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Circular economy – From review of theories and practices to development of implementation tools

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ABSTRACT

The paper provides an overview of the literature on Circular Economy (CE) theoretical approaches, strategies and implementation cases. After analyzing different CE approaches and the underlying principles the paper then proceeds with the main goal of developing tools for CE implementation. Two tools are presented. The first is a CE Strategies Database, which includes 45 CE strategies that are applicable to different parts of the value chain. The second is a CE Implementation Database, which includes over 100 case studies categorized by S*cope*, *Parts of the Value Chain* that are involved, as well as by the used *Strategy* and *Implementation Level*. An analysis of the state of the art in CE implementation is also included in the paper. One of the observations from the analysis is that while such *Parts of the Value Chain* as Recovery/Recycling and Consumption/Use are prominently featured, others, including Manufacturing and Distribution, are rarely involved in CE. On the other hand, the *Implementation Levels* of the used *Strategies* indicate that many market-ready solutions exist already. The *Scope* of current CE implementation considers selected products, materials and sectors, while system changes to economy are rarely suggested. Finally, the CE monitoring methods and suggestions for future development are also discussed in this paper. The analysis of the theoretical approaches can serve as an introduction to CE concept, while the developed tools can be instrumental for designing new CE cases.

1. Introduction

The topic of circular economy (CE) is high on the political agenda and in particular in Europe (EC, 2014a,b, 2015a), it is expected to promote economic growth by creating new businesses and job opportunities, saving materials' cost, dampening price volatility, improving security of supply while at the same time reducing environmental pressures and impacts. It has been estimated that eco-design, waste prevention and reuse can bring net savings for EU businesses of up to EUR 600 billion, while at the same time reduce greenhouse gas emissions. Moreover, the additional measures to increase resource productivity by 30% by 2030 could boost GDP by nearly 1% and also create 2 million additional jobs (EC, 2014a,b). In the UK, it is has been estimated that a circular economy could help generate 50,000 new jobs and €12 billion of investment (ESA, 2013), while in the Netherlands the potential benefits of a circular economy have been estimated to amount to €7.3 billion a year in market values, leading to 54,000 jobs and numerous environmental benefits (TNO, 2013). Following this prospects, the European Commission (EC) and member states governments are developing agendas, policy documents and investment strategies, which will promote circular economy. Recently, the EC proposed the Action Plan for the promotion of circular economy (EC, 2015b). The Dutch government, together with facilitator stakeholders, is currently executing Realization of Acceleration of a Circular Economy (RACE) project launched in 2014, with the goal of making Netherlands a "circular hotspot".

However, we argue that dissemination of the circular economy is hampered because the CE field is currently populated by diverging approaches. Also, no analysis of the available CE implementation strategies and the CE implementation experience have been developed yet, thus, in particular, precluding effective CE implementation and putting the planned CE investments at risk.

This paper aims to address these two challenges. One of the goals is to contribute with an overview of the CE concept as presented in literature that will assist those actors that wish to work in this field in having a more clear definition of CE. Another goal of this paper is to provide tools for CE implementation. The tools consist of CE Strategies Database, containing available CE-enabling strategies, and CE

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implementation Database, containing CE case-studies. Among other possible uses, these cross-referenced databases allow finding a suitable CE strategy for designing new CE cases.

This paper has the following structure: Section 2 (Methods) provides details about the method used for literature selection and analysis and the method for construction of the CE Strategies Database and the CE Implementation Database. Section 3 (Results and Discussion) gives a summary of the studied literature (3.1); provides the CE concept overview (3.1.1); presents CE Strategies Database and CE Implementation Database and their possible use scenarios (3.2); and describes the state of the art in the CE implementation (3.3). Section 4 (Conclusions) summarizes this study's main outcomes and their applications.

2. Method

2.1. Literature review

The literature search has been performed during spring 2015 in Scopus database, Google and Google Scholar using "circular economy" as a keyword in the title, keywords or abstract of the document. The search resulted in collection of both academic and non-academic literature (NGOs and companies' reports, policy documents, etc.). Please see Section 2.3 Limitations for description of possible implications of the search boundaries applied in this study.

A screening of the literature has been performed directly during the search by reading the abstracts and discarding the documents where circular economy has not been the main topic. An example of such discarded document was where authors claimed that the described study may contribute to a circular economy, while the main topic has been technical development of a recycling method for a certain material. The selected for the review 118 documents have been categorized into four main categories depending on their content: Theory, Policy, Case Studies and Practice (Table 1). Theory category contains documents discussing the CE concept; Policy category contains legislative and other policy documents; Case Studies contain research and development studies, which have not yet been implemented in the market, e.g. academic studies while the Practice category includes implementations that are already in the market. Different categories of literature have been used towards two goals of this paper. Literature from all the categories has been used to develop the CE Database, literature from the Theory and Policy categories are discussed in the CE concept review, while literature from the Case Studies and Practice categories has been used to develop the CE Implementation Database. References to the reviewed literature, by category, can be found in Table 1. It should be noted, that Table 1 doesn't include fourteen supporting literature documents that describe related to CE concepts, such as: cradle to cradle, performance economy, life-cycle assessment, matter out of space, planetary boundaries, material flow accounting and extended producer responsibility, informal recycling sector challenge in the developing countries. The supporting literature doesn't contain "circular economy" as a keyword and is therefore omitted from the literature review.

2.2. Development of the CE strategies database and the CE implementation database

Strategies for the CE Strategies Database have been collected from all the reviewed literature (see Table 1). The following definition of a strategy has been used for extraction of information from the documents: "a method worked out in advance for achieving some objective, the means or procedure for doing something" (Merriam-Webster, 2017). Definitions for the strategies were composed by the authors based on the descriptions in the original documents or through synthesis of definitions from different sources identified by google search.

Fig. 1, contains a possible CE value chain, where the parts of the

value chain are designated by numbers 1–9. The CE value chain is distinguished by a closed loop of material flow and is driven by renewable energy. There are several possibilities for materials to circulate in tight loops. One is a loop through Sharing inside node 5 (Consumption and Use). Other possibilities are through Re-manufacture, Node 8 or through Circular Inputs, Node 9. Circular Inputs are resource inputs or, in general, materials that last for longer than a single life-cycle and can easily be regenerated.

The CE Strategies Toolbox has been arranged in correspondence with the parts of the CE value chain (Fig. 1). The strategies are indexed by two numbers, the first one is the part of the value chain that is addressed and second is the strategy sequence number when the strategies are ordered alphabetically. Such indexing allows easier data handling and cross-referencing. For instance, strategy 1.25 Material Substitution corresponds to Materials Sourcing that is 1st part in the value chain and 25th in the alphabetically ordered strategies list.

The CE implementation cases have been assembled from the literature in the categories Case Studies and Practice in Table 1. For each case study, a suitable strategy from the CE Strategies Database was matched. In the event a strategy used in the case study was missing in the CE Strategies Database, it has been defined and added to the CE Strategies Database. The CE implementation cases have then been systematized into the CE Implementation Database following a new developed classification, see Section 3.2 for details. One of the categories in this classification is the strategy number and name, and another is the part of the value chain. The CE Strategies Database and the CE Implementation Database are therefore cross-referenced through the strategy number/name as well as the addressed part of the value chain.

It should be noted, that no screening has been performed either for the strategies nor the case studies, i.e. all the strategies and all the cases that were found in the reviewed literature are presented. Therefore, no judgment regarding the type of the source (for example internet article, academic paper or an NGO report) or of the case study (what is the agenda behind the case, what is the effect etc.) has been made. Each strategy was assigned to the suitable part of the value chain, unequivocally. Case studies classification is also straightforward: by the Scope of CE (system, sector, product, material or substance) and by Implementation Level (Plan/Policy, R&D or Market Implementation). Within some of the case studies, multiple strategies have been employed. These case studies are reported multiple times, for all the suitable strategies.

The entire population of the case studies has also been used to show a state of the art of CE implementation (the CE Implementation Scene, see Section 3.3 and Fig. 2). The number of case studies for each of the classification categories has been plotted, also indexed by the strategy number employed in each case. In particular, the case studies were plotted regarding the CE Scope – system, sector, product, material or substance, as well as according to the Part of the Value Chain and the Implementation Level (Plan/Policy, R&D or Market Implementation). These plots show a snapshot of the CE implementation within the boundaries of the literature search in this paper and the resulting CE Implementation Scene is therefore not comprehensive.

2.3. Limitations

The literature search has been bounded by the keyword "circular economy" being present in the title, keywords or an abstract of the document. Different terminology may be used for the concepts similar to CE, among them "closed loop economy" and "zero waste economy". In addition, CE appropriates knowledge from several other environmental and engineering fields and suitable strategies and case studies may be contained in documents related to other concepts, such as "green supply chain management", "performance economy", "cradle to cradle", "industrial symbiosis" etc. However, it was chosen not to include similar concepts and other terms possibly used for CE as the keywords for the literature search. This is because branding the content