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Circular Economy: Technologies for Circulation

Justina Banioniene, Lina Dagiliene

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Justina Banioniene, Lina Dagiliene
justina.banioniene@ktu.lt, lina.dagiliene@ktu.lt
Kaunas University of Technology, School of Economics and Business, Department of Accounting,
Gedimino st. 50, LT-44239, Kaunas, Lithuania

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Abstract

Research background: Circular economy in the most recent scientific literature and conducted research is recognized as one of the most advanced models of sustainable economic growth, ensuring competitiveness and opening new businesses with the potential to offer long-lasting economic, environmental and social benefits. Investment in technological innovations may be a way to implement the principle of circular economy at micro (company) level. However, there is a gap in the literature in a systemic research of circular economy technology definition and classification of technologies in the context of creating eco-design products and achieving zero-waste production. Thus this theoretical paper provides a contribution to fill this gap.

Purpose of the article: The aim of this theoretical paper is to define the concept of circular economy technology and to classify these technologies.

Methodology/methods: The methods of systemic, comparative and logical scientific literature analysis, constructive research approach were used in the research. This study provides an extensive review of the scientific literature, with the purpose of grasping the concept of circular economy technology at micro (company) level: origins, definitions, classification, modelling of possibilities to gain, adapt or create circular economy technologies for circular economy implementation.

Findings: Results evidence that technologies can be classified into basic technologies and technologies to implement circular economy, and the latter could be separated into technologies for eco-design products and for future manufacturing technologies as been detailed in the paper. This research could be useful for preparing government regulation in order to enable the implementation of circular economy, forecasting the need government investment and the institutional efforts to advise and convince companies towards actions implementing circular economy.

Introduction

Lately the definition of circular economy (CE), CE development and benefit of CE implementation have been widely presented in scientific publications (Ellen MacArthur Foundation, 2012; Lieder & Rashid, 2016, pp. 36-51; Ghisellini et al. 2016, pp.11-32; Murray et al. 2017, pp. 369-380). CE model is presented as the way to ensure economic growth in the next decades and be environmentally sensitive.

Influence of technologies on economic development is analysed in various economic theories such as neoclassical growth theory (Solow, 1957, pp. 312-320), endogenous growth theory (see Romer, 1990, pp. 71-102; Grossman & Helpman, 1991; Aghion &Howitt, 1997, pp. 323-352) and other theories. The technological innovation has been analysed in the economic growth theory as a key stimulus of growth.

Stahel (2016, pp. 435-435), Geng et al. (2012, pp. 216-224) and Jawahir & Bradley (2016, pp. 103-108) emphasize that technologies and technological innovation is a very important condition for CE. The transition from linear to CE might be implemented due to technological progress by increasing resource efficiency, cleaner production and waste recycling.

Still a systemic research on CE technology definition is missing as well as classification of technologies in the context of creating eco-design products and achieving zero-waste production. To fill this gap, the paper seeks to answer the following research question: what is the definition of CE technology and how to classify the technologies in the CE context?

The aim of this theoretical paper is to define the concept of CE technology and to classify these technologies.

This paper is organized as follows. Method of the research is presented in the first part of the paper. The second part presents the literature review of technology definition and classification while the third part presents the literature review of CE concept and definition. Then, the definition of CE technology and classification of CE technology is introduced. Conclusions are drawn based on the identification of the future insights in the last part of this paper.

Method of the Research

The definition of CE technologies was constructed by analyzing terms of CE and technology in scientific literature. The methods of systemic, comparative and logical scientific literature analysis, constructive research approach were used in the research.

A literature review for technologies classification was performed searching the keywords of “circular economy technology”, “circular economy innovation” and combining the keywords of “technology”, “innovation” and “circular economy" on Web of Science and Science Direct databases, among the papers published in the last 15 years.

Also, classification possibilities of technology concept were analysed by looking for universal classification methods, used by international organizations.

Defining and classifying technologies

The concept of CE technology can be defined after the analysis of separate definitions of technology and CE. Firstly, the term of technology is analysed in the literature.

Encyclopædia Britannica (2017) defines technology as "*application of scientific knowledge to the practical aims of human life or, as it is sometimes phrased, to the change and manipulation of the human environment*". The term technology is a combination of the Greek *technē*, "art, craft," with logos, "word, speech". The term embraced a growing range of meanings, processes, and ideas in addition to tools and machines by the early 20th century.

Nowadays the definition of technology has broader meaning. For example, Maskus (2004) defined technology as "*the information necessary to achieve a certain production outcome from a particular means of combining or processing selected inputs. Technologies may be particular production processes, intra-firm organizational structures, management techniques, means of finance, marketing methods or any combination of these*." Whereas, by L. Tihanyi & A. S. Roath (2002, pp. 188-198) the technology is understood as scientific information (patents, inventions, trade secrets), which can be transformed into products. The combination of tangible and intangible technologies let to create production technology/processes that require special knowledge and skills.

Ettlie (2000) defines technology as a set of principles, methods and knowledge incorporated into the products and procedures applied by the company in the production, commercialization and distribution of processes and services, capable of being stored in the human capital, materials, plans, equipment and tools. Ettlie (2000) divided technologies into material (physical objects, equipment and machines) and intangible (knowledge, know how, procedures, methods, experiences).

Moreover, Santos el. at (2009, pp. 3708–3716) refers to technology as a concept that deals with a human labour utilization and knowledge of tools and crafts in a particular area or sector. According Santos et al. (2009, pp. 3708–3716), technology is one of the main tools by which innovation takes place. Existing processes, equipment and knowledge or/and motivation is a background for technological progress in the form of new products or services.

According to R. Adlyte (2014, p. 38), the concept of technology can be separated into three components – resources, required to develop and adapt technologies, processes and products (tangible and intangible technologies). The interaction of these components enables the effectiveness of technology creation and usage. Resources (knowledge, financial, material resources) allow creating innovations (new processes and products). Processes can increase the availability of resources (knowledge and material) and to accelerate the process of product development. Created or adapted innovations (products) affect the resources (knowledge and material) and provide a basis for the improvement of existing processes and the creation of new processes.

According scientific literature, technologies can be classified by various objects as presented in Table 1 (see Table 1).

Table 1. Technology classification by author and type of object

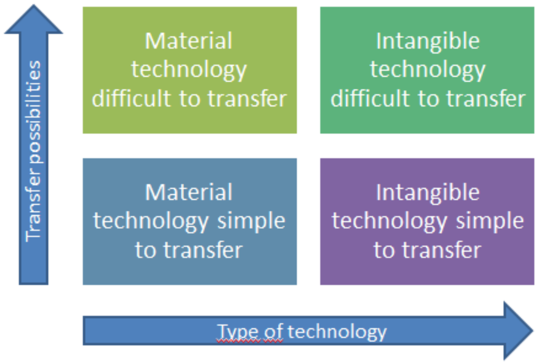
Authors	**Object of classification**	**Technology classification**
Hall and Johnson (1970)	By embodied object	Product-embodied, process-embodied and person-embodied technology
Robock (1980) and Chudson (1971)	By production chain	Product designs, production techniques and managerial functions.
Wahab et al. (2012, pp. 61-71)	By level of prevalence	General, system-specific and company specific technology. General technology includes technical information. System specific technology corresponds to knowledge and know-how. Company specific technology covers the corporate skills and capabilities from general activity and experience of each individual firm.
Dingding et al. (2009, pp. 1943-1947)	By innovation motivation	Interest-driven, market demand, staff impetus, technology condition, market competition and government impetus. Interest-driven, market demand, staff impetus, technology condition factors together have formed the inner impulse. While the pressure of the market competition and the government impetus form the exterior impulse.
Adlyte (2014, p. 38)	By components	Technological resources, technological processes and technological products.
OECD (2011)	By research and development (R&D) intensity in industry sector	High technology industries, medium-high-technology industries, medium-low-technology industries, low-technology industries
Eurostat statistics explained (2017)	By type of innovation in enterprices	Product innovative, process innovative, organization innovative, marketing innovative.

Source: made by authors

In the scientific literature the topic of technology transfer possibilities is relevant. Various authors (such as Radosevic 1999; Lin, 2003, pp. 327-341; Wahab et al. 2012, pp. 61-71; and many others) analyses the concept of technology transfer. According Radosevic (1999) and Wahab et al. (2012, pp. 61-

71), technology as the intangible assets of the firm is rooted in the firms' routines and is not easy to transfer, because of the learning process and additional costs for knowledge transfer. Whereas Lin (2003, pp. 327-341) argue, that the technological learning process is needed to assimilate and internalized the transferred technology. Other technologies as tools and equipment are easier to transfer if there is no specific knowledge related intangible technology installed.

Figure 1. Classification of technologies by difficulty to transfer and by type of technology



Source: made by authors

So, technology can be classified by the difficulty to transfer into technology which is simple to transfer and difficult to transfer. Moreover, this classification can be expanded by dividing these technologies into intangible and material, as presented in Figure 1. Material technologies simple to transfer have simple intangible technologies installed. Whereas, intangible technologies difficult to transfer have specific technological knowledge incorporated and their usage needs additional costs and learning. So, this technology classification is adaptable in the CE, because it is universal classification which can be integrated into other classification system.

Before classifying technologies in CE, the literature review of CE concept is presented to select and ground classification objects.

Circular economy

In this chapter the review of CE concept and CE implementation strategies are presented for the purpose to define the CE technologies and to select additional classification objects.

According Stahel (2016, pp. 435-438), “*bigger-better-faster-safer*” (fashion, emotion, progress) syndrome is the base of linear economy. Linear economy is driven on the principle of "*take, produce, consume and discard*”. Because of this the earth suffer from the growing amount of waste having negative impact on economic stability and the natural ecosystem integration (Ghisellini et al. 2016, pp. 11-32; Geng et al. 2010, pp. 1502-1508, 2012, pp. 216-224; Preston, 2012; Murray et al. 2017, pp. 369-380). Also, the use of natural resources is increasing but some of them are depleting.

The conceptualizations and definitions of CE is analysed by Ellen MacArthur Foundation (2012), Geng et al. (2012, pp. 216-224), Stahel (2016, pp. 435-438), Ghisellini et al. (2016, pp. 11-32), Murray et al. (2017, pp. 369-380), Geissdoerfer et al. (2017, pp. 757-768) and many other researchers.

According Ellen MacArthur Foundation (2012), CE can be introduced as “*an industrial economy that is restorative or regenerative by intension and design*”. One of the latest and comprehensive definitions of CE is defined by Murray et al. (2017, pp. 369-380) as “*an economic model wherein planning, resourcing, procurement, production and reprocessing are designed and managed, as both process and output, to maximize ecosystem functioning and human well-being*”. Geissdoerfer et al. (2017, pp. 757-768) summarized different contributions and stated, that CE is “*a regenerative system in which resource input and waste, emission, and energy leakage are minimised by slowing, closing, and narrowing material and energy loops.*”

CE model can be implemented and evaluated on several levels. Ghisellini et al. (2016, pp. 11-32) argue, that industrial systems (the model works in) can be divided in three levels: company/consumer level; industry level; the region/city/state level.

According Geng et al. (2012, pp. 216-224), businesses play a key role for promoting CE and two strategies can be selected for implementation of CE – eco-design and cleaner production strategies. The aim of these strategies is to improve significantly the eco-efficiency of a company.

Eco-design strategy means, that environmental aspects are incorporated into product or service concept. The lifetime extension and material-cycle closure, minimal use of materials, selection of environmentally compatible materials and less energy consumption are the key elements of eco design products.

The strategy of cleaner production consists of pollution prevention, toxic use reduction and design for environment (Ghisellini et al. 2016, pp. 11-32; Van Berkel et al. 1997, pp. 51-65). Thus, cleaner production strategy has a goal to increase economic efficiency by implementing innovative environment friendly (sustainability) decisions into production processes, products and services.

Li and Su (2012, pp. 1595–1601) measured CE implementation level in industrial sector. Authors proposed a five categories method and evaluated economic development, resources exploiting, pollution reducing, ecological efficiency and development potential. These categories of CE implementation could be used for technology classification.

The aspect of technology and/or innovation in CE is analysed by various authors. Stahel (2016 pp. 435-438) and Geng et al. (2012, pp. 216-224) emphasize that technologies and technological innovation is a very important condition for CE. Charter (2016) argues that one of key lessons to achieve sustainability is to develop technology. Leading companies such as Philips and HP have now developed hierarchies of circularity. So, new technologies need to be created or adapted to address circularity hierarchies. Moreover, Zheng et al. (2011) analysed the key factors influencing technological innovation process, to evaluate the impact it brings in order to explain the industrial structure‘s (such as CE) change. Authors found that the factors of production method, product function and knowledge have an impact for technological innovation process.

The literature analysis on CE and its connections to technology and innovation shows classification objects and key elements for technology definition.

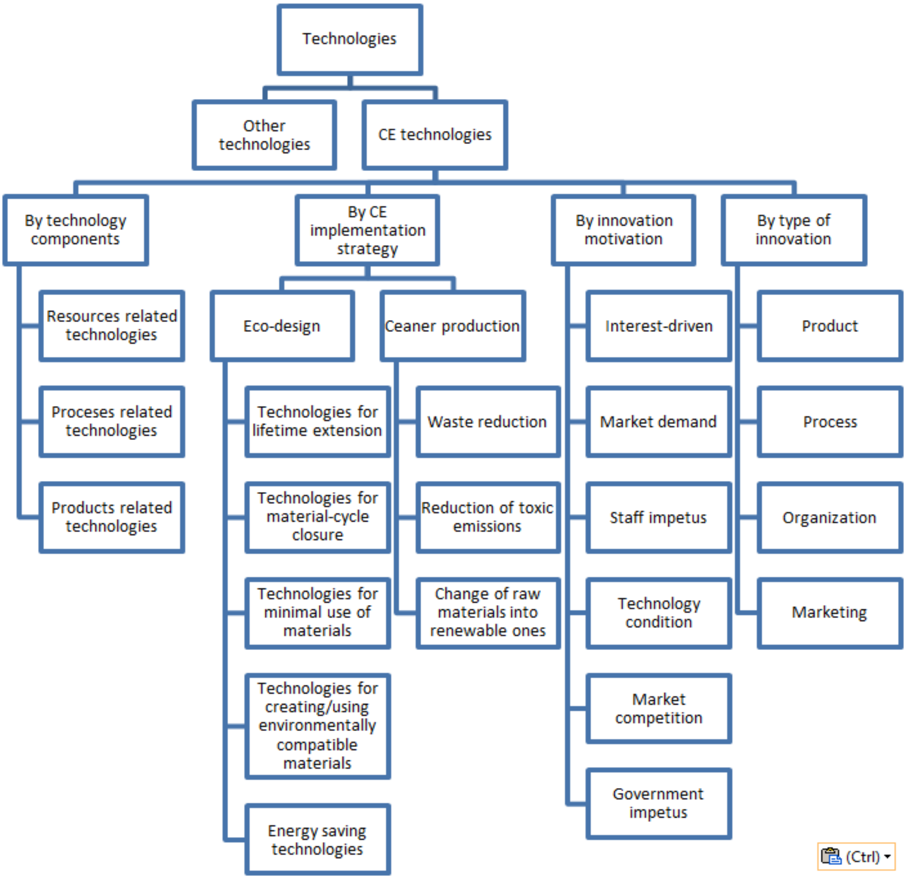
Technology in circular economy

Technology is not only the stimulus of economic growth, but important material and intangible asset, which could be used to create sustainable manufacturing and eco-design products. The definition of CE technology is constructed by logical conjunction of technology definition and aspects of CE.

First definition was constructed from the technology as an asset point of view and was presented in the conference “Sustainable Innovation 2016” (Banioniene & Dagiliene, 2016, pp. 33-39). CE technology was defined as principles, methods and knowledge designed to install CE principles (reduce, reuse, recycle) into the products and procedures applied by the company.

Also, CE technology is technological resources, processes and products used to create sustainable manufacturing, green products and full-cycle-material-flow.

Figure 2. Classification of CE technologies



Source: made by authors

In the context of CE technologies can be divided into CE technologies and other technologies (see Figure 2). Other technologies are technologies used for company's activities indirectly supporting cleaner production and eco-design strategies, or not supporting at all, such as technologies for economic development of a company. We can classify other technologies by technology components, by innovation motivation or by type of innovation as well as CE technologies. But, CE technologies can also be classified by CE implementation strategy into technologies for eco-design products and for future manufacturing technologies.

According Figure 2, all of these classified technologies can be divided into material and intangible, simple/difficult to transfer or by research and development intensity into high/medium-high/medium-low/low technologies.

Conclusions

Various objects of classification are presented in the scientific literature. The universal classification adaptable in the CE and other spheres is dividing technologies by the difficulty to transfer and by type of asset (into intangible and material). Results evidence that technologies can be classified into basic technologies and technologies to implement CE. Also, classification objects in CE can be technology components, innovation motivation, type of innovation and CE strategy (eco-design products and future manufacturing technologies) as been detailed in the paper.

This research could be useful for preparing government regulation in order to enable the implementation of CE, forecasting the need government investment and the institutional efforts to advise and convince companies towards actions implementing CE.

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