACE funds. During the transformation of the economy in the 1990s, she participated in research under the Cooperation Fund and published a monograph in the White Paper. She was chairman and member of the Supervisory Board in commercial companies.
Inspirations for Prof. E. Skawińska's scientific and organizational activities often came from the cooperation she developed with the environment and were supported by her studies and experiences from business and private trips to 25 states of the USA and 30 other countries in the world.

Romuald Ignacy Zalewski (Full Professor) in 1963-2013 he worked at the Faculty of Commodity Sciences at the Poznań University of Economics. He held a number of scientific and organizational positions (chair, dean, vice-rector). He is an Honorary Professor at W-M University in Olsztyn. He was a postdoc in Department of Chemistry University of Manitoba (Canada, 1967-9) and Professor of Chemistry at University of Sulaimani (Iraq, 1976-81). He studied the structures of organic compounds and their effects on flavour and biological properties. From the 1990s, he started research on quality management, SPC and innovation. Between 1986 and 2016 he coordinated scientific projects funded by Polish government agencies. Among others, he developed an open innovation platform called INNOPENA. He is the author of several books on physical organic chemistry, SPC and quality management (published by Elsevier, Wiley, UEP, PAN), editor and co-author of monographs and numerous publications. He organized several world scientific conferences e.g.: XIV IUPAC Symposium of Natural Products (1984); V Correlation Analysis in Organic Chemistry (1988). He was invited as a visiting professor by universities (e.g. Bradford, Lund, Lyon, Paris, Saarbrücken, Stuttgart, Marburg, Leipzig, Trieste, Louvain-la-Neuve, Wageningen, Tallinn, Taipei). He has also participated as a lecturer at numerous scientific conferences on all continents. Since 2003 he has been the chairman of the Commission on Quality Sciences of the Polish Academy of Sciences. Recently, he has been working on circular economics through the lens of natural sciences. For many years (1993-2018) he chaired the Gold Medal Judges of the Poznan International Fair MTP. He belongs to several national and international organizations and scientific societies (e.g. IGWT COPE, IIIS, TCI).

LIST OF ABREVIATIONS

CE	Circular Economy
COP 24	United Nations Climate Change Conference
CSO	Central Statistical Office
CSR	Corporate Social Responsibility
ESD	Economics of Sustainable Development
EU	European Union
EUROSTAT	Statistical Office of the European Union
FAO	Food and Agriculture Organization of the United Nations
GDP	Gross Domestic Product
IMF	The International Monetary Fund
ISO	International Organization for Standardization
IT	Information Technology
OECD	Organization for Economic Cooperation and Development
OPEC	Organization of Petroleum Exporting Countries
PIE	Polish Economic Institute
R & D	Research and development,
SD	Sustainable Development
SDE	Sustainable Development Economy
SFVC	Sustainable Food Value Chains
SWOT	Strengths and Weaknesses, Opportunities and Threats
TQM	Total Quality Management
UN	United Nations
UNDP	United Nations Development Programme
WB	World Bank, World Bank for Reconstruction and Development
WFP	World Food Programme
WTO	World Trade Organization

INTRODUCTION

In the 21st century, and especially during the Covid-19 pandemic, there has been an increased awareness among the general public that the continuation of the methods and models of micro-economy used so far in the world will lead to negative consequences that are difficult to reverse. These include climate disruption, income and wealth polarization, and a decline in the quality of life of societies due to increased poverty and social exclusion, growing pollution of the terrestrial and marine biosphere, overexploitation of resources, etc. It is documented in the literature that already in the second half of the 20th century, the thesis that development is necessary "without compromising the ability of future generations to meet their own needs" was gaining strength in science, politics and intellectuals. (Brundtland, 1987). A research program of ecological economics emerged, the representatives of which, in conducting economic activity, adopted a position:

- the primacy of the natural environment over economics,
- the perspective of sustainability based on not wasting scarce environmental resources and
- inter - and intra-generational equity.

In this context, proposals are being made for ways of farming that can contribute to reducing the hitherto unfavorable trends and tendencies of economic development. In the last decade, the ecological economics agenda has underpinned the development of several SDG policy documents. These are: Europe 2020 - A Strategy for Smart, Sustainable and Inclusive Growth (European Commission, 2010); Agenda for Sustainable Development 2030: Towards Successful Implementation in Poland (OECD, 2017) and Operational and Implementation: Roadmap to a Resource Efficient Europe (European Commission, 2011), European Green Deal (European Commission, 2019), obliging national governments to transform their economies for a sustainable future. In economic processes, this trend became institutionally applicable from 1992, i.e. from the adoption at the Second United Nations Conference, known as the Earth Summit, of Agenda 21 containing the Programme of Action for Sustainable Development (UN, 1992; Kołodziejczyk, 2015, pp. 77-78).

In the presented work, the following questions constitute the research problem: 1) what contemporary factors limit the implementation of sustainable and balanced development (SDG), 2) what challenges face the applicability of this concept at different levels of management, 3) can it be implemented and develop at a low rate of growth of the rate of investment in enterprises, science and R&D? and 4) what innovations: technical-technological, organizational, production, social, management will be strategic for the fulfillment of the SDG mission? In this context, it should be noted that the concept of SDG has an interdisciplinary character and is the subject of research of many sciences, including economics, management and quality sciences, law, sociology, agricultural and regional policy. Therefore, one can also find in the literature the use of categories that are close to the concept of RTZ, e.g. sustainable development, eco-development and integrated development.

The cognitive aim of this paper is to present and explain the negative consequences of a linear economy and the rules of functioning of a circular economy (CE) as a model of production and supply chain management in the paradigm of sustainable development. The complementary aim is to indicate the factors conditioning the effective implementation of the circular economy model in the process of sustainable development at the micro and macro level. To achieve the objectives of the study, the method of desk research, comparative, modeling, descriptive, statistical and visualization was used. The source base is the world literature and statistical data from international organizations (EUROSTAT, WB, EU. FAO, OECD, ISO) and Central Statistical Office (CSO) of Poland. The scope of the study is global with particular emphasis on the EU area, including Poland.

The structure of the monograph reflects its objectives and includes two parts, which consist of 4 chapters plus introduction and conclusion. The first chapter presents the characteristics of the concept of linear economy and the effects of current economic processes in the linear model (Chapter I). Then, the concept of sustainable and balanced development is presented, highlighting the diversity of its models at the micro and macro level. An important role is played here by indicating the factors accelerating changes towards sustainable development (Chapter II).

The content of the first part of the monograph (Chapters I - II) stimulates the discussion on the perspectives of linear economy in the paradigm of sustainable development. In it, the authors pursue 5 objectives: a) present the characteristics of the development of economy in the linear model and the negative consequences resulting from it; b) present the concept of sustainable and balanced development distinguishing its main models at the micro and macro level; and c) discuss the limitations occurring today in the application of these models and factors supporting their effectiveness; d) interpret the advantages of circular economy over the linear model of management, in the pursuit of sustainable development; e) indicate the role of non-material factors of formal and informal institutions in the process of changing management models. The authors show that the circular economy is consistent with the concept of sustainable development (SDGs) and fits into the European Green Deal.

The next part II presents the concept, definitions and models of the circular economy and explains the principles of functioning of the circular economy (Chapter 3). The circular economy proposes some new rules of conduct for both producers and consumers, mainly related to the optimal use of natural resources, optimizing the useful life of products and using them after their end of life through recycling or ultimately energy recovery. It draws attention to the need to change consumption patterns on the part of consumers and to prevent the phenomenon of obsolescence on the part of producers and current barriers limiting its effective implementation. Among the causal conditions in the development of this concept of economy, the authors point out the role of states in the institutional aspect, especially boards of supranational organizations (e.g. European Union), and in the subjective context, the knowledge and behavior of consumers and employees in the process of implementing the circular economy. Among other intangible factors, they present the role of innovation, especially technological innovation, recognizing its high importance in sustainable development. Chapter 4 presents some objective limitations and consequences resulting from the inviolable laws of nature and especially of physics, chemistry and nature, which the circular economy cannot exceed. To approximate them, the circulation of matter and energy in the biosphere caused by solar energy is described, taking into account inorganic and organic forms. The importance of the principle of conservation of energy and matter in nature and the importance of entropy is also emphasized. Three debatable problems related to CE are also presented at the end of this chapter. There are also debates in science about which are the barriers to economic goals such as unlimited availability of raw materials, increasing development and consumption. The authors emphasize that the circular economy is consistent with the concept of sustainable development (SDG) and is part of the European Green Deal.

Part I. From a linear economy to sustainability and the circular economy

Chapter 1: The linear economy and its consequences

1.1 Characteristics of the linear model of economy

In the world literature, it is assumed that the main negative phenomena created by linear economics in neoclassic paradigm are: the climate warming effect caused by the increase in the concentration of greenhouse gases in the atmosphere, the depletion of raw materials and the increasing trend of their prices along with their fluctuation in world markets, increasing environmental pollution, including water and food resources, local water scarcity, increasing municipal and industrial waste, increasing energy demand, destabilization of ecosystems and species extinction (Lee B. et. al., 2012). Economic actors in the linear model have long been unable to solve the problems generated by the effects of economic growth. Globalization, competition, the rising wealth of many societies, consumerism and the increase in the world's population, from around 6.8 billion today to over 9.8 billion in the next 30 years (UN, 2017), are causing a rapid increase in the consumption of basic resources, much of which is finite and non-renewable, which is a natural barrier to future growth. Raw material consumption has doubled in the last forty years and will continue to rise sharply unless there is a rapid change in business models (Ellen MacArthur Foundation, 2013a, pp. 14-16). Even the development of resource-efficient technologies and the dramatic increase in the price of some raw materials cannot adequately address the dilemma of contemporary demand growth (Jackson, 2011, pp. 155-164). In addition, the far-reaching effects of economic growth, such as the impact on climate change and deregulation of the mechanisms of cycling of essential elements in the biosphere, population health and species extinction, must be taken into account. Thus, attention has gradually turned to the need to reduce the rate of growth and consumption, to the inclusion of external costs and environmental mechanisms in the evaluation of the management process, and to technological solutions such as material recycling and new technologies based on closed production cycles, the so-called circular technologies. In the search for the most effective models in the paradigm of sustainable and balanced development applied in the 21st century, the GC model is considered as one of the leading ones.

The linear model of economic development as currently understood can be briefly characterized as the following sequence of activities: acquisition of materials and raw materials - production (transformation into goods or services) -

consumption and discard. The different stages of the production process are shown in Figure 1.

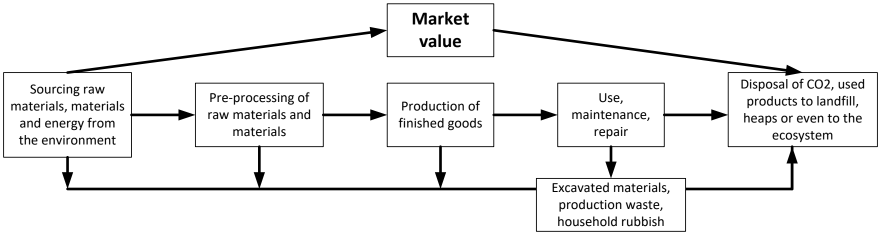

Figure 1. Development of food economic processes in a linear model
Source: own elaboration.

The flow of raw materials and energy here is in one direction from the natural environment to the economic system, which sucks up resources and then burdens the ecosystem with the solid, liquid and gaseous wastes created in the process. In the initial phases of the process, there is an increase in value added until the finished product is obtained (represented as an upward-pointing arrow). Then, after acquisition, its value decreases over time (downward-pointing arrow). Its functionality also decreases, breakdowns occur and it needs maintenance or repair. After some time its value decreases to the minimum for the owner and he decides to dispose of it.

As Lester Brown (2006) argues, the global ecosystem is declining and shrinking, as evidenced by a variety of quantitative and qualitative data. These include decreasing area suitable for settlement, expanding desert areas, increasing population, rising ocean levels, land degradation and shrinking biocenozis. Population, consumption, livestock, intensive agricultural production are increasing. However, biodiversity is decreasing. These processes are accelerating, requiring a rapid preventive response.

In the past, economic actors sought to maximize economic benefits by increasing production and market share. The principles of this model were shaped in different historical formations and stages of agrarian or industrial development. The agrarian stage lasted for thousands of years. The Enlightenment saw the rapid advance of the natural sciences, beginning the wave of industrial development of the age of steam, coal and steel in the 18th century, and now driven by information and information technologies. Until recently, industrial societies did not clearly perceive the problems created by the linear economic model or consciously shifted them to poor and peripheral countries, relative to the centers of the world economy (Welford, 1998). Here we mean the physical movement of materials and energy across organizational, administrative and geographical barriers. The phenomenon of "displacement", i.e. moving part of the production in order to reduce the negative impact of economic activity on the environment in a country with a high level of economic development, at the expense of another area, usually a country with a lower level of development (Korhonen, 2004), should be minimized. Numerous negative examples include the overexploitation of rainforest resources (e.g. Amazonia, Southeast Asia), which has a very negative impact on the environment there, as well as on the planet's climate (Mayer et al., 2005). There have also been exports and disposal of used products or dumping of manufacturing and even municipal waste from developed countries (e.g. the EU) on the territory of poorer countries (e.g. China). In 2018, at the UN COP24 Climate Summit on climate change and climate policy, representatives of these countries demanded reparations for the harm done and expect assistance in repairing the environment once destroyed (COP 24, 2018). The United States, on the other hand, at the aforementioned COP24 conference, opted for transparent methods of measuring emissions that would allow for an objective assessment of countries as polluters in order to enforce compensation from them. It is worth emphasizing in this context that there are examples and mechanisms proving the positive impact of more developed countries on the economy, efficiency, ecology and social affairs in less developed countries both directly and indirectly through supranational organizations such as the UN, WHO and WTO. It should also be acknowledged that craft and municipal waste were also a dilemma century ago, as evidenced today by sections of numerous excavations around the world, e.g. under the Krakow market square, numerous mine tailings piles, settling ponds near chemical factories (e.g. soda), polluted air and historical data. However, as already mentioned, in recent decades these problems have become particularly large and important. The main negative effects of linear model farming processes in the 21st century are discussed below.

1.2. The negative effects of linear model farming in the 21st century

1.2.1. The greenhouse effect

One of the main culprits of climate change on Earth, especially the increase in atmospheric temperature and further effects in the atmosphere, is carbon dioxide. This phenomenon, known as the greenhouse effect, causes further effects in the biosphere and translates directly or indirectly to the economy as a whole. According to global data from 2019, bi-carbon monoxide emissions into the atmosphere totalled around 36 million tonnes. The largest contributors were coal (14.5 million tons), petroleum fuels (12.5 million tonnes), natural gas (7 million tonnes) and cement production (2 million tonnes) (www.globalcarbonatlas.org/en/CO2-emissions). Data for the period 2004-2016 show that all emission sources increased their share during this time, including coal 4.4 times, petroleum fuels 4 times and gas 4.9 times. It should also be noted that a significant emitter of carbon bi-oxide is now maritime and air transport.

Also "The residential sector, representing 27% and 17% of global energy consumption and CO2 emissions, respectively, has a considerable role to mitigate global climate change" (Nejat Payam. et al., 2015).

Table 1 presents data that document the increase in the amount of carbon dioxide emitted into the earth's atmosphere over the last 50 years. Previously, one of the main emitters, until the 1960s, was burning coal. In the following years, more carbon dioxide emissions came from the combustion of oil derivatives. In the middle of the previous century, natural gas and cement production joined the significant emitters. After 1950, the total emission of carbon dioxide into the atmosphere has had a strongly increasing trend, exceeding 8000 million tonnes on average per year, with some fluctuations related to economic crises.

Table 1. Total global emissions of di-carbon monoxide in Gt/year in five sectors from 1970 to 2019

Year	Sectors				
	Power industry	Industrial combustion	Buildings	Transport	Other sectors
1970	4	5	4,5	3	1,5
1975	5,5	5,5	4	4	2
1980	6	5	3,5	4	2,5
1990	7	5	3,5	4,2	2,5
2000	10	5,5	3	5,5	2,5
2010	11,5	7,5	3,5	7	3,5
2015	14	7,7	3,5	8	4,0
2019	14,5	8,5	3,5	8,6	4,5

Source: own study based on: Fossil CO2 emissions of all world countries - 2020 Report. https://publications.jrc.ec.europa.eu/repository/handle/JRC117610)

1.2.2. Degradation of ecosystems

The implementation of production in a linear system leads to the creation of various types of waste at individual stages of production processes. Large streams of waste materials are directed to landfills, settling ponds or mine waste dumps. Their management is possible, but difficult and costly. Production requires energy, and the extraction and processing of energy resources also generates waste. Open cast mining, for example, poses a great threat to the environment. Apart from the heaps of overburden soil on previously arable land, and often in human settlements, it also devastates water relations in large areas. A large proportion of the production materials are incinerated, generating not only carbon dioxide but various other gaseous inorganic substances such as sulphur dioxide or nitrogen oxides, as well as dust of various particle sizes. Some waste, especially from the chemical and pharmaceutical industries, poisons river and lake waters or groundwater, which is even more dangerous. There are numerous known examples of such waste being stored in illegal and unsuitable landfill sites, and of its dangerous burning (deliberate fires) in Poland.

Similar problems are created not only by industrial production, but also by large-scale agricultural, horticultural and livestock production. According to J. Korhonen (2018), incineration of materials of biological origin to obtain energy should be the penultimate option in a number of other activities, while landfilling - the last one. Only in this way will the maximum economic and social value in the cyclical chain of transformation be preserved.

1.2.3. Enhancing water scarcity

Water availability is crucial for sustaining life on Earth, for food and (energy) production and for sustainable development. The demand for freshwater is increasing due to population growth, urbanization and changing diets. Agriculture and livestock farming are the largest users of water resources today. They also consume about 25% of the energy produced. Projected population growth in the next 30 years from over 6 billion to about 9 billion (UN, 2017) will increase the demand for these resources by about 50%. Although the basis of agriculture is still rainwater-based production, irrigated agriculture now already occupies 20% of arable land, i.e., 275 million hectares, and accounts for 40% of global food production. In order to feed the growing population it will be necessary to expand the area under irrigation. Table 2 shows past and projected data on this subject.

Table 2. Artificially irrigated area in million ha

	1961	2006	2050
World	139,0	300,9	318,4
Highly developed countries	26,7	54,0	45,1
Medium-developed countries	66,46	137,9	159,4
Low developed countries	45,8	108,9	113,8

Source: http://www.fao.org/docrep/017/i1688e/i1688e.pdf

Due to rapid population growth, water consumption has tripled over the past 50 years. This trend is largely explained by the rapid expansion of irrigation, stimulated by the demand for food in the 1970s and the continued growth of agriculture-based economies (http://www.unesco.org/new/en/natural-sciences/environment/water/wwap/facts-and-figures/all-facts-wwdr3/fact-24-irrigated-land). According to Salmon et al. (2015) "...Irrigation accounts for 70% of global water use by humans and 33-40% of global food production comes from irrigated croplands...". We estimate that 314 million hectares (Mha) worldwide were irrigated circa 2005. This includes 66 Mha of irrigated paddy cropland and 249 Mha of irrigated non-paddy cropland. Additionally, we estimate that 1047 Mha of cropland are managed under rain-fed conditions, including 63 Mha of rain-fed paddy cropland and 985 Mha of rain-fed non-paddy cropland".

New data published by FAO (2019) indicates that about 22% of croplands are artificially irrigated in 2019.

Despite the globe's almost infinite water resources in the oceans (97%), the demand for freshwater (of which 1% is land water, 2% is glaciers) is growing exponentially and its availability is limited in many regions of the world. This will result in the need to smart management of water resources for agricultural, sanitary, industrial and human uses by balancing supply and demand and by undertaking innovative solutions. These include advances in genetics and technologies to sustainably grow crops, livestock, fish and seafood with the highest possible efficiency (UN 2019) (http://www.unwater.org/water-facts/water-food-and-energy). The answer to the question of whether nature's circular water cycle will be sufficient to meet future demand is not clear, although current demand is well below the planet's potential capacity (Taikan Oki, 2006). This circulation is strongly dependent on the climate system and the stewardship of this resource. It is estimated that currently 3800 km^3 of water are consumed, which is about 10% of the total land water resources. Its main components are water from transpiration of crops (about 7600 km^3 and pastures 14000 km^3), representing about 1/3 of the total terrestrial water resources subject to evaporation and transpiration.

Increasing atmospheric and soil pollution, scarcity and contamination of terrestrial (rivers, lakes) and deep water, increasing municipal and industrial waste, increasing demand for energy resources, energy, and many basic materials (Lee et. al., 2012) pose numerous problems for ecosystems in individual countries and for the globe as a whole.

1.2.4. The increasing trend in the extraction of non-renewable raw materials

For a long time, the linear economy has been unable to face the problems generated by the effects of its growth, the causes of which include consumerism, the increase in wealth of many societies, and the growth of the world population. There are currently about 6.8 billion people living on Earth. Demographic forecasts predict that in the next 30 years it will increase to over 9 billion (UN World Population, 2017). Current economic development trends suggest that a relative slowdown in world product growth and raw material needs will lead to a decline in resource demand. However, these reductions according to Jackson will be caused by a sharp increase in material prices (Jackson, 2011). Consumption of various raw materials has increased by a factor of two or more in the last forty years. Below, Tables 3 - 5 present data on the extraction of various important raw materials and materials in the last few decades. Similar data have been presented in other sources (Schafartzik et al., 2014). Further increases in demand are to be expected if there is no rapid change in business models (Ellen Macarthur Foundation, 2013, pp. 14-16).

Table 3. Global energy resources extraction and electricity production from 1990 to 2020

Year	Coal mln/t	Crude oil (thousand barrels a day)	Electricity (mld kWh)
1990	4700	60400	10395
1995	4600	62430	13500
2000	4500	68300	15500
2005	6000	73500	15800
2010	7500	74200	21500
2015	7200	79800	24500
2018	7800	95000	26000
2019	7900	100000	26100
2020	7600	.	25500

Source: coal (www.iea.org/newsroom/energyshapshots.world-total-coal-production-1971-2016.html); crude oil (www.indexmundi.com/energy); electricity (https://www.statista.com/statistics/270281/electricity-generation-worldwide)

Between 1965 and 2020, the production volume and the structure of the share of energy raw materials as primary energy carriers changed. Coal mining increased from about 3 to almost 8 billion tonnes in 2019 (Table 3). However, in the period of the Covid-19 pandemic, the demand for coal decreased due to lock-down and to the contraction of economies, the output fell to 7.6 billion t in 2020. The share of coal among energy resources is decreasing and ranges from 25 to 38%. In Poland, on the other hand, the production of energy from wind installations has increased in recent years and photovoltaic sources are growing. Currently the electricity mix in Poland is 48% hard coal, 17% lignite, 25% renewable energy sources and about 10% other (https://300gospodarka.pl/300klimat/transformacja-energetyczna-polska-2020-forum-energii-spadek-wegiel). Oil production has increased from 1965 to 2020 by more than 300% % (Table 3). The decline in oil demand between 1973 and 1975 (the so-called oil crisis) led to the formation of the OPEC organization. After it was brought under control, the demand for oil increased in line with the development of motorization. Since 2000, oil demand has been increasing and production reached 100,000 barrels per day in 2019.

The years 1965- 2017 saw a slow increase in the share of natural gas in meeting energy demand from about 14% to about 24%. Hydropower resources have remained almost constant at around 8%. Nuclear power increased its share from zero to around 7% in the 1990s. But after 2005 its share decreased and currently remains at around 5%. A noticeable share of renewable energy has taken place since the end of the 20th century but has now only reached a level of about a dozen percent of demand (https://www.bp.com/content/dam/bp/en/corporate/pdf/energy-economics/statistical-review/bp-stats-review-2018-full-report.pdf).
One projection for the future is given below in Table 4.

Table 4. Global Renewable Energy Projections

	2001	2020	2040
Oil equivalent (million ton equivalent)	10.000	11.500	13.300
Renawable sources contribution	13,6%	23,6%	47,7%

Source: Demirbas, 2009.

As stated in Global Energy Review (2021) renewable energy use in 2020 reach approximately level of 29 % as demand for all other fuels declined. This result is significantly better than forecast (Table 4), indicating a determination to increase their share in the world's 'energy mix'.

In the production of steel (Table 5), three periods can be distinguished after 1950: growth (1950-1985), slowdown (1985-2000) and more than doubling after 2000. Between 1950 and 2015 it increased tenfold. The development of aluminium production was much faster. Between 1975 and 2017 it increased fivefold. There has been a systematic increase in copper production from 2.1 million tonnes in the 1950s to 20 million tonnes in 2020.

Table 5. World production of selected strategic metals from 1970 to 2020

Year	Steel (million tonnes)	Aluminium (thousand tonnes) *	Copper (million tonnes) *	Lithium (thousand tonnes) *	Rare earth oxides (thousand tonnes) *
1970	595	-	5,9	8,0	16
1980	717	15,1	6,8	9,5	26
1990	770	19,5	9,5	15,0	41
2000	850	24,6	13,5	20,0	83
2005	1148	31,5	15,1	-	-
2010	1433	42,20	16,0	28,0	120
2015	1621	58,57	-	-	200
2017	1732	73,7	-	-	-
2019	1869	-	-	-	-
2020	-	65,3	20,0	82,0	240

Sources: steel – www.world.steel.org/steel-by-topic/statistics/World-Steel-in-Figures.html; alluminium: www.world-aluminium.org/statistica/#data; lithium: e.wikipedia.org/wiki/Lithium_as-an_investment; copper: https://upload.wikimedia.org; https://www.statista.com/topics/1409/copper/#dossierKeyfigures; rare earth oxides: https://www.statista.com/ statistics/1187186/global-rare-earths-mine-production/ https://upload.wikimedia.org/Wikipedia/commons/9/93/Rareearth _production.svg

The growth in the extraction of rare earth oxides and the production of metals such as lithium and rare earth metals is much faster. Lithium production, due to demand between 1950 and 2015, increased from 10 to 600 thousand tonnes and continues to grow. The level of its production in different years has fluctuated widely in the short term progressing along a rapidly increasing average.

Rare earth oxide production followed an upward trend with strong fluctuations until 2000, while it is now increasing rapidly due to the demands of modern industry (wind turbines, aircraft, professional and consumer electronics, liquid crystal displays, fibre optics, X-ray films, strong magnets, reactor control rods and many others) (Klupa, 2012; Global, 2018; Global Rare Earth Metal, 2018; Zhou et.al. 2017). Across the group of these elements and their compounds, there is so far some excess of supply over demand.

Platinum and the platinum group are also economically important metals. The maximum production of platinum took place in 2006 and amounted to about 220 tonnes. The total production of these metals in the years 2008 - 2012 was at the level of: 468, 448, 467, 487 and 451 tonnes per year. The share of platinum each year oscillated to about 190 tonnes (USGS 2012) decreasing to 160 tonnes in 2014. In the following years it increased to 190 tonnes before decreasing again to 170 tonnes in 2020 (https://www.statista.com/statistics/1170691/mine-production-of-platinum-worldwide). Due to very high market prices, much of the metals in this group, especially platinum, are recovered from discarded car parts. Gold is also among the metals important in industry. Its extraction was sufficient for about 75 % of the annual demand. The rest is covered by recycling. Of this source, around 90 % comes from jewellery purchases and the remaining 10 % from industrial recovery (https://www.gold.org/about-gold/gold-supply). In 2018 and 2019, the total extraction was 3509 and 3464 tonnes, respectively. In addition, the market was supplied with recycled gold in quantities of 1176 and 1304 tonnes (https://www.gold.org/goldhub/research/gold-demand-trends/gold-demands-trends-full-year-2019/supply).

Similarly to the growing production of energy raw materials and basic metals characterized above, the production of basic chemical products is also increasing (Table 6). Among many large-tonnage products of heavy organic and inorganic chemistry one should mention plastics, sulphuric acid, ammonia, fertilizers of key importance for many branches of economy.

Table 6. Production of selected chemical products (million tonnes) in 1960-2020

Year	Plastics	Ammonia	Total fertilizers	Sulphuric acid
1960	-	12	33,51	50
1975	50	51,5	94,12	110
1980	-	80	124,72	140
1990	100	98	148,29	162
1995	137	90	142,69	160
2000	190	100	143,18	180
2005	222	120	172,01	210
2010	270	130	193,22	-
2015	322	146	207,98	260
2016	335	-	230,00	252
2019/20	368	230	250,00	256

Sources: plastics: https://www.statista.com/statistics/282732/global-production-of-plastics-since-1950/; ammonia: http://www.roperld.com/science/minerals/ammonia.htm; fertilizers: https://ourworldindata.org/fertilizer-and-pesticides; http://www.fao.org/3/ca6746en/ca6746en.pdf; sulphuric acid: https://publications.jrc.ec.europa.eu/repository/handle/JRC121460

In 1950 the production of plastics was less than 1.5 million tonnes and today it exceeds 365 million tonnes, creating great problems for the land, rivers and sea environment. They have advantages such as resistance to weathering, high mechanical strength in relation to their weight, resistance to external and even chemical agents, and ease of shaping. They often replace many natural materials (e.g. fibres) or construction materials (wood, light metals), but they also have many disadvantages. They are very harmful to the environment due to their resistance to degradation by external factors of a chemical and micro-biological nature. As Śmiechowska (2019) writes, plastic particles are now found not only in the body of fish and other marine organisms, but also in the internal organs of humans posing a health risk. As reported by (Hernandez et. al., 2019), their source is also teabags, among others.

The increasing production of heavy inorganic chemicals such as ammonia, fertilizers in general and particular types of fertilizer, especially phosphorous and sulphuric acid, means that crop yields are rising, which should be regarded as positive. However, the pollution of groundwater, lakes and rivers, and consequently of the sea, is increasing. An increase in the concentration of inorganic substances in water, adversely affects the changes in these ecosystems.

Pesticide use in the period since the 1940s has been - almost zero, increased to about 3 million tonnes in 2000 (Tillamann et al., 2002) and is still increasing rapidly (Table 7). (http://www.fao.org/faostat/en/#data/RP/visualize).

Table 7. World production of pesticides (million tonnes)

Year	1950*	1970*	1990*	1995	2000	2005	2010	2015	2019
Production	0,100	1,400	2,500	2,711	3,082	3,452	4,015	4,128	4,151

*Data aproximation from Tillaman et al. (2002).

The breakdown of pesticides in soil occurs at different rates. However, trace amounts of one of the first - DDT and its breakdown products are still present in ecosystems today. More detailed data on the increasing use of pesticides and their impact on crop production can be found in (Wen Jun Zhang, 2018).

1.2.5. Increasing supply risks

In a linear economy, as the economy grows, the uncertainty about the availability of raw materials and materials also increases. This uncertainty is due to the fact that the Earth has a finite amount of materials, the availability of which depends on various factors. These include global market mechanisms, available technologies, extraction costs, price fluctuations, limited supply of certain materials, the subsequent atomization of many raw materials (dispersion) and others. It consists in the fact that some raw materials extracted by industrial methods from the lithosphere are dispersed on a different scale and their recovery depends on it. For example, scrap iron is easy to melt, but gold used to coat the contacts in a mobile phone is not. Other raw materials, after being used (e.g. coal, oil), are transformed into carbon dioxide, which in the biosphere can be included in the assimilation process and transformed into plants, but never into lignite or hard coal. Threats to the availability of materials translate into price fluctuations, the health of industries, the formation of product-process relationships and even the emergence of economic crises.

Significant fluctuations in the prices of basic raw materials (e.g. oil) cause perturbations not only in the market for petroleum products and give rise to serious economic crises (e.g. the fuel crisis of the late 1960s). This crisis led to the formation of an organization of countries with the character of a cartel, the large oil producers - OPEC. Such events raise concerns for producers and buyers and increase risks in doing business (Lee et. al., 2012). Some of the above-mentioned raw materials and commodities are now among those critical to the further development of certain industries. These include the metal, electrical engineering, computer, automotive, and transportation industries, where fluctuations in material and component prices make it difficult to predict and reduce competitiveness against other industries (Accenture, 2014; Lee et. al., 2012). This is evident in pandemic periods that destabilize or break supply chains especially air and sea. Recently, there has been a fuel crisis in EU countries and the UK caused by rising fuel prices. In addition, the availability of containers on transoceanic routes has decreased.

However, it turned out that the linear economy, although it contributed to the material growth of industrialised countries, caused much irreversible damage (Sariati, 2017; Kyoto Protocol, 1997 and 2005; UN Climate Conferences). The cited sources states that in the past, consumers of natural resources came from highly developed regions and many material and raw materials were imported from poor countries experiencing an abundance of cheap material resources and energy. Imported raw materials were cheap compared to the cost of human labour in the home countries. As a result, production models were based on extensive use of materials and saved human labour. Moreover, by using cheap resources, they gained a competitive advantage as a complement to human capital. A natural consequence of cheap resources was their overuse or waste and reluctance to reuse them (recycling). Producers as well as consumers did not pay attention to environmental externalities. In turn, the Kyoto Protocol "operationalizes the United Nations Framework Convention on Climate Change by committing industrialized countries and economies in transition to limit and reduce greenhouse gases (GHG) emissions in accordance with agreed individual targets". Recently concluded UN Climate Conference in Glasgow Nov. 2021 (https://ukcop26.org/cop26-goals/) will put stress on “the phase-out of coal, curtail deforestation, speed up the switch to electric vehicles, encourage investment in renewable” and finalize the Paris Rulebook (the detailed rules that make the Paris Agreement as well to accelerate action to tackle the climate crisis through collaboration between governments, businesses and civil society).

SUMMARY

This section of the paper presents the main negative effects on the development of economic and social growth and the environment occurring in a linear economy. These are:

- the greenhouse effect, for which all sources of energy emissions are responsible, showing an increase:
- degradation of ecosystems involving producers, service providers and consumers,
- pollution and reduction of water resources and their availability, for which population growth is also to blame,
- increased demand for raw materials for energy, metals and chemicals,
- increased risk to security of supply and operations.

The demonstrated environmental and social losses are the basis for making other choices in the management process, i.e. changes towards sustainable development. This is influenced by changes in mentality, culture and awareness of societies. These changes are determined by formal institutions and intellectual capital, including social capital. Authors in earlier studies proved that raising its level increases the efficiency of public management, entrepreneurship, the quality of business processes and innovation (Skawińska, ed. 2012, pp. 46-63). One may ask, however, if we are dealing with economic growth, is this phenomenon accompanied by intellectual development of people, in connection with the possibility then to increase spending on the education, research, acquisition of knowledge, skills, development of abilities? Well, it turns out that these opportunities are not always realistically exploited. For the priority of needs is often determined in the state's investment policy according to the criterion of priority in satisfying existential (food) or demographic needs. Meanwhile, in another paper (Brzęczek, 2011, p. 197, Tab. 8.3), the author found a moderate statistically significant correlation between education level and individual social capital. This could mean that as the level of education increases, social capital increases. But this is not the case, because its level is the result of many social capital resources, not one. Moreover, in the process model of social capital formation, education, social networks, public organisations, institutions, NGOs and others have a strong influence on its level (Skawińska, Zalewski, 2020 s. 186). Some of them may then reinforce their negative impact on social capital, e.g. trust, norms and values, solidarity. That is why these resources need to be built and grown by the system of institutions in the first place. Already the posing of the above questions and the ambiguity of their answers in the literature indicate the great importance of the problem undertaken and the lack of sufficient recognition through empirical research.

Therefore, in the next chapter (II), the authors explain the concept of sustainable and balanced development and the principles on which it is based and the conditions whose improvement will foster its implementation.

Chapter 2: Sustainable and balanced development in the context of EU policies

2.1 The concept of sustainable development

Alternative economic theory for counteracting the negative social, economic and ecological effects in the resulting global economic disorder points to proposals in complexity economics, including new institutional economics (Coase, 1998; Williamson, 1973; North, 1960; Wojtyna, 2014; Rogowska, 2021; Zrałek, 2016), social economics, new pragmatism (Kołodko, 2020), ecological economics (Constanza, 1992) and sustainable development economics (Daly, 1996; Rogall, 2010; European Commission, 2010).

Today, sustainable development economy is the dominant trend in the economics of the future. A simple definition of sustainable development is non-declining human wellbeing over time (Pearce, Atkinson, Dubourg, 1994).

It is in the process of development and definition and represents a new paradigm of economics as a scientific discipline. This is because it proposes a change in values, objectives and ways of achieving them by actors in the economic process at each level. These changes have already been reflected in the strategies of many global international organizations, e.g. WTO (Puślecki, 2021) and in the policy objectives of governments of European Union members and other countries. They are intended to counteract the deepening economic and socio-economic and ecological imbalance in the current process of management, implemented according to the principles of neoliberal economics in a linear model. This is indicated by the development of the Compass for Systemic Change (Rome Report, 2020).

Representatives of the economics of sustainable development presented their views at various international organizations as early as the 1970s. Reflections on this subject, in connection with global threats to the future development of the world, were mainly aroused by the Report of Secretary General U'Thant entitled "Man and his Environment" from 1969 and Reports for the Club of Rome: "Limits to Growth" of 1972. (Meadows et al, 1973) and "Mankind at a Turning Point" (Mesarovic, Pestel, 1974). The date of the formation of the theory of sustainable development is taken to be the 1980s, as in 1972, at the first UN conference "Only One Earth" in Stockholm, the terms "environmental policy" and "environmental protection" were introduced. Then, in 1975, the United Nation Ecological Programme (UNEP) Governing Council of the United Nations gave the first formally defined definition of sustainable development in its environmental programme.[1]

Note that as a result of the financial and economic crisis at the turn of the first and second decades of the 21st century, there has been increased intellectual effort in the more pragmatic direction of sustainable development economics (SDE). There is increasing pressure on the practical usefulness of its assumptions, bearing in mind the sustainability of development, threatened by the rate of population growth, changes in its structure, the scale of environmental deterioration, the development of consumerism and the growth of economic inequalities. Therefore, it is difficult not to notice that an increasing number of economists, as well as representatives of other sciences, mainly sociologists, psychologists and politicians, as well as intellectuals in Poland, leaning on this problem, undertake discussions about the economy of the future (Forum of Strategic Thought; Kołodko, 2017; Filek, 2017). They are interdisciplinary in nature as evidenced by the cited context of not only the limits of economic growth and dysfunctions of the modern economy, but also ethics, justice, morality, culture, norms and values. This is evidenced by the fact that in 2015. UN in the "Agenda for Sustainable Development"- (UN Agenda, 2030) formulated as many as 17 cross-cutting goals for this development (https://www.un.org/sustainabledevelopment/).

The UN Agenda 21 and its successor, the Agenda 2030, are important documents that provide inspiration on sustainable development and environmental protection and guidance for the development of regional sustainable development strategies. They form the basis of the European Union's socio-economic development programmes for 2000-2030, as reflected in the Lisbon Strategy, Europe 2020 and the current strategy, Europe 2030 (European Commission, 2019), which includes assumptions on sustainable development and growth (including on the basis of the circular economy, social inclusion and the investment programme for research, technological development and innovation, Horizon Europe (European Commission, 2019a). According to the Europe 2030 strategy (European Commission, 2019), the EU is to become a world leader in implementing the concept of sustainable development. This document proposes rational policies concerning the common good and the increase in the quality of life at local and regional levels.

[1] The first definition of the 3 interdependent pillars of sustainable development (economic, social and ecological) appeared in 1987 in the Report G. Brundtland "Our Common Future" of the UN World Commission on Environment and Development. A calendar of the development of thought concerning this category is contained, among others, in the work by E. Skawińska; R. I. Zalewski; B. Lubos (2016), Commission of Commodity Sciences of the Polish Academy of Sciences, Poznań Branch.p.59.

The addressees of the policy of such development are all actors at the macro and micro level. At the micro level, for example, models are proposed:

- Corporate Social Responsibility - CSR (Adamczyk, 2009; Fiedor, 2016; Filek, 2017; Corroll, 2018), and Total Quality Management (TQM), increasing the quality of processes, goods and services (Zalewski, 2016),
- Sustainability, sustainable enterprises (Grudzewski et al., 2010; Hejduk, 2016),
- Sustainable supply chain (UN, 2015). (Koberg E., Longoni A., 2019).

In turn, from a macro perspective, models are invoked:

- moderation and low-carbon economy (Kołodko, 2014, pp. 30 - 34; 2017 p. 67),
- economical management of natural, non-renewable resources (Reports for the Club of Rome and Reports of the Council of this Club; Poskrobko, 2007; Wąsowicz, 2011 and 2014; Borys, 2010),
- social market economy (Pysz, 2008; Mączyńska, 2010, p. 20 - 21),
- inclusive economic and non-economic institutions; formal and informal (Kolodko, 2014, p.19; Filek, 2017, p.34),
- neutral (zero growth) and negative growth (degrowth) models, promoting lower economic growth rates (Wordwatch Institute, 2012, pp.22ff)
- the country's ecological footprint, which quantifies the nation's natural resources and their consumption (Global, 2018).

It follows from the above that sustainable development is a concept in which model solutions are sought that would indicate harmony in the use of resources and the application of instruments and methods of action that enable sustainability of development. These models are oriented towards shaping the current economic, social and environmental order and the future, as a desired state in the face of civilization threats.

However, questions arise:

1. what is the degree of adaptation of real processes to the SDE theory taking place in countries with different levels of economic development?
2. what is the state of knowledge about the effects of implementing the assumptions of this theory in individual countries?

The pursuit of answers to these questions inspires research and the search for evaluation measures and the construction of further model proposals.

2.2 Socio-economic aspects of sustainable development

Thinking back to the conceptualization of sustainable development in the SDE, we notice that in relation to the paradigm of neo-liberal economics[2], the interests of the theory have broadened to include the environmental and social aspects of the management process. What is more, the quality of life of societies has become a fundamental element in the construction and understanding of the term "sustainable development". Well, in the light of the findings of the Second UN Conference of 1992[3], sustainable development means "a process of change in which the use of natural resources, the directions of technological development and institutional change must take place in such a way as to meet the needs of the present generation without compromising the ability of future generations to meet their own needs". In this definition, as emphasised by I. Hejduk, it is the development and improvement of the quality of life of present and future generations that is highlighted (Hejduk, 2014, p.48), as well as the increase in social cohesion (reduction of income polarization).

Further considering this issue, it should be stated that the social dimension included in the category of quality of life is reflected in the food security of the society (physical and economic availability), in the assurance of employment and work, in the access to health protection of citizens, without limiting or excluding them from the participation in the production of national income. This means, inter alia, guaranteeing:

- on the labour market - availability of work in accordance with qualifications and skills, improvement of the quality of working conditions, observance of workers' rights and the formation of favourable wages, as well as social security,
- on the investment market - investment in human capital, through various forms of employee education, development of adaptability of the employed,
- on the cultural, educational and scientific market - opportunities for self-realization of the population and use of offered goods and services.

However, let us ask whether this is possible in every country? The answer in the affirmative is provided by G. Kołodko, who proposes the application of economic policy instruments shaping an economy of moderation in each country. The author defines the concept of economy of moderation as "adjustment of the

[2] Where the economic power of companies has been directed towards increasing profit (profitability, productivity), and this has increased the consumption of resources and created barriers to development. In the light of SD, other values should also be the motive for action.

[3] The so-called Earth Summit in Rio de Janeiro. The Declaration on Environment and Development called the Earth Charter and the Agenda 21 document containing the Programme of Action for Sustainable Development were adopted there.

size of streams - human, natural, financial and material - to the requirement of maintaining a dynamic balance". Its basis, as the author states, is to be moderation on the supply and demand side, i.e. in production and consumption. It is about moderation expressed in the creation of the productive capacity of companies, in indebtedness, in marketing instruments developing the needs of consumers and in differences in income and wealth, (Kołodko, 2014 p, 33). It is the lack of moderation in economic processes that causes imbalances in the environment. Meanwhile, its balancing is a condition for the growth of national prosperity (Corrigran et al.ll, 2014). The increase in environmental protection and reduction of the mentioned environmental imbalance is influenced by formal institutions of national and international policy, concerning the use of renewable resources and counteracting environmental degradation (Kowalski, Weresa 2021, p.23). This does not mean diminishing the role of informal institutions, among them mainly knowledge and social capital. On the contrary, they constitute elements of the local and regional environment as basic determinants of the quality of formal institutions, national policies and the effectiveness of their implementation. The view that in the implementation of sustainable development strategies, social capital is a priority (Kronenberg, Bergier, 2010, p. 24; Matson, Clark, Andersson, 2016, p. 46) is gaining popularity.

Assuming that the primary goal of sustainable development economy is the quality of life of the society and its growth, let us look at the evaluation of this category in Poland. Of course, one should bear in mind the methodological weaknesses of measuring the quality of life, as a widely understood economic and social-cultural concept, especially in the comparative aspect, as pointed out by E. Polak (2018, pp.423-426). Since there is no single measure to assess this category, such indicators (measures) were used in which strategically important elements of the quality of life category dominate (Table 8).

The indicators in Table 8 give a rough indication of a country's assessment of its quality of life. Ewa Polak points to the good direction of changes in this area in Poland. But she also lists its weaknesses as components of this category. These include: "relatively low life expectancy, low level of people's trust in authority and in each other, low social activity of Poles, structural problems of the labour market, low income, income polarization, low level of accessibility to affordable housing, poorly functioning health care system, high rate of premature deaths, alarmingly high suicide rate" (Polak, 2018, p. 437). The level of indicators in Table 8 was influenced by the global Covid-19 pandemic, which lasts in 2020 and 2021. The current assessment of their level requires research using a uniform research methodology for all countries. Partial data for Poland indicate a reduction in the ranking of the SEDA, WHI, SLI and HPI indicators.

Table 8. Poland's position in the assessment of quality of life using the indicator method in 2017 and 2020

No.	Indicator	Dominant dimensions of quality of life	Number of countries surveyed		Poland's rank	
			2017	2020	2017	2020
1	ESCAPE	Quality of growth, stability, social cohesion, sustainability, institutions, technology	42	.	21	.
2	SEDA	Health, access to healthy water sanitation	150	141	27	28
3	WHI	Life expectancy, job security, trust in government, consumption levels	156	149	42	43
4	BLI	Employment and life security social support, education	38	40	27	27
5	EPI	Environmental performance, state of nature biodiversity, health care	132	100	22	16
6	EHCI	State of health care	37	.	31	.
7	HDI	Life expectancy, school enrolment GDP p.c.	168	189	36	35
8	SLI	Health, life satisfaction	178	95	51	73
9	HPI	Life expectancy, ecological footprint, well-being, social stratification	140	.	62	71
10	Gini	Income stratification	136	130	51	21

Explanation of symbols: ESCAPE - escape from stagnation after the financial crisis for developed economies; SEDA – Sustainable Economic Development Assesment; WHI – World Happiness Index; BLI – Better Life Index; EPI – Environmental Performance Index; EHCI – Euro Health Consumer Index; HDI – Human Development Index; SLI – Satisfaction with Life Index; HPI – Happy Planet Index; Gini coefficient – Income stratification.

Source: own elaboration for 2017 based on Polak E., 2018 pp. 425-437, and for 2020 the sources are given below:
No. 3. World Happiness Index https://countryeconomy.com/demography/world-happiness-index, No.4. https://en.wikipedia.org/wiki/OECD_Better_Life_Index#2020_ranking, No. 5. hpps://epi.yale.edu, No. 7. http://hdr.undp.org., No. 9. http://happyplanetindex.org, No.10. https://www.statista.com/forecasts/1171540/gini-index-by-country

2.3 Environmental aspects of the economics of sustainable development

As already mentioned, the economics of sustainable development emphasizes the efficient use of existing environmental resources in order to preserve them for future generations. In addition to the economical use of resources, priority is given to the protection of nature against devastation, overuse and to ensuring climate neutrality. The way to achieve these goals is becoming the restoration of biodiversity, which is a guarantee for the maintenance of ecosystem services and the provision of ecosystem services, which are the basis for prosperity and the source of financial capital (Skubała, 2010, p. 26; WWF, 2020). The importance of addressing these issues has become particularly topical in the aftermath of the Covid-19 pandemic crisis and the intensification of climate disruption in the 21st century, resulting in catastrophic events. This is evidenced by the voices of the leaders of 196 countries of the world at the UN COP 26 world climate summit in Glasgow in November 2021, backed up by dramatic words from politicians, experts and representatives of NGOs and business, on the global environmental imbalance. Once again, concern for the future of the world shines through at UN conferences by criticizing unsustainable production and consumption patterns and logistics. In practice, however, there is no such unanimity among decision-makers as to establish guidelines for shaping formal institutions so that knowledge of existing threats can influence practical countermeasures and ensure effective, coherent strategies in the fight for sustainable development at national and global levels.

However, the economist, being obliged to take an interdisciplinary view of contemporary economic phenomena, should evaluate the natural environment through the functions it performs. Therefore, below, the functions of natural capital are presented in the context of biodiversity and ecosystem services, as well as the threats resulting from their loss, due to a violation of environmental stability.

Natural capital is, in other words, the natural capital that constitutes the earth and everything on its surface and in its interior that is useful to humans but is not the result of human labour. According to R. Constanza and H. Daly, natural capital is the extension of economic capital by environmental goods and services (Constanza, Daly, 1992). It is divided into renewable, i.e. self-sustaining or regrowing (e.g. solar energy, to some extent land, ecosystems, water) and non-renewable (e.g. oil, coal, natural gas, minerals), and the authors have already written about the state of their use in chapter I of this work. Natural capital, together with the services it provides, determines the existence of societies and life on Earth. Meanwhile, over the last 30 years or so, its resources have declined by 40% (UNEP 2018). The functions of natural capital are ecological, socio-cultural and economic (Jeżowski 2012). The possibility and extent to which they are realized is largely determined by biodiversity. This category refers to "the diversity of all living organisms found on earth in terrestrial, marine and freshwater ecosystems and the ecological communities of which they are part. It includes diversity within species, between species and of ecosystems" (Convention 1992). Its deteriorating status in relation to food and agriculture is reflected in an FAO report (FAO 2019).

Biodiversity is important for food security and health and is reflected in the ecosystem services provided, particularly in agriculture, medicine and industry, but also in recreation and tourism. These include the provision of food production on land and in the sea, water, wood, cellulose and renewable raw materials. They can therefore be called production services. Conversely, waste treatment, absorption and regeneration, air regulation, climate regulation, pollination, mitigation of extreme weather events, etc., are regulating services. Cultural services, which include recreation and tourism, arts and culture, play an increasingly important role in societies seeking to increase well-being. According to B. Poskrobko, environmental services can be divided into biological-ecological (processes that provide people with a basis for life and development) and socio-economic (everything that is relevant to economic processes) (Poskrobko 2010).

The data in Figure 2 on environmental products and services indicate that Poland faces urgent challenges to catch up faster with the peloton of European countries in terms of their development, although the value added of the eco-industry, i.e. the sector of environmental products and services, compared to GDP is the same in Poland as the EU average and was in 2018. 2,2%.

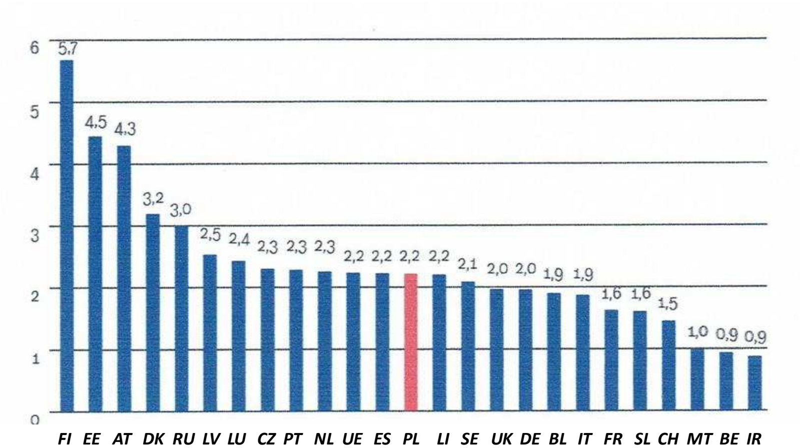

Figure 2. Value added of the environmental products and services sector relative to GDP in 2018 (in %)
Source: Economic Weekly (04.11.2021), Polish Economic Institute, Warsaw (https://pie.net.pl/wp-content/uploads/2021/11/Tygodnik-Gospodarczy-PIE_44-2021.pdf)

Meanwhile, in the literature, it was already recognised at the beginning of the 21st century that humanity benefits from the biodiversity resources of future generations, and not vice versa, taking into account the need for intergenerational justice (Venetoulis J., Talberth J. 2006). The problem of this justice has long been considered in philosophy, ethics and economics, but no coherent theory of justice for modern times is yet available. An exhaustive review of various approaches in literature to the problem of obligations towards future generations is presented by Katarzyna G. Sobiech-Grabka in the context of undertaking public-private partnership projects, from the perspective of the theory of justice. She states that "what connects the present generation with future generations is the environment in which they are likely to live" (Sobiech-Grabka 2019, p. 57) and reminds us that in Article 2 of the 1997 Constitution of the Republic of Poland there is an indication of the need to "realize social justice" (s. 58).

Understanding that social justice also concerns future generations, measures should be taken to stop further impoverishment of biodiversity, reflected in habitat loss, species extinction and reduction of gene diversity in populations. Human economic activity should therefore conserve the natural environment and help maintain it, in accordance with the principle of intergenerational equity. However, climate change, i.e. increases in air temperature, warming and sea levels, ocean acidification, etc., pose an additional risk of reducing biodiversity. The extent of these adverse global changes since 1970 is confirmed by various indicators presented, inter alia, in the WWF report mentioned above.

The increase in environmental protection and the reduction of its imbalance mentioned above are influenced by formal institutions of national and international policy concerning the use of its resources and counteracting environmental degradation (Kowalski, Weresa 2021, p. 23). This does not mean diminishing the role of informal institutions, and among them mainly knowledge and social capital. On the contrary, they constitute elements of the local and regional environment as basic determinants of shaping the quality of formal institutions, national policies and the effectiveness of their implementation. The view that in the implementation of sustainable development strategies, social capital is a priority (Kronenberg, Bergier, 2010, p. 24; Matson, Clark, Andersson, 2016, p. 46) is gaining popularity. Therefore, the search for regional models and reconstruction of existing patterns of sustainable development, in the aspect of the European Green Deal, becomes so important.

2.4. EU policy for sustainable development

The problem of sustainable development was raised in literature already in the first half of the 20th century in the context of the development of economically weak countries. However, formally, the category of sustainable development appeared first in the documents of international organizations, including the EEC, and then in national normative acts. The Single European Act came into force in 1987 and defined the principles of sustainable and balanced development in the Community countries. In turn, the principles promoting such development were included in the EU Lisbon Strategy, adopted by the European Council in 2000. Subsequently, in 2001, the Gothenburg European Council endorsed the EU Sustainable Development Strategy as a set of recommendations complementing the Lisbon Strategy. The 2004 Treaty establishing a Constitution for Europe, as well as the 2007

Treaty of Lisbon amending the Treaty on European Union and the Treaty establishing the European Community, state that the basis for the EU's development will be sustainable development based on a social market economy. The theoretical assumptions of this model take into account the adaptation of economic policy methods and instruments to a competitive economic order.

Currently, the core EU document in this regard is the European Green Deal, adopted by the European Commission in July 2021, which continues the EU strategy for smart, sustainable and inclusive growth, Europe 2020 - A strategy for smart, sustainable and inclusive growth. Already in this strategy, a new paradigm was formulated for the development of sustainable enterprises using sustainable innovation. Furthermore, the use of EU financial support by individual national entities was made conditional on the implementation of the policies set out in the strategy. Member State-specific commitments and targets have been consolidated in national strategies for sustainable and balanced development.

Seven flagship initiatives have been identified among the objectives of the Europe 2020 strategy. From the point of view of the circular economy, the Innovation Union Initiative and Resource Efficient Europe are important. The 7th Environmental Action Programme, which directly relates to circular economy principles, entered into force in 2013. Its guiding vision is: "In 2050, citizens enjoy a good quality of life within the ecological limits of the planet. Our prosperity and a healthy environment result from an innovative circular economy where nothing is wasted and natural resources are managed sustainably" (European Commission, 2013). In turn, the UN, in paragraph 12 of Agenda 2030, demands:

- improve resource efficiency and the efficient use of materials at all stages of their life cycle,
- strengthen the implementation of the Innovation and Efficiency Strategy,
- ensuring strong national frameworks for sustainable consumption and production integrated into national and sectorial plans, and
- use economic instruments on a larger scale to promote more efficient waste management (cf. OECD, 2017, p. 15).

The European Green Deal strategy goes even further, assuming that by 2050 Europe will become the first climate-neutral continent by, among other things, significantly reducing greenhouse gas emissions and the processes that cause emissions (e.g. energy and transport industries, agriculture), economic growth will not be based on the consumption of natural resources, and economic processes will be based on low-carbon and circular industry and sustainable agriculture and food production 'from farm to fork', neutral for the climate and the environment (European Commission, 2021a;

https://ec.europa.eu/info/strategy/priorities-2019-2024/european-green-deal_pl).

In Poland, the concept of sustainable development, in connection with the model of a social market economy as the basis of the economic system of the Republic of Poland, is included in the Constitution of the Republic of Poland of 1997, in the National Development Strategy until 2025 adopted by the Parlament - Sejm (Strategy, 2000), (Strategy, 2013) and in the Environmental Protection Act 2001 (Act, 2001) into a vision for the development of the Polish economy in the document "Strategy for Innovation and Efficiency of the Economy - Dynamic Poland 2020" (Council of Ministers, 2013). It contains 4 operational objectives. Due to the purpose of this work and further considerations, it is worth mentioning objective 3, which reads - "Increase in efficiency in the use of natural resources and raw materials". However, ambitious assumptions of the new Green Deal together with restrictive standards and limits will certainly pose a challenge for Poland, but together with the funds launched also an opportunity to transform from an economy consuming non-renewable natural resources to a low-carbon and environmentally friendly economy (Infrastructure and Environment Programme Service, 2021, https://archiwum.ncbr.gov.pl/en/programmes/european-funds/infrastructure-and-environment-operational-programme/about-the-programme).

The policy of sustainable development of national economies is shaped by external and internal entity relations. The models listed above at the micro level correspond with this idea: Customer Social Responsibility (CSR), quality growth and sustainable energy. However, none of them fully covers all components of the theoretical concept of sustainable development. The first of the mentioned models is most often communicated to the society by large companies and reflects the presented idea quite well. It means, despite the ambiguity of its definition, that the adoption of this orientation by the company requires the creation of value for all its stakeholders.

A formalized approach to CSR is reflected in the standard adopted in ISO 26000 in 2010. (ISO, 2010), which is applicable to and can be implemented in all organizations. It covers seven areas: organizational governance, human rights, labour relations, environment, fair market practices, consumer relations and community engagement. The evolution of enterprise's goals from economic to gradual orientation towards social responsibility, is becoming a fact in EU countries, also in Poland. However, many studies and reports show that activities of enterprises in our country, in this area are still uncoordinated and selective. In the short term, the implementation of this model, through intensive activities, encounters a profit barrier. Therefore, a long-term orientation is desirable, which strengthens the position of the enterprise on the market, through the competitive advantage of CSR (PARP, 2015).

In turn, the model of quality in the management process in relation to the concept of sustainable development covers a narrower area. The policy of its implementation uses various parameters, models, standards defining the principles of quality of products and services in the production process, logistics and consumption, as well as their safety. They are created in the global economy by international organizations ISO, WHO, FAO and recommended for use in all countries, mainly member states, also in the EU. This policy has a positive impact and an effective influence on the quality of life of societies now and will play an increasingly important role in the future.

It is precisely to the future perspective of business operation that the next proposal for business management towards sustainable development, in the sustainable enterprises model, refers. Its primary objective is also to increase the quality of life. This concept has been promoted since the last decade of the 20th century by the World Business Council for Sustainable Development and the International Institute for Sustainable Development. It is understood as a continuous process of balancing economic, social and environmental goals in companies, which involves a flexible reallocation of resources in line with changes in the environment. Moreover, it assumes a stimulating influence on the company's environment in order to increase market opportunities. Therefore, it allows many authors to use in this context the notion of the enterprise of the future. Such a model of sustainable development concerning both micro and macro scale is a proposal of implementing the principles of circular economy, reflected in the European Green Deal.

By acting together, the EU is able to put its economy and society on a new course towards greater sustainability. In the process, the EU can build on its strong global leadership on climate action and the environment, as well as consumer protection and workers' rights.

SUMMARY

Adjustments of the competitive linear economy towards sustainable and balanced development take place using different models at different levels of governance in terms of objectives, principles, instruments and methods of actors. Some of these are presented in subsection 2.1. Many of the questions posed in the literature, also in this thesis, require international research. However, the mere availability of many synthetic and partial hard economic and social indicators for individual countries makes it possible to assess the level of advancement of the adjustment process. Poland has made significant progress in this respect and has been steadily improving its image in recent years, although some issues (e.g. emissions, energy independence and biodiversity) still place our country in the position of a laggard. The institutional guide for our country is the UN and EU policy linking sustainable development with innovation policy and the circular

economy model. However, such development of actors' activities requires different forms of cooperative support.

There is a documented view that in countries with real support by state policy, both in economic-financial and organizational terms, adaptations take place faster and to a greater extent. This is the case in countries with a higher level of education in SHE and social capital, especially its resources: trust, norms and values, solidarity (understood as transparency of action, primacy of common good over private, ethical behaviour, shared beliefs, readiness to take risks), cooperation and high quality of formal institutions and innovation. Raising its level results in increased efficiency, public management, entrepreneurship, quality of business processes and innovation (Skawińska, 2012 (ed.), pp. 46-63). In the EU, among CEE countries, social capital is still at a low level, albeit increasing. This constitutes a significant barrier to the adjustment of the economy to sustainable development. The authors of the article, joining the global debate on this issue, raise in subsection 3.1, the causal aspect of innovation in the process of shaping the circular economy model for sustainable development.

Part II. Circular economy – stimulants and barriers

Chapter 3. Circular Economy (CE)

3.1. Background

The turn of the 20th and 21st centuries is characterized by many changes in political, social, and economic relations around the world. For the third year in a row, China is the world's largest economy in 2019. It contributed 17.3% of the world's GDP according to estimates by the World Bank. The U.S. was second, with 15.8% share and European Union was in third place with 15.3% of world GDP. The three combined represented 48% of the world economy (Amadeo K., 2021). The world economy is caught between the waning influence of the industrial era on most spheres of life and the rapidly rising tide of computerization, which is increasingly affecting all areas of social and economic life. Both in the past and now, the waning influence of the agrarian or industrial era should be understood in a relative sense as a function of time. Moreover, these changes are shaped differently globally and regionally. Currently, there are still countries where the agrarian economy is the basis of existence. In the region of Southeast Asia, the growth of the industrial economy has been very high in recent decades. The Chinese economy is developing very rapidly, especially in the field of high-tech, including information technology and Industry 4.0. It exerts great influence on the world economy as a supplier of relatively cheap but modern products (e.g. in pharmaceuticals, integrated circuits and high-tech). In contrast, the share of industrial production of European countries in the world is decreasing. This is due to the favourable purchase prices and high quality of many products. However, some European industries (e.g. automotive) are currently experiencing a shortage of supply of ICs. This is partly due to the disruption of supply chains during the ongoing Covid-19 pandemic. The impact of IT (information technology) and Internet on the economy has not only affected industries and services, but to a significant extent consumer behavior. The next generations are more and more consumer oriented and expect new, better, and innovative products. This expectation spiral is used by industry and the retail sector. However, the demand for energy and raw materials is increasing, as is the problem of environmental pollution on Earth, in the oceans and in the atmosphere by the waste created. This is evidenced by data on the demand for fuels, ores, minerals and biomass, showing a strong upward trend. In 1970, 26.7 Gt of these were consumed, in 2015, 84.4 Gt, and the projection for 2050 is over 170 Gt (Global Circularity Gap Report, 2018).

The research problem of this chapter are the following questions:

1) What contemporary factors support the development and implementation of the circular economy,

2) What are the challenges to the wider applicability of this model?

The primary objective is to explain the principles of the circular economy as a model of management for the sustainable development of enterprises.

The pragmatic goal is to present the importance of innovation in the circular economy. For their realization the method of desk research, comparative, model, descriptive and graphical analysis was used. The source basis is the world literature and statistical data of international organizations such as EUROSTAT, World Bank, World Economic Forum.

The authors attempted to provide a proof that the circular economy is consistent with the concept of sustainable and balanced development (SDG) and that it is a broad concept.

Current research problems for science are the questions: 1) can the circular economy be implemented and develop with a low rate of investment in enterprises and R&D? 2) what innovations: technical-technological, organizational, productive will be strategic to fulfill its mission?

The development of humans and civilization for many millennia has gone through successive phases (agrarian, industrial, information and technological (Toffler, 2003) and was made possible by careful observation of the living and non-living nature, gaining knowledge and skills in its use. For centuries, people have been observing nature and trying to imitate and exploit it. In order not to go too far into the past, it is worth mentioning Newton's formulation of the principles of dynamics (falling apple) and Leonardo da Vinci's design work which was widely used in technology in later periods. Other further examples can be found in many sources and books (eg. Braun, 2012 p. 153-158). The industrial revolution and the development of natural sciences, which accelerated rapidly in the eighteenth and nineteenth centuries, led to the observation, knowledge and partial understanding of the mechanisms of cyclicity of many processes occurring in non-living but mainly animate nature, especially in the biosphere. It was observed that biological systems and forms are ideal solutions developed at particular stages in the process of evolution, in order to achieve maximum benefits with minimum inputs, maximum strength with the least use of building and construction materials, etc. Moreover, as Bernd Hill (2012, p. 148) writes, they are in the sense of their ideality self-organizing systems. It consists in self: production, optimization, regulation, regeneration and reconstruction.

Cyclicality has also been observed in inanimate nature. It was exploited in the era of industrialization by discovering the potential and using it practically in the implementation of some production processes (e.g. Desrochers 2002). This idea has been exploited mainly for economic reasons (e.g. cost reduction by using the by-products of a chemical reaction). As Korhonen et al. (2018 p. 37) believes, environmental impact was probably also considered to some extent. One of many examples is the Solvay method of continuous sodium bicarbonate (Na_2CO_3) production. Its scheme is shown in Figure 3. The main raw materials are sodium chloride NaCl, calcium carbonate $CaCO_3$ as a source of carbon dioxide and ammonia NH_3. In the technological process, a significant part of them (40% of CO_2 and significant of ammonia) is recovered and returned to feed the production process. This decreases atmospheric pollution and reduces the need for and cost of these components. Despite the fact that natural and technical sciences have made great theoretical and technological progress, the practical application of the knowledge of these achievements in conducting economic processes in such a way that they do not harm nature did not occur widely until the turn of the 60s/70s of the 20th century.

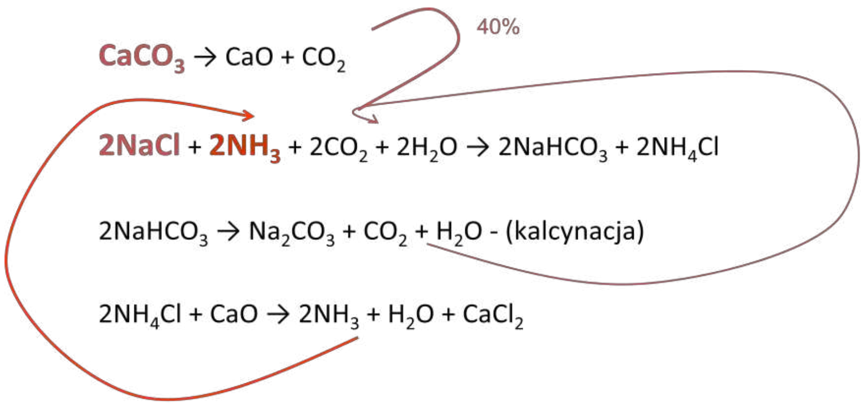

Figure 3. Scheme of chemical reactions in the production of soda by the Solvay method
Source: own elaboration.

It has been noted that the development of processes and their vitality over time follows a sigmoid curve until a maximum is reached (Osenton, 2004). Unless new stimuli appear, each process is slowly destroyed, according to the axiom of deterioration (Oakland, Followell, 1992). But new needs, scientific or technical achievements, positive stimuli can trigger another phase of growth increasing the efficiency of the process. Such stimuli are incremental innovations, which are used in a limited way to improve the quality and functionality of products (Skawińska, Zalewski, 2009). Probably this mechanism is general to all processes. It is commonly used in many areas of industrial activity, especially, for example, as car facelifts, new models of mobile phones or laptops and many others). Stronger and even revolutionary impact in the past was and is exerted by technical radical innovations such as, for example, steam or combustion engines, telephone, radio. Current and rapidly developing radical innovations include computers and information technology, the Internet, the Internet of Things, Big Data and many others. Radical innovations are also emerging in many other fields like medicine, biology, aerospace, agriculture. It is also important to note that currently the progress of science and technology is not linear in time but is happening in an accelerated and in some areas turbulent way.

It can be argued that the most recent shift in the evolutionary path was initiated by the oil crisis in the early 1970s, which was triggered by the establishment of the OPEC organization by the countries, the main oil producers, and the sharp increase in oil prices on world markets. The strong upheaval in the world fuel market most likely made producers, scientists and politicians alike realize that the previous linear production systems (discussed in Chapter 1) needed a radical innovative change. One of the earlier works on circular material flows was K.H. Boulding's The Economics of the Coming Spaceship Earth (Eoearth.org., 1966).

More than forty years ago Stahel and Reday (1977) described some features of circular economy (CE). Their concept of the circular or loop was based on the reduction of waste, the creation of jobs at regional level, the efficient use of resources and the dematerialization and humanization of the economy, paying particular attention to the industrial sector. A little later, Stahel proposed the sharing and renting of some goods, considering this alternative to ownership as the best sustainable GC business model. According to him, industry would make a profit by reducing the risks and hassles associated with waste. The concepts of sharing were developed today by Porter and Kramer (2011). This idea is currently being implemented in many countries, also in Poland, especially in the sphere of city bicycles, car rental in large cities, renting office space by the hour, renting computers with specialized software and many others.

3.2. Overview of circular economy conception

The term 'circular economy' i.e. (CE) was first used in the book 'Economics of Natural Resources and the Environment' by D. Pearce and K. Turner in 1989 (Pearce, Turner, 1989). The cited researchers found that traditional economics and production systems did not contain clear incentives for resource recovery. On the contrary, in the past producers treated the environment as a dumping ground for waste and post-production pollution. The basis for a new way of looking at these issues and instilling the idea of GC were observations of biological systems and processes in the biosphere. These are characterized by circular transformations of matter and energy in animate nature, which were already studied and described decades ago.

The following statements developed by EMAF (2013 a) form the basis of the circular economy:

1. waste is a raw material,
2. diversity is an advantage,
3. energy should come from renewable sources,
4. thinking is systemic,
5. waste-free production design,

building on earlier work by Pearce and Turner (1989), who address the "inter-linkages of the four economic functions of the environment. The environment not only provides amenity values, in addition to being a resource base and a sink for economic activities, it is also a fundamental life-support system" (Andersen M.S., 2007). At this point it is worth quoting Geogescu-Roegen's opinion that "In the ultimate analysis man struggles for low entropy, and economic scarcity is the reflection of the Entropy Law, which is the most economic in nature of all natural laws" (Georgescu-Roegen N., 1971; 2012).

This way of circulating matter has received attention from later followers of Pearce and Turner. The concept of circular economy has caught the attention of both academics (e.g. Ghisellini et al., 2015; Kirchher, Reike, Hekkert, 2017; Murray et al. 2017) and practitioners for several years. Critical voices point out that it is an incomplete, vague and ambiguous concept for many of them. For example, according to Ghiselini (2015) " GC is most often understood as more efficient waste management". This narrowed approach can lead to the idea of GC being lost, where recycling, reuse or recovery may be possible in some conditions and in others has example concerning 'green' chemistry and biotechnology impossible for fundamental reasons? or uneconomic due to high costs.

Prevention is therefore more important in such cases. There is also the increasingly used possibility of replacing traditional processes, technologies, materials, chemicals or biochemical methods using harmful reagents and substances by instrumental analysis methods based on physical phenomena (e.g. Sikorska, 2018). However, replacing traditional chemical and biochemical processes in industry does not seem possible to us. Despite the needs and opportunities for more friendly and regenerative methods of eco-industrial development, according to Geng and co-authors (2014a), this does not imply a demand for green technologies only. Instead, what is needed is a broader and comprehensive view of design and the search for radically alternative, innovative solutions. These need to project into all stages of processes and the product life cycle, as well as into the process-environment-economy interaction. In this way, the economy will be strengthened and not only raw materials but also energy will be regenerated. In addition, living conditions will be improved compared to previous business models, including resource management. The circular economy has the potential and many opportunities to introduce radically new patterns of behavior and help society and the environment (cf. Stahel, 2016, pp. 435-438; Charter, 2016).

Finally, it should not be forgotten that the conditions and frameworks for a sustainable economy, including GC, require creative and innovative workers in the first place, not just innovative concepts, technologies, new patents. The complexity of the vision of sustainable development means that its practical implementation requires visionary designers and a whole support system to implement radical changes in industrial practice, research, government support policies and the decision-making system (Golińska et al. 2015). One can hope that one of the many sources of support for such transformations will be offered/proposed by start-ups (Skawińska, Zalewski, 2020).

3.3. Definitions of circular economy

Several definitions of CE are given below. For example, Webster (2015 p. 16) adds that "CE is restorative by design, and which ensures that products, ingredients and materials have the highest utility throughout time". In contrast, Yuan et al. (2008 p. 5) states that the core of GC is the circular (circular) turnover of materials and the use of raw materials and energy in multiple process phases. In contrast, Bocken et al. (2016, p. 309) defines CE as "a design and business model that slows down, closes and reduces raw material loops". Whereas according to Murray and colleagues (2017, 369-380) it is a business model in which planning, resourcing, resource management, production and reprocessing are planned as a process and product so as to maximize ecosystem functioning and human wellbeing. And according to Geissdoerfer et.al (2017, pp. 757-768)

Furthermore, Geissdoerfer and team (2017) performed an analysis of scientific papers published in earlier years taking into account the name of the journal, the country of origin of the authors and the keywords associated with GC. In turn, the author team of Kirchher, Reike and Hekkert (2017) performed a systematic analysis of 114 definitions of GC taking into account the frequency of use of the 17 characteristics mentioned in them. Its authorial summary is presented in Table 9. It shows that the most frequently used descriptors were: Reduce, Reuse and Recycle referred to as the 3Rs. At the same time, it is emphasized that the need to make systematic changes to the above actions is not always mentioned. Another worrying finding from this analysis is the low number of indications of a direct link between CE and sustainable development and only one indication of 'concern for the fate of future generations'. A certain dissonance is created, because, after all, there is constant talk in the mass media and the construction of all kinds of strategies that aim to protect and preserve the environment in a non-deteriorated state. Various authors stress that the main role of CE is to achieve economic prosperity, which results in environmental quality. In contrast, its impact on social equity and the fate of future generations is treated marginally or completely ignored in many definitions. It is also important to note that neither new business models nor changes in consumer behavior were often found as enabling activities in the GC definitions analyzed.

According to these researchers, such a large number of inconsistent definitions and terms of GC can lead to a weakening of the whole concept. Their analysis of the available literature enabled them to formulate a new definition. It is "an economic system that replaces the 'end-of-life' concept with the 4Rs concept (philosophy) through Reducing and alternatively Reusing, Recycling and Recovering materials in production, distribution and consumption processes". This system should operate at each of the three levels of the economy: micro (producer, product, consumer), mezo (eco-industrial parks) and macro (city, region and above) in order to achieve sustainable development. This, in turn, is to create together the basis for environmental quality, economic well-being and social equality now and in the future. This will require new and rational business models and responsible consumers". Of particular concern are the figures for the Recover category (3-8 indications) and the concern for future generations indicated only once in these publications.

Table 9. Context of the use of the circular economy concept in the world literature

Indications in a set of 114 publications (in %)					
	Publications	Practitioners		Publications	Practitioners
ACTIVI-TIES	-	-	PURPOSES	-	-
Reduce	54-55	44	Sustainable development (SD) of which:	11	11
Reuse	74-75	68	Environment	37	28
Recycle (recycling)	79	68	Economic prosperity	49	53
Recover	7-8	3	Social equity	19	16
Waste	30	11	All	13	8
SYSTEM			Future generations	1	0
Mikro	19	22	OPPORTUNITIES		
Meso	21	22	Business models	11	14
Makro	24	22	Consumers	19	22

Source: own elaboration based on: Kirchher, Reike and Hekkert (2017).

According to Geissdoerfer et al. (2017, p.759) and Schut et al. (2015, p.15) another interesting definition of GC was developed by the Ellen MacArthur Foundation (2012, p. 7). According to this organization, GC is, in concept and execution, a production system with the character of saving and regenerating resources. It proposes replacing the 'end-of-life' concept associated with material recovery by the use of renewable energy, the exclusion of poisonous chemicals that will prevent reuse, the elimination of waste through the best design of materials, products, systems and business models.

Korhonen, Honkasalo and Seppala (2018, p. 39) promotes CE as an economy built from social, production and consumption systems that maximizes the benefits inherent in a linear economy with the characteristics: environment - society - environment. These arise from how - when and where material and energy resources flow in the processes carried out. The circular economy places a strong emphasis on the cyclical use of materials, production waste for energy and its cascading flow. The latter concept is a euphemism that replaces 'energy recycling' as thermodynamically (physically) impossible. Cascade in this case means producing heat (or electricity) from production waste and using the heat produced in a sequence of production processes requiring different temperatures (from higher to lower) e.g. for steam generation, space heating, gardening, etc. Up to 40% of the energy can be recovered in this way.

3.4. Models of CE

Geisdorfer and colleagues (2017), mentioned earlier, identified numerous similarities between sustainable development and CE. Among these, they listed:

- trust with global achivement resulting from the inclusion of non-economic pathways for the development of societies,
- the need for systemic change and innovation resulting from multidisciplinary research and the creation of new business models as key to industry transformation,
- knowledge of the costs, risks and value of cooperation for development,
- the importance and advantages of collaboration between different stakeholders,
- the concern of current generations for the fate of future generations, the importance of regulation, standards and legislation,
- the importance of the private sector in proportion to its resources and capabilities,
- the availability of diverse and coexisting development paths,
- proposing innovative, mature technological solutions that do not generate new environmental problems and reduce the impact of previous ones.

On the other hand, Ghisellini et al. (2015), who have been researching CE before many years noted that its conceptualization originated from the ecological and environmental economics and industrial ecology streams. In contrast, Murray et al. (2017) believe that the definition of CE should also include the "social dimensions inherent in sustainable development" (Murray, A.; Skene, K.;

Haynes, K. (2017). Sauve and colleagues (Sauve S., Bernard S., Sloan P, 2015), on the other hand, consider that the goal of circular economy is to "decouple prosperity from resource consumption, i.e., how can we consume goods and services and yet not depend on extraction of virgin resources and thus ensure closed loops that will prevent the eventual disposal of consumed goods in landfill sites". Due to a certain generality, diversity and richness of objectives, there is a need to precisely define the path from the initial state to the desired state to achieve which the circular economy will be used. For example, Morsaletto (2020) identifies five such objectives: efficiency, reduction, recovery, recycling and design. All of them are multi-elemental, which means that the number of combinations in practical applications is considerable.

Despite the many similarities and convergences of views presented in the scientific literature, Geisdorfer et al. 2017 pointed out the differences between the sustainable development models and the circular economy as shown in Table 10.

Table 10. Comparison of sustainable development with the circular economy

Concept	Sustainable Development	Circular Economy
Name	Environmental sciences, sustainable development and circular economy: Alternative concepts for trans-disciplinary research clearly defined	CE is the opposite and an extension of the linear economy, from 'cradle to grave'. Regulations introduced by governments, international organisations, regional programmes such as European Horizon 2020 play an important role in shaping its principles.
Aim	It mainly promotes targets at the end of the chain that depend on the company, region, country, etc.	Closed-loop processes, reducing the consumption of raw materials and, finally, reducing waste to an absolute minimum and using it in other production processes.
Model	The basic production model in sustainable development is linear	A closing cycle from which materials useful in other processes leave and are incorporated into other cycles.
Beneficiaries	Economy, society, environment	Economy and environment; benefits to society include improved environment, increased role of manual labour, fair trade etc.
Responsibility	Clearly defined	Manufacturers and regional or national administrations.
Production model	Linear	Closed cycle
Result	Reducing waste, increas-ing profits and prices	Economic and financial for the producer, (measurable for the environment)

Source: own elaboration based on Geisdorfer et al. (2017).

On the other hand, in an interesting publication, Sariatli (2017, p. 33) presented an interesting comparison between linear economics and circular economics using the SWOT method. Among several strengths of GC, he mentioned: reduction of waste in the value chain resulting in a lower environmental burden, reduced costs and demand for primary raw materials, increased role of R&D, demand for innovative solutions, investments and better quality of products, and reduced fluctuation of raw material prices. The above-mentioned author included among the weaknesses: the low awareness of the idea and principles of GC among the public and the small number (lack) of social campaigns, the lack of technical knowledge and research on the possibility of recovering raw materials dispersed in waste. In the meantime, the British Standard on Circular Economy has been published (BS 8001, 2017) This has weakened some of the conclusions mentioned by Sariatli. In addition to the obvious benefits, among the risks Sariatli mentions: managing the entire life cycle of products and strong collaboration, which can lead to subsidies for different activities, price increases, the creation of unnecessary products and the formation of cartels. To become successful circular economy strategies and business models must therefore be better linked to ongoing processes in policy making, in particular, the sustainable development goals (UN, 2017) and the climate. Pauliuk (2018) believes that "To become successful circular economy strategies and business models must therefore be better linked to ongoing processes in policy making, in particular, the sustainable development goals (UN, 2017) and the climate targets".

Economic activities produce desirable products and undesirable waste streams. Undesirable matter, in turn, is only partially absorbed by the environment, through its inclusion in various cycles functioning in the biosphere (e.g. carbon dioxide is assimilated by plants, plant waste is decomposed into simple substances). The remaining part constitutes a growing threat to the environment and requires adequate counteraction. There is general agreement that it should be utilized wherever possible. The simplest, albeit insignificant, way is efficient waste separation. This makes it possible to recover many basic materials (e.g. paper, glass, plastics, metals, food industry and household waste, green waste, etc.) and then recycle them. However, it appears that only a small proportion of this matter is recycled. Many types of technical (industrial) waste have yet to be integrated into the various stages of the circular economy model. Waste contains a lot of valuable materials, substances and chemical elements which are dispersed in its mass and whose recovery is theoretically and practically possible. Unfortunately, this is labour-, energy- and cost-intensive. This creates new challenges for the management of entities at macro, mezo and micro level.

In order to sort out these matters and create some compact and transparent policy for the future conduct of manufacturing companies, Hartley et al. (2020) propose some recommendations for the industrial sphere concerning the sphere of product planning, the way of consumption and waste handling. These are contained in the eight principles outlined below:

1. Further adoption of circular design standards and norms at the EU level.
2. Expand circular procurement by the EU and member states.
3. Alterations to taxes on CE-based products.
4. Liberalization on waste trading.
5. Facilitate development of circular trading platforms.
6. Creation of eco-industrial parks.
7. Circular economy marketing and promotion campaign.
8. Global material flow accounting database.

The circular economy builds on a diverse collection of scientific and semi-scientific concepts, for example, "ecological economics, industrial ecology, cradle-cradle design, performance economy, mimicry, eco-efficiency, resilience science, natural capitalism, and cleaner production" (Korhonen et al., 2018, p. 549). Over a hundred definitions of circularity have been inventoried, with the consequence that the term means different things to different people (Kirchherr et al., 2017). This could be because the concept and its application have almost exclusively been developed and driven by practitioners, that is, policy makers, businesses, business consultants, business associations, business foundations, and so on (Korhonen et al., 2018a).

With a view on its potential impact, a concern is that CE has been argued to lack conceptual clarity and an accepted definition (Yuanet al., 2008; Lieder and Rashid, 2015; Zhu et al., 2010). This almost paradoxical framing suggests that fundamental paradigmatic questions of CE conceptualization re-main indeed unsolved. (Reike et al. 2018, p. 247).

Mavropoulos and Nilsen, as the chairman of the International Solid Waste Association (ISWA) noted "there is no single commonly accepted definition of the term "circular economy", but different definitions share the basic concept of decoupling of natural resource extraction and use from economic output, having increased resource efficiency as a major outcome" (Mavropoulos, Nilsen, 2020). Moreover, there are distinct differences, separations, and exclusions between research communities engaged in circular economic research, for example, between scholars in engineering and in business (Korhonen et al., 2018a).

The concept of the circular economy has been and continues to be graphically represented by numerous authors. In the meantime, the concept of the circular economy has been developed in various research centers, adding a list of additional activities to the life cycle. In the first models, five activities were introduced, the names of which began with the letter R. Three of them characterize the handling of a product until it is owned by an owner. Three of them characterize the handling of a product until the owner considers it redundant. Another two relate to the action of possibly using it for other purposes (Remanufacture) or finally destroying it (Recycling). In recent years, the list of possible product operations has been extended and their names also begin with the letter R. In all constructions, there are two elements that end the existence of the product.

The main elements of these constructs are given below:

3R Reduce, Reuse and Recycle,
4R Reduce, Reuse, Recycle, Recover (Kirchherr et al. 2017; Mihelcic, 2003),
5R Reduce usage, Repair, Reuse, Remanufacture, Recycle (Zalewski R.I., Skawińska E., 2019),
6R Reduce, Reuse, Recycle, Recover, Redesign, Remanufacture (Venkatachalam J.K., Jawahir, I.S., 2006),
7R Rethink, Refuse, Reduce, Repurpose, Reuse, Recycle, Rotate (The 7 Rs of Sustainability https://www.dunedingov.com/live-work-play/dunedin-green-scene/the-7-r-s-refuse-reduce-repurpose-reuse-recycle-rot-rethink),
10R Refuse, Rethink, Reduce, Reuse, Repair, Refurbish, Remanufacture, Repurpose, Recycle, Recover (Potting J. et al., 2017; Hekkert M. et al. 2017; Morseletto P., 2020).

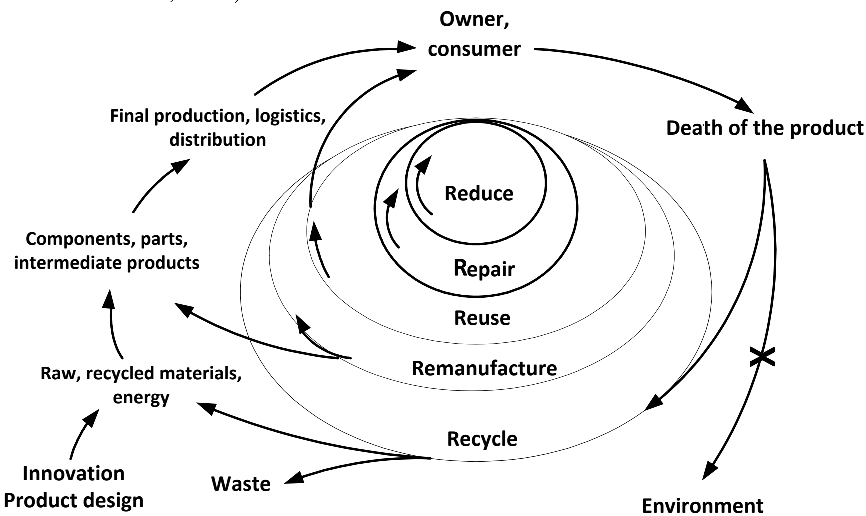

Figure 4. An expanded CE concept of Mihelcic
Source: Zalewski, Skawińska, 2019.

Figure 4 shows the developed overall author's conception of the R5 model, modelled on the 4R work of Mihelcic and colleagues (2003). The changes introduced are the expansion of the inner part of the diagram to include 'Reduce usage', i.e. reducing the frequency with which consumers buy new products while the current ones are still good, and their 'Repair' - repair when necessary and possible. New trends in design, technology and manufacturing processes repeatedly lead to changes that facilitate service repairs through the use of bundles of parts, components, etc. These simplify and shorten servicing times but mean that even a minor part failure requires replacement of the entire component and is costly for the user. The user is often faced with a dilemma: whether to repair or buy a new product.

Limiting the presentation of the different circular economy models, it is worth noting the model proposed by Morseletto (2020) in the convention of the ten R's (from R0 to R9) with three separate groups of activities (Figure 5). The first includes such as R0-R2. Its stakeholders are businesses and consumers. The second is dominated by manufacturing and service companies (R3-R7). The role of customers here is limited to the service sphere user. The third group (R8-R9) is the organization of waste collection and disposal. A brief description of the individual symbols is given below.

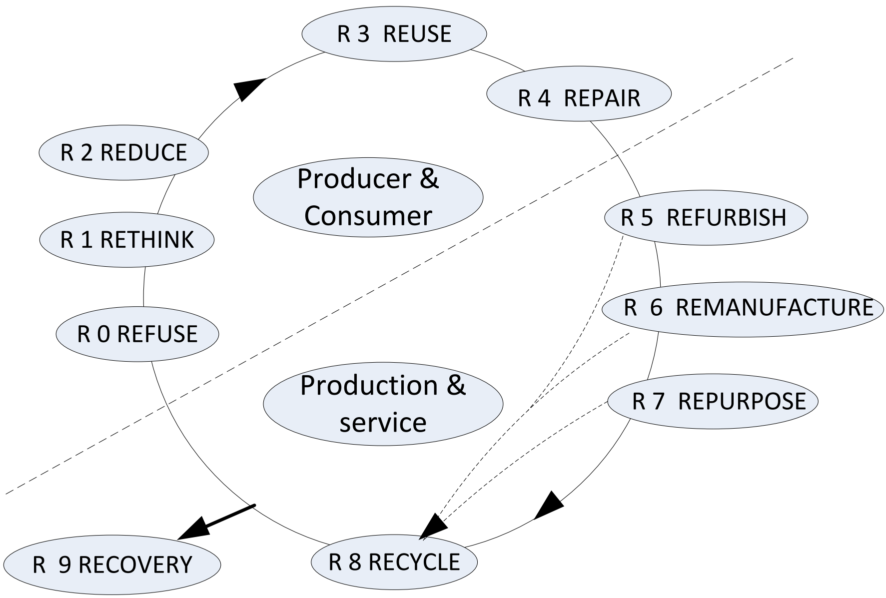

Figure 5. Expanded CE model in 10 R convention
Source: own elaboration based on the Morseletto model

Rethinking (R1) is one of the most important and creative elements of CE. It involves increasing the intensity of use of products through shared use (e.g. by neighbours) or extending their functionality. Achieving the latter requires the manufacturer to make technical and conceptual changes, to innovate, to change its way of thinking, to invest, to seek new sources of supply (eg. Lindner 2017). This is also the moment to introduce beneficial changes in terms of environmental protection (reduction of waste, emissions and other effects affecting the environment). This function should be performed by the producer in cooperation with consumers and the market sector by seeking their opinions, comments, complaints, etc. Refuse (R0) refers to making a product redundant by abandoning its function or offering the same function with a radically different product. Refuse can also extend to the use of certain harmful materials (eg. European Commission 2020 a) or banned production processes to make the economy more circular and healthier. Reduce (R2) implies using fewer natural resources, and therefore fewer inputs of resources (energy, raw materials), and restrict waste production. This definition can be extended to reducing of the number of products (see Reike et al., 2018) in a way to incentivize Reuse. In these terms, Reduce is associated to Reuse. To some extent, Reduce can be also interpreted as a less drastic form of Refuse. Targets for Reduce can also mirror targets for Rethink because both are linked to the Concept/Design (using less material per unit of production), or to 'dematerialization' (eg. Worrell and Reuter, 2014).

Main objectives of R3 - R7 are the maximum extension of the life of the product to the final point. This means that a product may be finally recycled (R8) or recovered (R9) from any phase of the cycle between R3 and R7 if its further exploitation would be costly, economically and environmentally unjustified. The technical design of the product, the quality of the workmanship and the way it has been used so far are of great importance.

On the other hand, a certain group of consumers, for example early innovators, should give durable goods, still in good technical condition, for reuse phase (R 3) and resell it to new owners. This will extend the service life and postpone the physical destruction of the product. This model is already present, for example, on the second-hand clothing market and many other products (as second-hand shops, exchange via online platforms). Leasing activities in the markets for cars, construction machinery, copiers, computers, software, etc. can be considered a variation of this model. The possibility of changing the ownership of equipment is logically consistent with the idea of GC. This suggestion is in opposition to the practice of deliberate design of a shortened useful life of a product by manufacturers (so-called planned obsolescence). Another possibility to extend the use of the product is to repair it (Repair -R4) during the warranty period or later. Further possibilities are: R5 – Refurbishment, R6 –Remanufacturing and R7 – Repurposing.

Refurbishment (R5) takes place when "…products that consumers no longer desire or need are collected and then refurbished (renovated). Refurbishment entails that the products are cleaned, tested, and repaired, replaced, generally upgraded before they are being resold to consumers" (Wallner et al., 2021; Reike et al. 2018).

According to McIntosh and Bras (2021) "…In order to achieve an expanded role of product reuse, it will be first necessary to integrate remanufacturing capabilities (R 6) into original equipment manufacturers (OEMs) such that reuse can be 'in advance' carefully planned by both product and process design…". However, the implementation of OEM reuse is currently limited to not many examples and faces numerous barriers such as: incomplete incentives due to the product disposal externality, the trends in production towards rapid innovation, mass customization. It is obvious that remanufacture presents fundamentally new set of challenges that producers are not prepared to deal with. For those reasons reuse will not play a larger role in society until produces have both the incentives and ability to implement remanufacture given their business conditions. Other authors understand it as reconditioning, reprocessing or restoration (Reike et al. 2018).

Repurposing (R7) refers to products or parts that do not meet the conditions for use in repairing or manufacturing products with the same function, but that can be used in the manufacture of equipment with a different function (see: Potting et al. 2017). According to Reike et al. (2018) repurpose is useful for fashion upgrading, part reuse or adopt for another function. Among the many activities that Morseletto and other authors present, we see two main groups of stakeholders: consumers and businesses. The objectives and actions of each of them are partly consistent and partly divergent. We consider that the activities R0 - R4, are mainly on the side of the consumer, who makes the decision to buy, to use or to repair minor damages. Whereas actions R5 - R9 are mainly the domain of business, innovators, environmental management companies. Both sides' behavior is strongly influenced by the activities of opinion-making, social and educational organizations. The institutions creating and enforcing relevant national and international legislation are extremely important. It is obvious that this division is not sharp. The aforementioned possibilities are to some extent related to the practice of obsolescence as pointed out in the literature. From the model shown in Figure 4 and in Merseletto's model (Figure 5), it can be read that the passage of the product through all phases R3 - R7 is not necessary.

Shifting production towards CE usually requires interventions in the production processes. The projects undertaken are innovative in nature with varying degrees of uncertainty, are complex, must take into account the possibility of multiple life cycles and are strongly interconnected with diverse stakeholders. It is therefore necessary to effectively select proposals and evaluate them in terms of design, materials and service. Many manufacturers are afraid to switch production towards CE due to lack of experience, uncertainty of success.

A number of criteria are usually taken into account, such as innovation, quality, usability, durability of new proposals. Financial criteria are of course important: the expected revenue, the costs of implementation and conceptual work. Related to these are market measures such as expected potential and share. Organizational issues are important (culture and social capital, organizational structure, innovation capital of employees (Eisenreich et al. 2021).

Recycling (R8) is the processing of materials to obtain the initial - high-grade, or low-grade quality of recycled (secondary) materials (Worrell and Reuter, 2014). Secondary materials may be up-cycled - converted into materials of higher quality and functionality (as in the case of extracted bioactive organic compounds from waste of food industry) or down-cycled for most materials. Up-cycling should be the preferable solution because of its higher value and applicability in food processing or pharmacy. Examples include the seeds, peel or rind of many fruits and vegetables, which contain natural pigments, vitamins and a wealth of other organic compounds.

The principle of cascading, the sequential and consecutive use of resources, is a potential method to create added value in circular economy (CE) practices (Campbell-Johnson K. at al. 2020). Despite conceptual similarities, no research to date has explored how cascading has been operationalized and how to integrate it with CE R-imperatives (Reduce, Reuse etc.) to facilitate implementation practices. CE practices emphasize value creation and retention, yet there has been little reflexive examination of explicit and intrinsic value considerations; namely, how allocation choices, i.e. the decision-making process, for resource utilization are made.

Recycling is the last R to use the principle of cascading, the sequential and consecutive use of resources, is a potential method to create added value in circular economy (CE) practices (Campbell-Johnson K. at al. 2020). Despite conceptual similarities, no research to date has explored how cascading has been operationalized and how to integrate it with CE R-imperatives (Reduce, Reuse etc.) to facilitate implementation practices. CE practices emphasize value creation and retention, yet, there has been little reflexive examination of explicit and intrinsic value considerations; namely, how allocation choices, i.e. the decision-making process, for resource utilization are made.

Down-cycling is recycling something in such a way that the resulting product is of lower value than the original item". Here, down-cycling concerns value or purpose lost in comparison to the original item, which indicates a loss of material/product functionality due to quality.

Up-cycling involves the conversion of product into a more valuable one. Some studies claim upcycling results in products with higher quality and performance than the original, using refurbishing (R 5) or remanufacturing (R 6) .

This is however up-stream way, which will not bring the product to the initial value it had in phase R 3. However, the literature is inconsistent with what constitutes upcycling.

We understand to use cascading, integrated within CE, as a socially contextual concept used to contribute to the broader sustainable development agenda. Two of the above dimensions are easily understood: market dynamics and quality and functionality.

Recovery (R9) refers to waste that is not recycled, but can be used mainly as a source of energy or valuable biochemical compounds. Recovery process includes several conversion processes mainly related to organic waste (see Demirbas, 2009) and inorganic elements and compounds (eg. gold).

From the model shown in Figure 3 and in Merseletto's model (Figure 4), it can be read that the passage of the product through all phases R3 - R7 is not necessary, although possible.

Within these R0 - 9R strategies, the categorization system calls for assessments of resource efficiency gains and evaluations of activities' impacts on a lifecycle basis to demonstrate their substantial importance to the circular economy.

In the recently published paper (Lingaitiene, Burinskiene, 2021) a classification of over fifty publications was carried out, taking into account the frequency of inclusion of individual elements of the R0 - R9 model. It turned out that most of the over 50 analyzed publications from years 2016-2020 are dominated by the traditional elements: reduce - 50 times, reuse - 47 times and repair - 34 times, as well as recycle - 52 times and recover - 49 times. In the analyzed set of publications, the R0 (refuse) category was only included in five publications. In turn, the R1 element (rethink) was mentioned only 11 times. On the other hand, R5 (refurbish) and R6 (remanufacture) were cited more often - 28 times. Whereas R7 (repurpose) was cited in 21 articles. It should also be emphasized that in all analyzed publications the variable R8 (recycling) was mentioned, while recovery (R9) was quoted only twice. Only five papers indicated the importance and necessity of all activities from R0 to R9 for effective implementation of the circular economy.

The information quoted above leads us to reflect that the concept and application of CE among representatives of science is not fully formalized. Also, it can be assumed that the state of knowledge of the public, including entrepreneurs, about the circular economy, its principles and practical achievements is not stabile. The advantages and necessity of implementing a circular economy are widely discussed in the European Union. However, research on the success of its implementation is scarce at European Union level.

The most significant and dangerous, in negative consequence for environment, variables among others are: in waste generation (waste excluding major mineral wastes per domestic material consumption), in waste management (recycling rate of municipal waste; recovery rate of construction and demolition waste; percentage of construction and demolition mineral waste recycled; recycling rate of plastic packaging; recycling rate of glass packaging waste) and trade-in secondary materials (circular material use rate as % of total material use). The similar results for EU countries were presented by Mazur-Wierzbicka (2021).

3.5. Circular Economy against Obsolescence

Mellal in his review of literature mentioned following types of obsolescence: technological, functional, planned, styled (psychological) and optional (Mellal M.A., 2020). From a consumer perspective, planned obsolescence is the most important. The term planned obsolescence was coined in the time of Great Recession (London, 1932, p. 3). At that time strategy aimed at designing and producing goods in such a way so that they have a limited lifetime (Packard, 1960, p. 53; Aladeojebi, 2013;), after which they become unserviceable or unprofitable to repair and need replacement. In other words "describes a strategy of deliberately ensuring that the current version of a given product will become out of date or useless within a known time period. This proactive move guarantees that consumers will seek replacements in the future, thus bolstering demand". (https://www.investopedia.com/terms/p/planned_obsolescence.asp). This strategy has both positive and negative effects. These include a reduction in the quality and usefulness of products over the long term, unpredictable production setbacks and increased environmental pollution. A reduction in the useful life of many groups of consumer' products has been observed in many manufacturing sectors for some time. This is a driving force and a way of increasing material consumption, especially in wealthy countries. The time and willingness to repair equipment is shrinking; warranty extensions beyond two years have to be paid for additionally. Consumers are often in a dilemma: whether to buy new appliances or repair their old ones due to high service costs or the impact of advertising. Many manufacturers introduce planned obsolescence by reducing the quality of construction materials or the construction of products. This consists in using modules of parts, which cannot be repaired for structural reasons (they are difficult to access, cannot be disassembled, require special tools, etc.), but only replaced by a service centre. This means that the failure of one part of the module requires its replacement, which entails significantly higher costs. Consumers are encouraged to buy new models through obtrusive marketing and minor technical and design changes. Psychological obsolescence is at work here. New products are designed in such a way that during the statutory warranty period the probability of failure is low. The result can be a general deterioration in the usable quality of the products and a spiralling consumerism. In this sense, the actions of industry are contrary to the principles of the circular economy. In this view, obsolescence is a strategy of opposition to CE.

For example, over two million fridges and freezers are thrown away in the UK each year. The average lifespan of these refrigerators is eleven years, with newer models often only lasting half that time. The results show that the majority of the steel components are underexploited – still functioning when the product is discarded; in particular, the potential lifespan of the steel-rich structure is typically much greater than its actual lifespan…Over a period of ten years, lubricant loss from the compressor causes the small bearings to wear out. With compressor replacement cost comparable to that of a new refrigerator, consumers typically choose to replace rather than repair (Cooper et al. 2014).

3.6. Evolutionary paths of circular economy into ecology

The circular economy concept requires now an expansion of the firm-level perspective to an ecosystem-level perspective (Pieroni et al., 2019). For a theoretical contribution, our article provides insights into the inter linkages between biological and technical cycles in the circular economy. While the circular economy is often conceptualized as being restorative and regenerative by design, research combining both biological and technical cycles seems limited (Morseletto, 2020). Terrestrial ecosystem including: soils, atmosphere, aquatic ecosystem, the earth's crust and many others is called an ecological resource. Technological resources, human labour, use of agricultural land and fossil resources, technology, technical infrastructure, science, innovation are a social resource. Ecological economists study and try to quantify the properties of stock, fund and flow elements in the interaction between economy and nature, reconceptualised in material terms as the techno-sphere and biosphere, respectively. Basic resources such as energy, water, raw materials and many others are extracted and transferred from the earth's ecosystem to the technical system and used by humanity. In turn, the resulting pollution and waste are returned to the natural environment. There is a growing imbalance between these systems. The techno-sphere is a dissipative structure that, in order to maintain and grow, has to destroy order and equilibrium (Giampietro, 2020; Kovacic, 2020).

The circular economy aims to minimize resource inputs at the entry to production system and decrease amount of waste and emission outputs of the production systems. All this will required adopt or spectacular change of its organizational subsystems. This can benefit both financial and sustainability performance of companies in a long period. To analyze industrial implementation of the concept, the prevalent unit of analysis on the firm level is currently the circular business model. Industries, companies can be expected to face numerous organizational obstacles, for example the need to change logistics chains, suppliers, technology, create new products, carry out research, implementation and many others to overcome constraints and build new opportunities.

Research and applicable work on the transformation and development of circular economy concepts into ecological economics and circular business systems is still scarce. According to Kanda et al. (2021) "…comparative case analysis points towards circular ecosystems being a more appropriate concept to describe the high level of coordination between different stakeholders necessary to implement circular systems". This increases the suitability to analyze, plan, and communicate circular economy systems on an organizational level, especially if value chain integration is low. An ecosystem perspective can thus support innovation and entrepreneurship in the context of the circular economy.

Such an approach is suitable for carrying out an analysis of the current state and exploring the possibility of changing it in the future. The results of this work will enable planning studies and action to be taken to promote the principles of introducing a circular economy system at enterprise level in the short term. The planning of forward-looking activities, taking into account the ecology and needs of the ecosystem, will highlight the need to take action on the necessary technical and organizational innovations within the organization. It will also show the possibility and potential of developing current technologies towards incremental innovations or the need to start research towards radical innovations. The exhaustive typology of eco-innovations (environmental technologies, organizational, product benefits, service offering environmental benefits and green system) has been overviewed lately (Venece and Pereira, 2019). The same authors have identified 6 types of eco-innovation: product design eco-innovation, process-eco-innovation, organizational eco-innovation, marketing-eco-innovation, social eco-innovation and system eco-innovation.

A transition from linear to a circular economy and afterwards into ecological economy (EE) will depend on the fruitful cooperation of governments and businesses (Lewandowski, 2016). The government role is regulate and adjust the market, creating collaborative platforms, providing financial support for industry, creating commercial law, eliminate regulatory failures specially during some economic depression or pandemics. In our opinion the third partner is necessary: research and science sector as a creator of innovative products or services proposals. Companies need to innovate their business models based on circular economy principles to decouple value generation from resource consumption and environmental impacts (Bocken et al., 2016). Business model is a construction in which the conceptual logic for value creation of product or service is based on utilizing the economic value retained in delivery of new offerings. In other words it is rationale of how organization understand conceptual logic and the architecture of value creation, delivery, capture planned to extend the product life cycle, slow and close resource cycles.

Since industrial ecology is a core theoretical root of circular economy, it can serve as a starting point for an ecosystem analysis of circular economy Industrial ecology presents the natural ecosystem as a metaphor for the design of industrial systems with the intention to close energy and material loops (Geissdoerfer et al., 2020). This article, extending upon these previous contributions, addresses two research gaps related to circular business models. First, there is a risk of underestimating the multiple sources of value creation and capture for firms implementing circular economy when using the firm perspective. Second, even though the industrial ecology and industrial symbiosis literature present an ecosystem view, they do not pay particular attention to the analysis of industrial ecosystems from a business perspective, but rather their development over time and impacts (Baldassarre et al., 2019). They address these gaps by analyzing companies with business activities based on circular economy principles from an ecosystem and business perspective using the industrial symbiosis and business ecosystems literature.

The circular economy concept requires an expansion of the firm-level perspective to an ecosystem-level perspective (Pieroni et al., 2019). For a theoretical contribution, our work provides insights into the inter linkages between biological and technical cycles in the circular economy. While the circular economy is often conceptualized as being restorative and regenerative by design, research combining both biological and technical cycles seems limited (Morseletto, 2020). The inter-linkage between technical and biological cycles can be facilitated by adopting an eco-system view which provides the opportunity to detect unconventional stakeholders connected to a business.

3.7. New modes of consumption

Since sustainable development concerns all economic entities, its element from the consumer's side is sustainable consumption, i.e. conscious purchase and utilization of products and services in accordance with the principles of sustainable development. The discussion concerning this category is related to a new paradigm in the stream of economics called moderation economics, which originates from the theory of alternative economics. The term was first used in 1992 in Chapter 4 of Agenda 21 (Agenda). One way to examine the level of individual consumption to assess its compatibility with the Sustainable Development Economy paradigm is to calculate the so-called individual ecological footprint.

An important component of CE is the new culture of consumption. Wellet. al. (2018, p.41) conceive it as a system composed "of user groups and societies that understand the use of service functions and the value of physical products as opposed to individuals who only individually own and consume different kinds of goods". Its essence is not ownership but the use of various goods and services on a sharing, lending, leasing basis. Its widespread introduction can lead to increased reuse of many resources and products. Examples include car-sharing, renting houses/holiday flats (instead of buying them), using office space, city bicycles, mutual use of gardening tools and many others. Behavioral change is now facilitated by widely developed internet-based communication systems but requires time to adapt in society. Currently, the beneficiaries of these new trends are younger people using the Internet and social media platforms. It should be noted that this is an idea that was recommended already in 1969 by Stahel and Reday (1969) and later described and propagated by Michael Porter (2011) using the term 'shared value'.

Małgorzata Koszewska (2017, p. 37) investigating the determinants of consumer behaviour in Poland conducive to GC concluded that the most important is the age of respondents. Younger and middle-aged people (generation Y) are more prone to consumerism. Hence, the author concluded that "the key role should therefore be played by education in sustainable consumption carried out at all stages of education, starting from the preschool level". One of the many evidences are the positive effects of childhood education in the circular economy by teaching sustainable practices in the case of aluminium packaging recycling (Buil et al. 2017).

In turn, Bylok F (2018, pp. 99-110) states that socially responsible consumption is complex and multidimensional, and the number of consumers who can be called socially responsible is small. They value relationships with other consumers, ethical content of the product, protection of the natural and social environment, etc. He further states that "There is a growing awareness of the need to change the ideology of consumerism in favor of sustainable societies. One of the factors stimulating these changes is the promotion of lifestyles associated with socially responsible consumption". This author, like Koszewska, concludes "that the concept of socially responsible consumption will materialize in consumer behavior in the future. The concepts cited in the article and research results concerning its scope of occurrence indicate its significant potential to occur in the future. Although, at present, it is largely an idea rather than actual human behavior on the market".

Knowledge of the principles of the circular economy in society is at a low level. However, their implementation enables sustainable development, so it becomes essential for the future. Their promotion may take place through:

1. transfer of knowledge from the scientific sector to a collective of consumers deliberately separated (e.g. youth, students, employees) covering aspects of the circular economy and the needs of its development, for the formation of innovative and socially responsible behavior of actors (education process).

2. to gain implicit knowledge from consumers concerning factors influencing changes in their behaviors on the market, in the processing and use process (research process)
3. creation of an Internet platform as a communication instrument for knowledge transfer (application process).
4. dissemination of new technology (platform) for the development of cooperation and consumer participation in building relations with business environment entities and the scientific sector within the quadruple helix (implementation process).

Implementation of the educational function by representatives of the science sector enables the acquisition of new knowledge among both consumers and producers, increasing their awareness and rationality of behavior, which may make them open to new innovative ideas related to the circular economy. The transfer of this knowledge from the scientific sector about circular economy theories and best practices worldwide to consumers is expected to stimulate creativity, entrepreneurship and innovation for circular economy development. Increased awareness in this area is a key determinant of improved cooperative skills, predispositions to cooperate, modifications in the hierarchy of value systems and activeness. Knowledge of the principles of the circular economy, the process of diffusion of innovation and adoption has a significant impact on its perception, acceptance of the need for development and on reducing the level of neophobia before the latest achievements in the world in this model of economy. This stage will enable the creation of leaders in changing consumer behavior.

The second stage is about acquiring new knowledge on innovation for the circular economy, taking a holistic approach to intellectual capital research. The acquisition of latent knowledge of consumer behavior and its changes towards social responsibility: a) in the market (purchasing behavior), b) in the household (use), c) in the environment (work and leisure) will allow a better understanding of the causes of their behavior, opinions, attitudes and intentions. This research seeks new selection criteria, the provision of new ideas and opportunities for their implementation. They aim to discover and clarify unknown opportunities in the given cultural and environmental context of consumers and agents in the sphere of cooperation regarding the development of the circular economy.

The third step is the creation of a web-based platform that should address the information and communication needs of users for the exchange of knowledge and information related to circular economy development needs. It will provide intelligent mobility for the transfer of knowledge about the circular economy from science, the economy and the submission of new ideas by consumers in the long term. Furthermore, it will enable the formation of pro-environmental and pro-innovation behavior of people who are aware, convinced and oriented towards building relationships and cooperation between science, consumers and the environment of the economy for the growth of innovation. This will allow the creation of network structures of innovative consumers, and the interaction occurring in the cooperative activities of the actors of the quadruple helix will lead to an increase in innovation for the development of the circular economy.

The fourth stage may lead to stimulating innovation and cooperation between consumers, science, producers and other actors within the quadruple helix. This will make it possible to develop ideas that are important for the concept of developing a circular economy. For let us remember that the formation of innovative and socially responsible behavior by actors is a function of time. The dissemination of knowledge is a positive stimulus for its recipients to reflect on the necessary cooperation with other entities of the economic environment and the need to build relations with them. This will be possible thanks to the Internet platform. The coherence of the presented stages and the development of innovative and social consumer behavior is shown in the Figure 6.

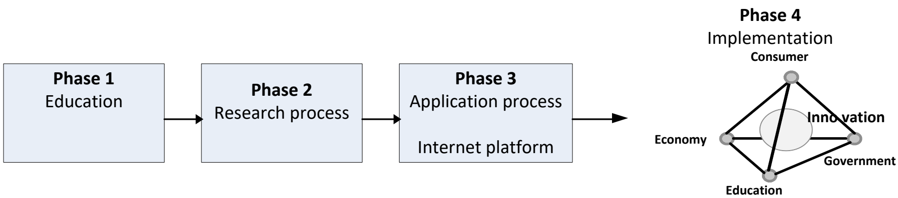

Figure 6. Theoretical model of shaping changes in socially responsible consumer behavior
Source: Skawińska, Zalewski, 2019

The Circular Economy has high economic potential for a modernizing EU economy with high environmental relevance but needs effective and strong research and innovation. Some of them might be incremental, but radical will be most welcome. To achieve this goal EU invested nearly 1 billion from Horizon 2020's final Work Programme (2018-2020) (Circular Economy Research and innovation Connecting economic & environmental gain, https://ec.europa.eu/programmes/horizon2020/sites/default/files/ce_booklet.pdf. However the CE must overcome barriers of different kinds eg. political and regulatory, cultural, financial and economic, technological and infrastructural, lack of competence, knowledge, and technical skills. The cost of new green innovation and business models is one of the main barriers to adopting sustainability practices by small and medium-sized enterprises (SMEs). In another work Hartley at al. (2020) identified from the point of view of European Union the following needs: "…more robust standards and norms in production, expansion of circular procurement, tax relief for circular products, liberalization of waste trading and its facilitation through virtual platforms, support for eco-industrial parks, and awareness campaigns. The set of policy recommendations is presented from a life-cycle perspective that is necessary for a transition towards a circular economy".

3.8. The place of CE in EU policy

The most important actions and decisions of the EU regarding the implementation of CE assumptions in the Member States are presented in Table 11.

Table 11. European Union initiatives

Year of decision / Source	Activities and decisions
2011 / Lassaux, 2015	The flagship initiative 'Resource Efficient Europe', which was part of the Sustainable and Smart Growth Strategy - Europe 2020.
2012 / Butterworth et al., 2014	The European Resource Efficiency Platform (EREP) publishes an opinion on the consensus among EU countries on the link between resource efficiency and the Circular Economy in the context of job creation and global competitiveness.
2013/ Raksit, 2014	A panel discussion on GC was organised at the 2013 Davos conference in anticipation of the definition of a non-binding target for resource producti-vity measured by the quotient of GDP and Raw Material Consumption (GDP / RMC - Raw Material Consumption). Other important measures adopted by the EU are the study on the environ-mental impact of raw materials, green public procurement and GC financing. Other initiatives indirectly related to GC are the directives on waste and eco-design.
Tost, 2015 Lassaux, 2015	A CG package was proposed with an extensive list of binding measurable targets. Among them were: recycling rates, landfilling, waste reduction etc. In addition, the document contained four Communications on: Sustainable Buildings, Green Jobs, MSP and a general one on Circular Economy "Towards a Circular Economy: Zero Waste Program for Europe"
European Parliament, 2015	Establishment of a team to prepare a new EU initiative taking into account the realities of member states. New legislation to strengthen waste management and include eco-designe, creation of markets for second-hand goods and recycled materials.
European Com-mission, 2018	Report on Critical Raw Materials and the Circular Economy
European Com-mission, 2019	European Green Deal - a set of policy initiatives from the European Commission with the overarching goal of achieving climate neutrality in Europe by 2050.
European Com-mission, 2020	Circular economy action plan
European Com-mission, 2020 a	Chemicals strategy. The EU's chemicals strategy for sustainability towards a toxic-free environment

Source: own elaboration.

On the second of December 2015. The European Commission has published a package for Circular Economy. The Communication is a set of proposals addressing all stages of the life cycle, the implementation of which should contribute to the European Union's transition to a closed loop pathway, ensuring the development of a sustainable, low-carbon, resource-efficient and competitive economy. The proposed actions will support the "closed-loop" life-cycle of products through the following activities:

- ecodesign including reparability and upgradeability, durability and recyclability of products,
- guidance on best practice for waste management and resource efficiency in the industrial sector, solutions to determine the environmental impact of products,
- introduction of waste management requirements and targets,
- solutions defining quality standards for secondary raw materials,
- specific and priority solutions for plastics, food waste, critical raw materials, construction and demolition waste, biomass and bioproducts (www.mpit.gov.pl/strony/zadania/zrownowazony-rozwoj/gospodarka-o-obiegu-zamknietym/informacje-podstawowe-o-gospodarce-o-obiegu-zamknietym/).

They will maximize value and ensure the use of all raw materials, products and waste, while contributing to energy savings and reducing greenhouse gas emissions. The proposals in question cover the entire life cycle: from production and consumption to waste management and the secondary raw materials market (Measuring (2018); europa.eu/rapid/press-release_IP-15-6203_en.pdf, 2015).

To facilitate the implementation of CE principles in the economy, the world's first standard BS 8001 - Guide BS 8001:2017 "Framework for implementing the principles of the circular economy in organizations. Guide" has been indroducing. On the other hand, McKinsey (2016), published in 2016 a guide "The circular economy: Moving from theory to practice" for businesses on managing waste, including plastics, new product development, food and clothing production, etc.

To steer the EU towards the 2050 goal of a healthy planet for healthy people named 'European Green Deal', the Action Plan sets key targets to reduce pollution at source, in comparison to the current situation (European Commission, 2019). Namely:

- improving air quality to reduce the number of premature deaths caused by air pollution by 55%,
- improving water quality by reducing waste, plastic litter at sea (by 50%) and microplastics released into the environment (by 30%),
- improving soil quality by reducing nutrient losses and chemical pesticides' use by 50%,
- reducing by 25% the EU ecosystems where air pollution threatens biodiversity,

- reducing the share of people chronically disturbed by transport noise by 30%, and
- significantly reducing waste generation and by 50% residual municipal waste.

Recently 14 October 2020) EU adopts new “Chemical strategy towards a toxic-free environment” (European Commission, 2020 a). The Strategy will boost innovation for safe and sustainable chemicals and increase protection of human health and the environment against hazardous chemicals. This includes prohibiting the use of the most harmful chemicals in consumer products such as toys, childcare articles, cosmetics, detergents, food contact materials and textiles, unless proven essential for society, and ensuring that all chemicals are used more safely and sustainably. The Strategy recognizes the positive and non-substitive role of chemicals. However, the urgent need to address the health and environmental challenges caused by the most harmful chemicals is highlighted.

The harmful effects of individual chemicals on living organisms cannot be eliminated, but at most reduced. In many cases the replacement of some chemical compounds by others is limited or impossible. Moreover, any adjustments to their structure change their properties. It is certainly necessary to strive for and limit the use of chemical substances in industrial production and other activities, especially mass production, which have harmful effects on living organisms and the environment as a whole. We should also be aware that a small change in the chemical structure of organic compounds can lead to an increase in their harmful effects on living organisms. The Strategy proposes out concrete actions ensuring that the most harmful chemicals for human health and the environment are avoided if not necessary or used more safely and sustainably. To achieve this, cooperation in triple helix of innovations (Leydesdorff, L. (2000) or extended triple helix (Zalewski R.I, Skawińska E., 2009). between research institutions, government, industry and customers with environment will be necessary to achieve incremental or radical innovation and investment actions. Seven key actions in the Chemical Strategy are listed (European Commission, 2020 a).

SUMMARY

The world economy is caught between the waning influence of the industrial era on most areas of life and the rapidly rising wave of computerization, which is increasingly affecting all areas of social and economic life. Both in the past and in the present, the waning influence of the agrarian or industrial era must be understood in a relative sense, as a function of time. Moreover, these changes are taking shape in different ways on a global and regional scale.

Successive generations are increasingly consumption-oriented and expect new, better and innovative products. This spiraling expectation is being exploited by industry and the retail sector. However, there is a growing demand for energy and raw materials, as well as the problem of pollution of the earth, oceans and atmosphere by the waste generated. This is evidenced by the worrying figures for the demand for fuels, ores, minerals and biomass, showing a very strong upward trend. In 1970 26.7 Gt of these were consumed, in 2015 84.4 Gt, and the projection for 2050 is over 170 Gt (Global Circularity Gap Report, 2018).

The research problems addressed in Chapter 3 were:

1. What factors limit the development and implementation of the circular economy.
2. What are the challenges to the wider application of this model.
3. What are the weaknesses and limitations of CE opportunities and what are the reasons for them.

Chapter three describes the concept of the circular economy in general and defines its principles. In recent years, it has been developed and made more specific, with the construction of successive models containing from 3 up to 10 features denoted by the letters R. All the elements present in the (4R) model (Michalcic et al. 2003) up to the one proposed by Morselatto (2019) (10 R: Refuse, Rethink, Reduce, Reuse, Repair, Refurbish, Remanufacture, Repurpose, Recycle, Recover) are described. The authors modified the latter model by highlighting the role of consumers and producers in the three groups of elements of R. Attention was also drawn to the phenomenon of obsolescence (Mellal, 2020), which is in part responsible for reducing the quality of products and shortening their lifespan, partly at the price of the pursuit of innovation, partly to evoke new desires among consumers. The need to adapt future CE models to ecological principles and current and future consumption patterns was also pointed out. At the end of this chapter, the most important documents of the European Union are summarized, characterizing its current and future policies in relation to the circular economy.

Chapter 4. Waste in a Circular Economy

4.1. Natural science and consequences for CE

The message of the CE is to ensure the availability of materials, energy and other resources for economic activity now and in the future. It results in desirable and undesirable streams of matter. The latter are only partly managed by nature and integrated into the various cycles of transformation operating in the biosphere. The others pose a growing threat to the environment and require complex countermeasures. There is general agreement that they should be utilized wherever possible, provided that they are recovered at economically justifiable costs. The simplest way to do this is efficient separation, which makes it possible to recover many basic materials (e.g. paper, glass, plastics, metals, food industry and household waste, green waste, etc.) and then recycle them. Many types of waste of a technical (industrial) nature need to be included in the outer sphere of the matter flow cycle. However, waste contains many valuable materials, substances and chemical elements that are dispersed in its mass and whose recovery is not possible or is too labour-, energy- and capital-intensive. As an example, the data in Table 12 document large differences in energy and water consumption when recovering metals from scrap and their ores. Circular economy calls for the introduction of a system for the recovery of useful elements (in free form or as chemical compounds). However this generates costs, requires energy and work, and often the use of technologies harmful to the environment. For example, obtaining 1 kg of magnesium or cobalt from scrap requires about 20 times less energy than extraction from ore. However, for platinum this ratio is already much higher. Similar refers to water consumption (eu.europa.eu/docsroom/documents/27327). And in order to recover gold from electronic products, it is unavoidable to use substances such as potassium cyanide or royal water, which are detrimental to the environment.

Table 12. Comparison of energy and water consumption in the extraction of selected metals from their ores and scrap

Metal	Energy consumption MJ/kg		Water consumption (m3/t)	
	Scrap	Ore	Scrap	Ore
Magnesium	10	165-230	2	2-15
Cobalt	20-140	140-2.100	30-100	40-2.000
Platinum	1.400-5.000	18.800-255.000	3.000-6.000	100.000-1.100.000
Rare earth metals	1.000-5.000	5.500-7.200	250-1.250	1.270-1.800

Source: eu.europa.eu/docsroom/documents/27327

However, when these metals are dispersed in the waste structure, these expenses increase significantly due to segregation costs.

The paper seeks to answer important and topical questions that appear in the literature: To what extent is the world economy circular? What is the actual state of its implementation in the world and in the European Union? What are the achievements? What are the obstacles?

By their nature, answers to these questions are fragmented, incomplete and dependent on the availability of data. For example, Haas et. al. (2015, 2016) presented its state in the world and the European Union in 2005. The inflow of new materials into the economies was then (62Gt), 41Gt of waste was generated and only about 4Gt was recycled. The authors gave two reasons for this: 44% of recycled materials are used for energy production, about 5Gt are products with a short 'life', while the rest are used in construction, infrastructure or products with a longer life. As a result, globally only 6% of waste was reused. Data published in 2018 by the World Economic Forum (Global Circularity Report, 2018) reported that the global economy was 9.1% circular. The most recent data (Global Circularity Report, 2021) states that this percentage is around 8.6% for the world. This shows that despite the spread of the circular economy idea, the effects are small and possibly negative. The difference may be due to imperfections in the measurement method or the inclusion of more backward countries and previously not included. The corresponding indicator for the EU is slightly more favourable. Estimates indicate that if there are no changes in "business as usual" in 2030, Green House Gas emissions will be 60-70 billion tonnes. At the same time, the use of new materials in the global economy is projected to increase to 170 Gt in 2050. However, it is important to note that recycling is only one part of the GC.

Nature on Earth has for billions of years functioned on the basis of energy emitted by the Sun (Figure 7). The Sun's energy is radiated daily into all directions of the Universe, where the temperature is around 2.7 K (−270.4 °C). Only small part of radiation is directed into Earth. Merely 0.024% of the Sun's radiation is stored through photosynthesis by plants. This fraction, in addition to the weathering effects of the Sun's energy on the crust as well as the internal heat on Earth, shaped the conditions for the creation and storage of all biological and mineral resources. Finally, only these resources can be used by humanity for growth and survival.

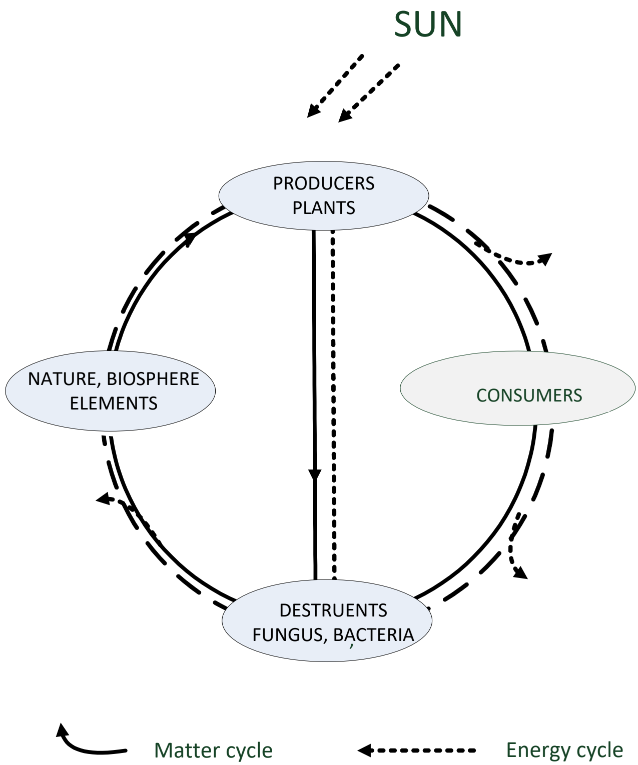

Figure 7. Energy and matter cycle in biosphere
Source: Skawińska, Zalewski R.I., 2020 a.

The circulation of matter in nature supported by solar energy was a set of processes of continuous circulation of biologically relevant chemical elements (so-called biogens) for million years. They run between the environment, which is a donor of carbon, nitrogen, oxygen, sulfur, phosphorus, hydrogen and many other elements needed in small or trace amounts and living organisms. The elements listed above occur in free form or as simple chemical compounds and are taken from the non-living environment by self-living organisms call PRODUCERS (e.g. bacteria, plants). Those organisms transformed them into the complicated organic and bioorganic compounds (e.g. starch, carbohydrates, enzymes, chlorophyll) that make up the structure of their own organisms, or are used to obtain the energy needed for their life cycle and feeding CONSUMERS or DESTRUENTS.

Other compounds are synthesized and used by animal and plant organisms to ensure their propagation. Dying plant and animal organisms are broken down by other organisms (DESTRUENTS, bacteria, fungus) into simple inorganic compounds or released as elements to NATURE, BIOSPHERE which are used by other organisms in their own life cycles. The next rungs of consumers on the trophic pyramid use the compounds obtained from other organisms for the same purposes. The organic matter of dying organisms returns to the environment after decomposition by reducers as water-soluble mineral salts, among other things.

Over millions of years, this excess has transformed itself into, for example, coal or lignite, oil deposits, rock salt or limestone. In addition to the weathering effects of the Sun's energy on the crust as well as the internal heat on Earth, shaped the conditions for the creation and storage of all biological and mineral resources humanity has at its disposal for survival. The Sun-Earth system in the past had strong global, spontaneous and vigorous tectonic processes such as continental migration, volcanic eruptions, collisions with other celestial bodies. Throughout the time they take place processes such as erosion, oxidation, mixing, cooling, melting, evaporation and precipitation, dispersion of materials, formation of mineral deposits. In many of these there was a circular turnover of matter.

The Earth is a physically closed system, characterized by the fact that no matter reaches it from the outside except comets, meteorites and cosmic dust and no matter is lost from the Earth. The conclusion from this is that in the whole biosphere there is no loss of mass of the elements mentioned above, only their relocation occurs. Circulation models in nature have been developed for the basic elements: oxygen, carbon, hydrogen, whose contents in the biosphere are respectively: 70%, 18% and 10%. All the other elements of the Mendeleev table constitute only 2% (including nitrogen and phosphor) of the total mass of the Earth's biosphere. For thousands of years man's influence on the relocation of basic elements and substances in his environment was marginal. It began only when the natural economy based on gathering and agriculture began to give way to the commodity economy (Toffler A., 1970) According to this author, economic development has a wave nature, which can be imagined as a series of irregular curves of increasing amplitude (Figure 8).

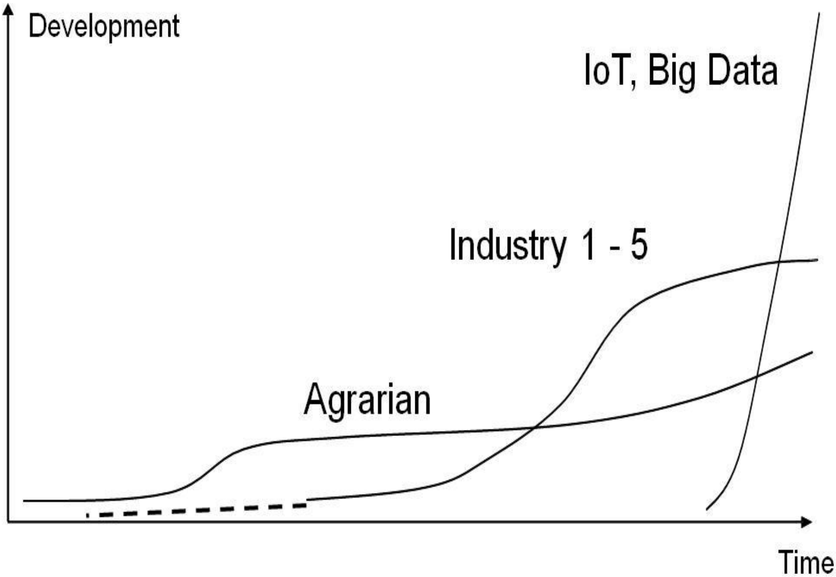

Figure 8. Development waves in human civilization
Source: own elaboration.

The natural economy based on gathering and cultivation of land gave way to the first technological wave well before our era. The turn of the 17th/18th century saw the beginning of the second technological wave called the industrial wave, which lasted until the mid-20th century. It was based on the rapid development of natural (physics, chemistry, biology) and technical sciences. Main achievements are presented on the following figure (Figure 8). Their progress led to the increasing importance of science and knowledge in the economic development of the technological wave and the emergence of the third technological wave at the turn of the 20th/ 21st century. It is now accepted that the manufacturing industry has embarked on a 4th stage of growth (Industry 4.0). The term was used for the first time at the Hannover Fair in 2011 during a presentation by the 'Smart Factory' research project. The aim of this project was to increase resource efficiency and ergonomics, and to integrate with customers, consumers and partners. The technical foundations are in between: cyber-physical systems, Internet of Things, BigData, augmented technology, 4.0 Industry processes, logistics, new business and work organization models. A convergence of technologies based on information, communication, automation is expected (Figure 9).

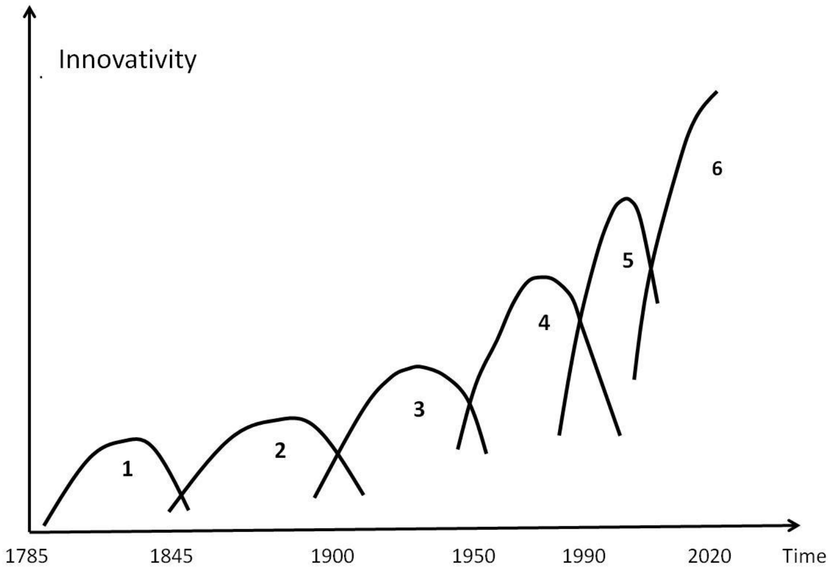

Figure 9. Technological developments after 1785
Source: own elaboration

Explanations: 1 - improving iron smelting technology, textiles, trade, 2 - steam engine, railways, steel, cotton processing, 3 - electricity, chemicals, internal combustion engine, 4 - petrochemicals, electronics, aviation, space, 5 - biotechnology, software, information technology, 6 - green chemistry and nanotechnology, renewable energy, industrial ecology, sustainability, systems planning.

However, human activity, such as the burning of oil-based fuels, coal, the clearing of vast tracts of forest and many others human activities, is altering the balance in nature and leading to a noticeable and harmful increase in the concentration of carbon dioxide in atmosphere. The increasing and widespread use of nitrogen fertilizers and the release of nitrogen from municipal wastewater has seriously disrupted its cycling in the biosphere (e.g. Kuypers, Marchant, Kartal, 2018). The concentration of animal husbandry in large farms, which generally do not cultivate the land, also contributes to this. Many of them use animal manure to produce biogas and electricity to power the farm. This has led to a reduction in natural soil fertilization on large farms specializing in cereals, oilseed rape, potatoes, sugar beet, etc. due to the lack of manure. Human activities have also altered the cycle of phosphorus in the biosphere through excessive use of phosphate fertilizers and washing agents (Conley et al. 2009). A serious problem for the world is the disruption of the carbon cycle in nature, which has been progressing since the industrial revolution and has increased rapidly in recent years. Its cause is, on the one hand, the increasing burning of coal and oil for heating, development of chemical industries (organic and inorganic chemistry, plastics, lime, cement, soda, fertilizers and many others) realizing carbon dioxide. On the other hand, the massive clearing of rainforests in Asian and South American countries does not ensure its inclusion in the photosynthetic process, as already written about 40 years ago (Falkowski et.al. 2000). This is evidenced by the doubling of carbon dioxide concentration in the air in the last two hundred years. The imbalance in this respect strongly influences the warming of the atmosphere, the climate change and the increase the number of violent atmospheric phenomena (precipitation, hurricanes, droughts) all over the globe intensifying in recent years.

An economic system, built on unlimited access to solar energy with low entropy, in theory allows the complete circulation of materials and thus their circular re-utilization. However, industrial society disperses matter: chemical elements and minerals all over the planet in a state of high entropy, which makes their recovery practically impossible (Kerschner, 2010) or requires considerable energy and auxiliary or harmful materials. Given adequate time, the Sun, along with the internal heat of Earth's inner cores, could provide the energy to partly restore irreversible degradation. However, the pace of such degradation is different for biological systems than for geological ones. Biological systems may be restored in decades or centuries, whereas geological resources such as coal or crude oil are non-renewable within the human timescale.

4.1.1. Circulation of inorganic materials

For many years there has been an increase in industrial production, which accelerates the circulation of elements and chemicals in production processes. It is assumed that the content of silicon, aluminium and iron in the lithosphere - (i.e. the outer crust of the Earth) is 37% and all the others, with the exception of oxygen (about 50%), only 14%. The thickness of this layer is not uniform and is estimated at several tens of kilometers. In the hydrosphere, other elements except oxygen and hydrogen constitute only 3% of the mass. In the biosphere, the proportion of all elements (except oxygen, carbon and hydrogen) is 2%, while in the atmosphere, nitrogen and oxygen account for 99%. From the above data, it is clear that practically the only source of raw materials for industry is the lithosphere, which contains 4% iron, 7% aluminium in the form of oxides or salts, and all other elements not mentioned here from the Mendeleev table are 14% (Morgan, Anders 1980). It is also known that most of them generally occur in considerable dispersion or in randomly dispersed deposits, in minerals of various kinds. Their extraction requires considerable expenditure of money and energy, followed by a series of further activities to separate them.

Current techniques for extracting minerals and raw materials only allow penetration of the earth's crust to depths of several kilometers. This limits their technical availability and results in a sharp increase in extraction costs as their depth increases. Subsequently, after the extraction of raw material (rock, liquid, gas), in order to obtain the desired elements or substances, further technological procedures are necessary. Thus, the following takes place:

- the process of transition from distribution of materials such as for example coal, oil, salt, metal ores in compact seams or scattered among rocks (gold, diamonds, amber) or marine water to ordering (desired material, ore, raw material, element) and increase of their market value, which requires considerable expenditure of labour, capital, energy,
- in further production processes the mass of raw material or elements (eg. gold, platinum, rare earth oxides and many others) is dispersed among individual units of the finished product,
- after meeting the expectations of the buyer and the passage of time, the product becomes waste, often of a very complex structure, which may be included in the circular cycle (R3 - R7) or used for recycling (R8) or recovery (R9). The consequences of these actions must obey the laws of thermodynamics (which means energy expenditure), development of technologies, use of auxiliary materials, human work etc.
- limitations on the physical scale of the economy and transport,
- managerial constraints,
- social and cultural constraints (partly from 'Circular economy: the concept and its limits) (Korhonen J., Honkasalo A., Seppala I., 2018).

But can a circular economy be realized in this way? (de Man R., Friege H., 2016). Many authors believe that the above statements need to be answered, confronted with the following caveats and after solving the following problems:

1. In reality, waste is almost never ‘food’ or useful material, understand as full quality resource dissipation. All production processes lead to waste, mixed materials, etc. Creating value from such materials needs energy, but creating a waste-free economy would need gigantic quantities of energy, appropriate technology and other supplementary materials. Complete recycling is therefore a thermodynamic impossibility: It will cost infinite quantities of energy and infinite time.
2. The assumption that natural nutrients can be fed into the ecosphere without any problems, regardless of their quantity is not true.

3. The production of beneficial consumer products almost always resulted in the generation of industrial wastes and used products or materials that turned out to be hazardous. Numerous manufacturing processes require technologies that require, for example, the use of chemicals that are harmful to human health and the cleanliness of the environment. Some of these technologies can be changed as a result of development and innovation research. This is the direction followed by the recommendations of the recently published and adopted EU Chemicals Directive (European Commission, 2020 a).

On this basis we conclude that the assumption that 'circular' solutions necessarily lead to sustainable outcomes is questionable if not doubt-full. Such an outcome cannot be guaranteed. 'Circular' solutions can and do have negative ecological impacts and they may even be worse than so-called 'linear' solutions, especially with respect to energy use and in cases of risks coming up with certain compounds entering raw material chains. The sustainability guarantee of 'circular' solutions is partly illusory and questionable This conclusion follows from thermodynamics and is related to entropy.

Entropy is a thermodynamic function that determines the direction of spontaneous processes in an isolated thermodynamic system. It is a measure of the degree of disorder of the system and the dissipation of energy. According to the second law of thermodynamics, if a thermodynamic system moves from one equilibrium state to another, without external input (and therefore spontaneously), its entropy always increases (eg. Georgescu-Roegen, 2012, p. 50). Irreversible processes occur in nature, that is, processes that cannot be undone by any means. This means that neither after them nor after the efforts made to undo them has the slightest trace remained in nature. Experiences gathered by representatives of various sciences clearly indicate their spontaneity and irreversibility. The basic types of irreversible processes are heat conduction, heat generation and diffusion. In order for a process to be reversible, it must be carried out in such a way that the surroundings also spontaneously pass to the initial state. A general definition of the second law of thermodynamics can be found in the statement that heat cannot move independently from a body at a lower temperature to a body at a higher temperature.

Entropy is a measure of system's disorder. In particular, in this way entropy is treated and understand from the perspective of thermodynamic, chemistry, biochemistry, food chemistry, life sciences. According to the Second Law of Thermodynamics, the total entropy of any isolated thermodynamic system tends to either remain constant or increase over time, approaching a maximum value. This also means that an isolated system (in our case solar system) will gradually become more and more disordered. Entropy is associated with the process of the transformation of a high-quality energy (useful energy) into a low-quality energy ('low - grade' energy), or with the process of dissipation of useful energy. High quality energy is determined by its ability to do (useful) work. In physics and other sciences including life science, work and entropy are inversely related. The principal way to decrease entropy is to do work through the expenditure of free energy. If free energy is available and is expended to do useful work, then the system becomes more orderly and entropy decreases. But if all available energy has been expended, then no more work can be done, and entropy will either remain constant or increase (Bailey, 2009). This state of maximum entropy is called thermodynamic equilibrium. This is sometimes described as the state of "system death." Such thermodynamic systems, as found in nature, are "irreversible systems," where heat cannot flow from colder to hotter parts of the system, but only from hotter to colder areas. Thermodynamic entropy is denoted by the symbol S, and the formula for change in entropy is:

$$dS > dQ/T$$

where Q is heat, and T is the temperature of the system. The difference in two entropy states, S_1 and S_2 is:

$$S_2 - S_1 > dQ/T$$

(irreversible process). Entropy (S) can only remain constant or increase, until it reaches a maximum. When the system is in thermodynamic equilibrium, then $dS = 0$.

In physics, work and entropy are inversely related. The principal way to decrease entropy is to do work through the expenditure of free energy is available, and is expended to do work, then the systems become more orderly and entropy decreases. But if all available energy has been expanded than no more work can be done, and entropy will either remain constant or increase.

Energy sources are very diluted (e.g. solar or geothermal), or highly concentrated (e.g. fossil fuels or nuclear energy) and both create problems. Fossil fuels have adverse effects on climate change due to carbon dioxide and smog emission on burning coal or lignit, whereas nuclear energy processing requires treatment of dangerous waste and entails the risk of accidents which happened in Czarnobyl (Russia) of Fukushima (Japan). To avoid the future problems, agreement exists that nations must promote renewable energies such as wind, sea waves or solar (photo-voltaic). In 2019 power generation from solar PV was estimated to have increased to 720 TWh and share almost 3% of global electricity generation. PV generation overtook bio-energy and is now the third-largest renewable electricity technology after hydropower and onshore wind (Global Wind Report 2021). For comparison 743 GW of wind power capacity worldwide, helping to avoid over 1.1 billion tonnes of CO2 globally – equivalent to the annual carbon emissions of South America "Achieving net zero greenhouse gas emission by 2050 will require the rapid development of clean energy technologies. Research is essential to the sources of this clean energy transition" (Pathways, 2021).

However, this requires raw materials for construction of equipment which is 'more mineral intensive'. Question arises: do we have enough copper, silver, silicon, cadmium, tellurium, indium, selenium, or gallium for photo-voltaic technologies? or for wind turbines: neodymium, praseodymium, cobalt, samarium and dysprosium with boron despite, copper and other structural materials such as steel and aluminum? Biomass, on the other hand requires fertilizers to growth and after burning yields CO_2. Recently Valero et al. (2018) published a list of elements that might be at risk because of supply shortages for the development of green technologies.

Circular economics postulates the introduction of a system for the recovery of useful chemical elements (in free form or chemical compounds). This generates costs, requires energy and human labour, and often the use of materials and technologies that are harmful to the environment. Given adequate time, the Sun, along with the internal heat of Earth's inner cores, could provide the energy to partly restore irreversible degradation. However, the pace of such degradation is different for biological systems than for geological ones. Biological systems may be restored in decades or centuries, whereas geological resources are non-renewable within the human timescale.

4.1.2. Circular of organic material

Industrial waste of organic origin should be included into the circular or cascading way before their final storage/disposal in the environment. Keijer et al. (2019) wrote: "By expanding the scope of sustainability to the entire lifecycle of chemical products, the concept of circular chemistry aims to replace today's linear 'take–make–dispose' approach with circular processes. This will optimize resource efficiency across chemical value chains and enable a closed-loop, waste-free chemical industry…" This opinion is strengthened for example by Elsevier's publication of the following 'Top 5 solutions suggested for chemical companies':

1. Source raw materials from safe and renewable points of origin
2. Treat internal manufacturing pipelines as sources of reusable material
3. Refurbish asset parts and machinery rather than discarding them
4. Form trade partnerships to exchange waste products for renewable resources Just as asset parts and machinery
5. Make safety and regulatory compliance core components of company culture (https://www.elsevier.com/__data/assets/pdf_file/0005/961601/Top-5-challenges-circular-economy_whitepaper_CHEM-RD_WEB.pdf).

The circular economy has gained wide interest in chemical industry to reduce harmful impacts while remaining economically competitive. For example Somoza-Tornos et al. (2020) explore the benefits of CE approach in the chemical industry, quantifying explicitly the economic 0.386 Euro vs. 0,835 Euro with the previous method. In addition, they use less harmful chemicals and more safe for humans and ecosystem. Other examples of new methods of synthesis with application of carbon bi-oxide in sustainable utilization and production of plastic were described by Clark et al. (2016) Some processes include the extraction of high-quality biochemical substances and materials (bio-refining), which occur in the biomass even in small quantities, or their conversion into high-quality chemicals for the fuel industry (e.g. alcohols, esters and others), packaging materials, pharmaceuticals, cosmetics, etc. However, most of the above-mentioned methods require the use of complex chemical and/or physical processes, which in their nature are energy-intensive and require the use of auxiliary chemicals, e.g. for extraction. Another author calls on chemists: “Chemists around the World, Take Your Part in the Circular Economy!” (Chatel, 2020).

Waste can also be converted into compost and fed to plant crops (CIRAIG 2015, p. 50), limiting the use of artificial fertilizers. Allocation of waste e.g. for energy purposes - incineration or subjecting to anaerobic processes (transformation by bacteria in an anaerobic environment) for the production of fuel materials, e.g. methane - should be the last option in the process of disposal of organic waste, including municipal and animal ones. According to Korhonan et. al. (2018, p. 40), as much as possible biological waste should return to the circulation in the biosphere and participate in its quantitative growth and diversity. This will decrease release of carbon bi-oxide to atmosphere.

Food waste caused by the growing human population (about 6.5 billion today, forecast to grow to 9 and 11 in 2050 and 2100 respectively) (GFSI, 2019), and the food chain losses (of about 1550 million tonnes or $1200 billion) is a special problem (Hegnsholt et al. 2018).

An organic waste with high harm to the terrestrial environment is non-degradable plastic packaging. Similarly, recovering tonnes of micro-plastic in the oceans, even in the presence of revolutionary solar-powered clean-up technology, is a highly unlikely task. (Śmiechowska M., 2019). Micro-plastic ingested by zooplankton can be transferred to commercially important fish species and through the food chain with potential effects on human health (Setälä, O. et al 2014).

Industrial waste of organic origin should be included into the circular flow in a cascading way before their final storage in the environment. These processes include the extraction of high-quality biochemical substances and materials (bio-refining), which occur in the biomass even in small quantities, or their conversion into high-quality chemicals for the fuel industry (e.g. alcohols, esters and others), packaging, pharmaceuticals, cosmetics, etc. However, most of the above-mentioned methods require the use of complex chemical and/or physical processes, which in their nature are energy-intensive and require the use of auxiliary chemicals, e.g. for extraction. Waste can also be converted into compost and fed to plant crops (CIRAIG 2015, p. 50), limiting the use of artificial fertilizers. Allocation of waste for energy purposes - incineration or subjecting to anaerobic processes (transformation by bacteria in an anaerobic environment) for the production of fuel materials, e.g. methane - should be the last option in the process of disposal of organic waste, including municipal and animal waste. According to Korhonan et. al. (2018, p. 40), as much as possible biological waste should return to the circulation in the biosphere and participate in its quantitative growth and diversity.

Waste streams can be used in natural cycles by the biosphere and at the same time benefit the economy. According to Korhonen and colleagues, an example is the carbon dioxide emissions of the Finnish timber industry, which is less than the amount consumed by the recovering forest resource (Korhonen et al. 2018, p 40). In this case, the forest functions as a carbon reservoir. This example leads to the term 'net carbon emissions' (NCE). It means the difference between the emission to the environment **EE** and the absorption by the environment **AE**. The problem is to make the net emission **NCE = EE – AE** as small as possible or even negative. Then the environment will accumulate this greenhouse gas. Forests are an important ally here. This issue received much attention at the 24th COP in Katowice, where a declaration „Forests for Climate" was adopted (COP, 2018). The exceptions to the document are set out below: "Acknowledging the important role of forests as sinks and reservoirs of greenhouse gases, in mitigating climate change, and simultaneously recognizing the need for reducing emissions from deforestation and forest degradation.". Further recognizing that forests have a decisive role to play in the sequestration and storage of carbon in the soil, trees and other vegetation, and in providing goods, resources and materials with a smaller carbon footprint, such as harvested wood products…". Sharing the UN Strategic Plan for Forests' vision of a world in which all types" (COP, 2018). Efforts have now been made in the EU to plant millions of trees in the coming years. Another initiative in this direction is the Declaration 'Partnership for Electromobility' proposed by Poland and the UK and supported by 40 developed and developing countries (COP, 2018a). "The aim of the partnership is to bring together countries, regions, cities as well as institutions, organizations and companies working on developing electromobility and particularly: construction of infrastructure for electric vehicles; creating an incentive system for buyers, setting targets related to electric fleets and to public procurements. The new fund for electromobility has been set up with the World

Bank within the framework of the "Mobility and Logistics Trust Fund" (https://cop24.gov.pl/news/news-details/news/driving-change-together0).

4.2. Barriers

The paper seeks to answer important and topical questions that appear in the literature: To what extent is the world economy circular? What is the actual state of its implementation in the world and in the European Union? What are the achievements? What are the obstacles?

By their nature, answers to these questions are fragmented, incomplete and dependent on the availability of data. For example, Haas et. al. (2015, 2016) presented its state in the world and the European Union in 2005. The inflow of new materials into the economies was then (62Gt), 41Gt of waste was generated and only about 4Gt was recycled. The authors gave two reasons for this: 44% of recycled materials are used for energy production, about 5Gt are products with a short 'life', while the rest are used in construction, infrastructure or products with a longer life. As a result, globally only 6% of waste was reused. Data published in 2018 by the World Economic Forum (Global Circularity Report, 2018) reported that the global economy was 9.1% circular. The most recent data (Global Circularity Report, 2021) states that this percentage is around 8.6% for the world. This shows that despite the spread of the circular economy idea, the effects are small and possibly negative. The difference may be due to imperfections in the measurement method or the inclusion of more backward countries and previously not included. The corresponding indicator for the EU is slightly more favourable. Estimates indicate that if there are no changes in "business as usual" in 2030, Green House Gas emissions will be 60-70 billion tonnes. At the same time, the use of new materials in the global economy is projected to increase to 170 Gt in 2050. However, it is important to note that recycling is only one part of the GC.

The implementation of circular economy principles in reality faces numerous obstacles. As an example, the results of a review paper of 195 publications (Galvao et al. 2018). The barriers that appear most frequently are: technological (11), policy and regulatory (19), financial and economic (11), managerial barriers (4), performance indicators (4), customer (interest in the environment issues or lack of information on environmental impacts) (8) and social (5). In turn, Grafstrom J. and Asama S. (2021) list the following barriers to CE: technological, marketing, institutional and social. In another paper (Ada N., et. al. 2021) authors investigate the main barriers to CE implementation in the food supply chain. Seven main categories of barriers were identified:

- cultural: a lack of consumer awareness and interest for cultural reasons,
- business and business finance: insufficient access to investment and infrastructure for market design,

- regulatory and governmental: weak regulations, policies, taxation, and incentives established by governments,
- technological: technological limitations,
- managerial: limited application of business models by management,
- supply chain management: poor cooperation between suppliers because of ineffective supply chain management,
- knowledge and skills: difficulties when defining the boundaries of CE due to the lack of knowledge and skills.

In another publication (Friant et al. 2020) the authors list and analyze a number of other barriers eg.: ignoring the principles of conservation of energy and thermodynamics, the links between matter, energy and bio-diversity, lack of knowledge identifying the full impact of CE and cultural change or alternative understandings of circularity. For example, they stress that materials degrade quantitatively and qualitatively and cannot circulate indefinitely. This means that they undergo dispersion in the environment. For this reason, total circulation is like a mirage. Furthermore, every activity in the circular economy requires energy. Even if it is from the sun, obtaining it requires huge inputs of materials (e.g. rare earth metals) whose resources are limited and difficult to access. It also appears that some production systems define themselves as circular but have a greater environmental impact than their linear competitors (e.g. bio-fuels, bio-polymers). One of the organizational barriers is the lack of objective methods to measure CE performance especially in terms of environmental benefit. It is also worth noting that the social dimension of CE is poorly presented in the literature.

According to other authors, the rapidly growing mass of raw materials and products produced and transported in the world, management difficulties, defensive posture of previous technologies and business models against the competition of new ones, the need to implement new social attitudes and cultural changes (Korhonen, Honkasalo, Seppala, 2018). A slowdown in the growth of demand for oil and coal can be expected due to an increase in the cost of carbon dioxide emissions and an increase in demand for electricity. Meeting it will be possible provided that radical innovative solutions are applied and that 'open innovation' is more widely used in the field of new solar and photovoltaic technologies, the use of sea and ocean wave energy, wind power, electricity storage, more efficient light sources and electrical appliances, electrically conductive materials, new computer technologies (bio-computers) and many others. Fast-growing and innovative startups can help here (Zalewski, Skawińska 2020; Bauwens T., et al., 2019). The increase in demand for food will most likely force new ways of growing plants and vegetables and new methods of animal husbandry or reduce meat consumption by synthetic one in future. Synthetic meat production is currently under development and consumer's trials. An increase in these productions will be associated with an increase in demand for water and energy. The organoleptic and sensory quality of food produced in this way are a separate issue. Innovations in biotechnology are expected (new generations of medicines and vaccines, medical materials, equivalents of human internal organs, blood vessels, bones and joints).

We also draw attention to one very important reason: economic, social, environmental and technical rationality, which in most GC functions is subject to the constraints of the laws of physics, especially thermodynamics, as well as chemistry and biology. In our opinion, among the problems requiring further intensive research in the field of GC are especially the broadly understood rationality of GC tasks, methods and activities in close connection with the laws of natural sciences. It is extremely important to confront the views of economists and the achievements of economic sciences in its field of competence with objective laws of nature and to point out the illusory nature of some economic constructions.

According to the authors, among the problems requiring further intensive research in the area of GC is especially the broadly understood rationality of tasks, methods and actions in close connection with the laws of natural sciences mainly: physics (thermodynamics), chemistry and biology. According to De Decker (2018) "…A more responsible use of resources is of course an excellent idea. But to achieve that, recycling and re-use alone aren't enough. Since 71% of all resources cannot be recycled or re-used (44% of which are energy sources and 27% of which are added to existing stocks), you can only really get better numbers by reducing total use". These words are supported by nine publications. In a similar vein Allwood (2014) stated that trying to "meet human needs while minimizing environmental impact" would be a better goal than material circularity" (Allwood, J. M., 2014, 445-477).

4.3. Debatable remarks

The first group of criticisms and doubts has a natural science and physico-chemical background. It has been argued that because engineering and natural sciences lay the ground for most knowledge behind the circular economy (Korhonen et al., 2018a), less attention is paid on:

- social pillar (Blomsma & Brennan, 2017; Murray et al., 2017),
- business routines, consumption patterns, and alternative approaches to circularity (Schulz Y., Lora-Waingriht A., 2019),
- socio-ethical issues (Inigo E.A., Blok A., 2019),
- trend to ignore basic principles of biophysics (Kovacic et al., 2020),
- the tensions between biophysical limits and progress and growth.

Constructive lessons can and should be drawn from this information for the future, setting new goals and recommendations by examining the holistic and complex interrelationships that exist between all stakeholders and the threats to the living and non-living environment. This is encouraged by numerous authors, among them Sauve et. al. (2015).

Globally, growth has been coupled with resource consumption and environmental pressures and is not likely to decrease. The concept of CE assume that material resources could be increasingly sourced from the Earth, environmental impact will slowly decrease and the reuse and recycling of materials will continuously increase. (Hickel and Kallis, 2020; Wiedmann et al., 2020). In fact "the low potential for circularity is because a very large share of primary material throughput needs energy carriers, which are degraded through use as explained by the laws of thermodynamics and cannot be recycled (https://www.eea.europa.eu/publications/growth-without-economic-growth). In fact the slope of relative changes global material footprint (GMF), gross domestic product (GDP) and greenhouse gases emissions (GHG) (https://data.worldbank.org/indicator/EN.ATM.CO2E.KT) have increased rapidly over time and strongly correlate.

The second line of criticism and doubts is based on the economic feasibility of CE in the current system of market capitalism, which is the dominant economic model in the European Union. In the 1980's, Schnaiberg (1980) introduced the theory of the 'production treadmill' (https://study.com/academy/lesson/ allan-schnaiberg-the-treadmill-of-production-environmental-sociology.html). It presupposed, that „rapid economic development and growth led to a huge demand of natural resources and new technologies required more and more energy use. Every time new investment were made or new industries popped up, we use more and more natural resources". This theory can now be expanded to include some new examples. The development of urban infrastructure, create a heat spot that increases air pollution and degrades the ecosystem. The availability of transport modes (car, aeroplane) causes an increase in noise pollution. The intensification of livestock farming and the increase in the number of animals in livestock farms often leads to epidemics. The increased affluence of the population in many countries results in spiraling consumerism, food waste and increased litter. Every time this happened environmental degradation got worse. Both industrialists and workers persist in the belief that new technologies will make production greener. In fact, this often does not happen. The only thing that makes the system work is increasing production and disposing of waste elsewhere. Such a system must eventually collapse.

This partly explains why, regardless of the obvious environmental benefits, the economic viability of the CE paradigm is challenged by market dynamics and regulatory inefficiencies that potentially lead to higher production costs (Genovese et al., 2019, p. 95-113). The environmental benefits may be obvious. Companies rely on the need to maintain the economic viability of their operations and investments, while market mechanisms (e.g. price increases for intermediate products, different components supplied by one company to another) can strongly discourage the adoption of CE strategies. Consequently, many researchers question its applicability in free-market and growth-oriented economic systems. Moreover, firms are already capturing most of the economically and technically attractive recycling, remanufacturing and reuse opportunities (for example de Man R, Friege H., 2016, 34, 93-5). This leads them to argue that achieving higher levels of circularity may come at an economic cost that European economies will not be able to cope with especially as companies are already struggling with high and rising resource prices. Indeed, the benefits of recycling materials tend to diminish until a tipping point is reached where recycling may be economically too expensive to provide a net benefit. For example, recycling of bulk materials (e.g. plastics) has not been sufficiently efficient in many European countries that have not invested in efficient infrastructure (Coyle, et al. 2017). Although the marine plastic waste and plastic waste trade have attracted global attention in recent years, the academic community has not paid much attention to it until recently (Śmiechowska, 2019; Zhao et al., 2021).

A third problem with CE is of political nature. It’s been observed that capitalism escapes regulation and tends to expand by removing state capacity to expand through new ways of commodification and appropriation. If this is true, achievement an ideal CE paradigm, would undermine a further expansion of capitalism (and economic growth itself). In addition a technocratic authoritative version of CE, in which resource access are denied to the vast majority of humanity and CE could lead to concentration of capital upgrading means of resources and production capability, more stringent legislation etc. As a consequence, oligopolistic structures could emerge, and control entire value chains. In this sense, the idea of CE could open the door to unexpected dystopian futures.

Policymaking by governments is the first step to creating an enabling environment for the circular transition: minimum percentage of recycled content in materials; setting environmental standards in public contracts; assigning higher weightage to circular suppliers when evaluating bids. Policymakers can encourage creation and encouraging collaboration for innovation activity across sectors by creating conditions for use public funds to encourage private investment (for example technological startups). Governments, through their policies also influence their global trade relations and political partners. (www.thecollective.com/post/four-ways-government-policies-are-accelerating-the-circular-transition? Policymakers can help pave the way towards a world without Covid-19, low-carbon environment and more prosperous future.

According to Hartley and colleagues (Hartley et al. 2020) there are relatively few academic studies on policies that may accelerate a transition towards a circular economy. Authors presents eight recommendations from a product life-cycle perspective that is necessary for a transition towards a circular economy in near future:

1. further adoption of circular design standards and norms (eg. BS 8000) at the EU level,
2. expand circular procurement by the EU and member states,
3. alterations to taxes on CE-based products,
4. liberalization of waste trading,
5. facilitate development of circular trading platforms,
6. creation of eco-industrial parks,
7. circular economy marketing and promotion campaign,
8. global material flow accounting database.

In our opinion those recommendations are mostly fair. However liberalization of waste trading seems to be very risky, especially for underdeveloped and less developed countries. Trade in pollutants can be abused by rich countries by 'exporting' them, which is often the case even in Europe. Development of special trading platforms to strengthen CE with the support of Internet of Things, BigData, Industry 4.0 (eg. Tseng M-L et al. 2018), Marketing 4.0, augmented technology and other tools seems to be very promising.

However recently, Kirchherr and Santen (2019) published a very short text analysing the quantitative and sectoral level of circular economy research (Kirchherr J., van Santen R., 2019). First, they found that economic practice is not interested in the theoretical nuances of circular economics. It expects science to provide knowledge and advice on how to implement CE in practice. Meanwhile, only about 20% of publications contain useful content and advice for business. Slightly more often it promotes information important for policy makers and politicians. Related to this is the observation that in much of the work at the science-industry interface, a small number of businesses are involved. For this reason, the results obtained in this way have limited weight. The cited authors, who are world recognized, state that most of the work on CE is on the manufacturing industry. Only about 9 % is devoted to the service sector. And yet circular economy models include numerous economic activities of a service nature. This applies, for example, to most of the R's in the Morselleto model. One comment also concerns the relatively low representation of research devoted to CE in developing countries. It is also worth mentioning an article, in which the authors present recommendations resulting from interviews conducted in 40 companies that have successfully implemented CE in manufacturing strategy (Galvao et al. 2021). „The results suggest that absolute barriers emerge as an extreme theoretical reference of minor occurrence in practice”. It is normal, that obstracles happen frequently and should be converted into advantage as strategy incorporated into CE business model.

It should also be stressed that there are some conceptual differences between economics, management and social sciences on the one hand and natural and technical sciences on the other, shown as dashed lines in Figure 10. They concern the impossibility of opposing natural forces that prevent the realisation of some important CE postulates.

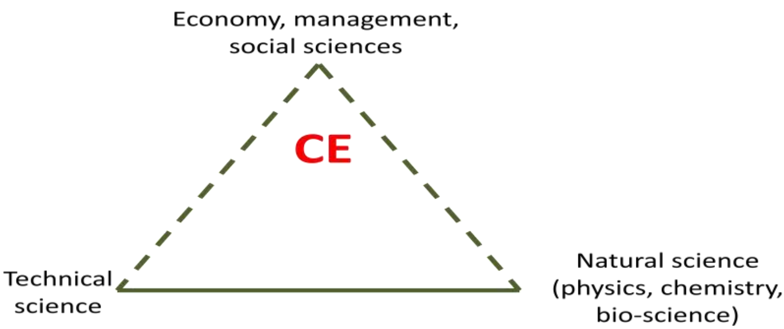

Figure 10. Relationships between actors "on stage" of the circular economy
Source: own drawing. Dashed lines indicate existing differences between the actors.

A circular economy future where waste no longer exists, where material loops are closed, and the products are recycled indefinitely is therefore, in natural science sense, impossible. Every loop around the circle creates dissipation of matter and entropy, attributed to losses in quantity (physical material losses, by-products) and quality (mixing, downgrading). New materials and energy must be injected into any circular material loop, to overcome these dissipative losses. (Cullen, 2017, p. 483). In other words even cyclical systems consume resources and create wastes and emissions (Korhonen et al., 2018a) and the energy required to operate a circular economy (Allwood, 2014).

In the current situation the world should solve the following problems: reduce consumption and demand for material goods, lower the average level of carbon bi-oxide and fight the COVID-19 pandemic.

SUMMARY

The literature on circular economics pays relatively little attention to the views of representatives of other disciplines. The message of CE is to ensure the availability of materials, energy and other resources for economic activity now and in the future. Circular economy requires the introduction of a system of segregation, recovery of all useful materials, parts of equipment, components, etc. However, this generates costs, requires energy and labour, and often involves the use of environmentally harmful technologies.The questions then arise: Is or can the global economy be a circular economy? What are its achievements? What are the obstacles?

Answers were sought mainly in the natural sciences: physical, chemical, biological. Other opinions touching on social and cultural aspects were also taken into account. The implementation of circular economy principles in reality faces numerous obstacles. One of them is the principles of conservation of energy and thermodynamics, the links between matter, energy and biodiversity, which are valid in the universe and in nature. To introduce these problems, the authors have presented the circulation of the most important elements in nature, which has been accurately recognized by science in its innovative development. Therefore, Chapter 4 briefly characterizes the circulation of inorganic and organic materials and the laws of nature governing them. It is noted that the extraction of fossil minerals (metal ores, oil, coal) is increasingly difficult and requires increasing resources. And most of them, once used, are dispersed and cannot be recovered or are transformed into harmful substances (e.g. carbon dioxide, sulphur dioxide, phosphorus compounds and many others).

Other concerns raised in the literature are based on the economic feasibility of CE in the current system of market capitalism, which is the dominant economic model in the European Union. It has been noted that "rapid development and economic growth leads to huge demands on natural resources, and new technologies require increasing energy consumption. The development of urban infrastructure creates heat spots that increase air pollution and degrade the ecosystem. The availability of transport modes (car, plane) increases noise and air pollution. The increased affluence of society in many countries is causing spirals of consumerism, food waste, waste of other goods and an increase in rubbish.

CONCLUSION

Adjustments of economies in linear development to sustainable adjustments face many difficulties or even resistance from the beneficiaries of the status quo. Research shows that the current way of managing the world is causing significant environmental and social damage, often irreversible. In view of this, the future scenarios for a better change and the related management choices are clear. Their implementation will be enforced by societies in their political agendas, business models and supported by changes in the value hierarchy of its members. The non-economic effects of economic activity, i.e. health, social, ethical, psychological and cultural as well as security, are becoming increasingly important for them. Thus, let us note that the primary cause of the need for sustainable development is the unpleasant and intensifying consequences of the hitherto way of managing, resulting from the assumptions of the linear model, and the secondary one is the change in the behaviour of society.

On the basis of a deep study of the literature on the problem, the authors have identified in the presented work the challenges facing science in relation to the circular economy, in the context of the growth of rational management in the future. They presented a model of the circulation of matter and energy in nature, affecting the cycle of life and development. The work has an interdisciplinary character, which is required by the broad concept of sustainable and balanced development and the circular economy.

A future circular economy where there is no more waste, where material loops are closed and products are recycled indefinitely, is therefore, in a natural sense, difficult to realize and perhaps impossible. Each loop around the circle results in dissipation of matter and an increase in entropy, quantitative losses (physical material losses, by-products) and qualitative losses (mixing, lowering of quality). In other words, even cyclic systems consume the resources and energy necessary for a circular economy and create waste and emissions.

In the current situation, the world needs to solve the following problems: reduce consumption and demand for material goods, lower average carbon dioxide levels, and combat the COVID-19 pandemic. The authors show that the circular economy is consistent with the RTZ concept and fits into the European Green Deal.

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