Circular Economic Modelling: Barriers and opportunities in turning circular within the construction sector

Birgitte Holt Andersen [1*], and *Anastasija* Komkova[2]

[1]CWARE ApS., BLOXHUB, Copenhagen, Denmark
[2]ETH Zurich, Chair of Sustainable Construction, Department Civil, Environmental and Geomatic Engineering, Switzerland

Abstract. Drawing on the findings and insights from two on-going research projects - WOOL2LOOP and URBCON, we have developed a model to assess the circular economic potential while using secondary raw materials (SRMs) to substitute OPC (Ordinary Portland cement) partly or fully within the building materials and construction industry. Applying our Circular Economy model (CEM), we have assessed the business case at each step of the value circle from sourcing, pre-treatment, production, and sales. At each step we describe the baseline, intervention, costs, and benefit flows identified as a result of introducing intervention. Furthermore, we assess the externalities and identify potential barriers preventing the business case to un-fold. While WOOL2LOOP focus on the usage of mineral wool waste, URBCON has a broader scope on different industrial residuals and waste streams suitable to produce geopolymer cement. Our analysis shows that pre-treatment costs of the various SRMs, future supply and geographical availability of SRMs, constitute critical factors to the overall business case for using SRMs. On the demand side, the main critical factors identified relate to building standards and resistance to change within the construction sector itself. However, there are also very strong macro trends encouraging for different reasons the various stakeholders to shift towards climate-neutral production and consumption. The paper concludes by discussing different scenarios for the evolution of new value chains and industry structures likely to happen in a 'perfect' circular economy reality.

1 Introduction

The circular economy concept has become 'mainstream' and a driving policy agenda both within the corporate domain, cities, regions, and countries [1–3]. There are two main reasons for this urgency. The first and most acknowledged in the public debate is the rush to cut Greenhouse Gas (GHG) emissions to keep global warming to 1.5ºC by 2050 [4]. The other reason, equally important but less often recognised, is the need to reduce depletion of natural resources. While the Paris agreement has made countries to agree on reduction of GHG emissions [5], there are no similar agreements in place to ensure a sustainable consumption

* Corresponding author: bgha@cware.eu

of natural resources. Global use of material resources has tripled since 1970 and accounts for 90% of biodiversity loss and 50% and GHG emissions [6].

We are currently consuming nearly double quantity of natural resources compared to what our earth can regenerate [7] . In the western part of the world the situation is even more extreme, the US uses 5 times the Earth's ecological resources and many countries in the EU up to 3 times the Earth's resources [8]. The material footprint which is the total amount of raw materials used to meet consumption demand has increased dramatically over the past years [9]. Of utmost importance for the construction and building industry, is the consumption of virgin minerals (e.g., sand, gravel, limestone), which are used in cement and concrete production. While there exist global reserves of natural aggregates, the local criticality of these resources is associated with supply risk and can lead to scarcity of supply in the future [10]. Furthermore, the production of conventional cement is CO_2 intensive, contributing nearly 7% to global GHG emissions [11]. Therefore, there is growing demand for less carbon intensive alternative materials from within the building and construction industry.

Several policy incentives, including European Green Deal are targeting to improve resource efficiency and to reduce CO_2 emissions [12]. Multiple research project supported by European Commission aim to investigate the use of waste materials in construction sector. Both the WOOL2LOOP [13] project and the URBCON [14] project are aiming at developing low-carbon concrete by applying geopolymer technology and using suitable industrial waste streams. The geopolymer technology allows to use industrial by-products and waste materials as alumini-silicate sources being activated with soluble alkaline solutions to produce binders with similar to OPC cement properties [15]. In WOOL2LOOP the focus is on exploring potential of mineral wool waste as precursor, while in URBCON several types of secondary raw materials (SRM) are used including recycled aggregates.

A number of macro trends, other than policy incentives as presented above, can be observed, likely to have a positive impact on the demand for low-carbon building and construction materials:

- Scarcity of critical raw materials [16]
- Increasing prices and CO_2 taxes on virgin materials [17]
- Extreme climate events are increasingly raising public awareness [18]
- High media attention on climate
- Increasing demand for carbon neutral products within the construction sector [19]
- Ambitious climate targets from the corporate world and increasing attention on securing supply chains [20]

In this study, we have applied our Circular Economic Model (CEM) that was developed in the context of the URBCON and WOOL2LOOP projects. The aim is to assess the business case at each level of the value circle. Furthermore, we examine the barriers and opportunities that emerge at each level of the value circle. We discuss how policy drivers and the observed macro trends are likely to impact the evolution of new value chains. The paper is based on preliminary findings as the projects Wool2Loop and URBCON still are on-going at the moment of this publication.

2 Methods

The Circular Economic Model (CEM) follows the stages of material's life cycle as the basis for describing the value chain in a circular economy context. The aim of the CEM is to understand the business case at each level of the value circle. We have conducted interviews

 https://doi.org/10.1051/e3sconf/202234901009

with stakeholders along the value circle and based on their narratives, available data and statistics analysed the baseline or business as usual scenario, the impacts of interventions, estimated costs and benefit flows, identified externalities and finally identified barriers and opportunities at each level of the value chain [16]. At this stage, we have completed the first four phases of CEM (steps 1 to 4 in Fig. 1).

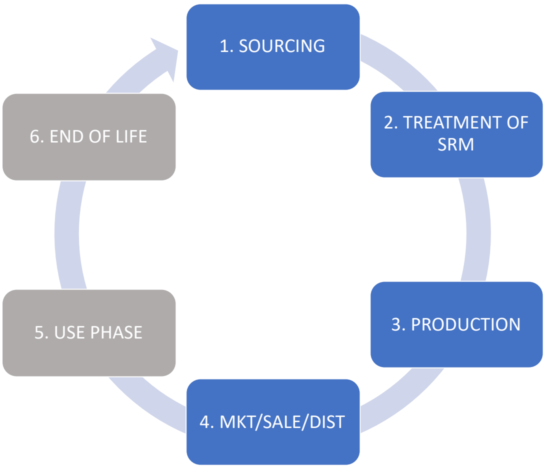

Fig. 1. Circular Economic Model (CEM).

3 Results

We have applied CEM in WOOL2LOOP and URBCON projects. The barriers and opportunities as have been observed at each level of the value circle from sourcing to Marketing & Sales are summarised in Table 1. Fortunately, most of the barriers observed are typical for emerging markets, e.g., lack of adequate infrastructure for collecting SRMs and a fragmented market for SRMs. Other barriers will require further public or private investments to overcome, including the development of new technologies for treating the 'waste' to make it clean and ready to be used a precursor in geopolymers, e.g., pyrolysis technology to remove heavy metals from ashes or separating composite materials. On the other hand, at each level of the value circle, there are also many business opportunities as well as huge societal-economic benefits to be gained.

Table 1. Barriers and opportunities on the way towards circularity.

	BARRIERS	OPPORTUNITIES
SOURCING	• Lack of infrastructure for collecting of SRM • Lack of procedures for separation of different waste streams • Pre-demolition audit is only standard practices in some countries • Fragmented market for SRM	• Saving landfilling cost of min 100EUR pr ton waste • Business opportunities in creating new markets for SRM • Environmental savings (landfill deviation,) • Saving virgin raw materials/mat footprint
PRE-TREATMENT	• Costs of pre-treatment of SRMs relatively high (at least at smaller scales) • CAPEX in pre-treatment equipment relatively high • Technology treatments still not at sufficient TRL • Composite waste/contaminated waste	• Business opportunities in creating new SRM markets, e.g. for waste mngt actors, or raw material suppliers • R&D opportunities to tackle treatment issues • Positive Environmental/circularity impacts
PRODUCTION	• Investments (time and resources) into product development • Technical challenges at production line • Investments into new equipment, dosing systems, or production lines • Uncertainty of future supply of SRM	• Some waste streams/cut offs can be re-used in production instead of going to deposit • Ambitions of reaching carbon neutrality in 2050 • Recirculation of own products
MKT/SALES	• Uncertainty about Price competitiveness of new 'green' products • Difficulties in obtaining product approvals due to the use of 'waste' • Sales department critical • Low costs of OPC and virgin materials (sand and gravel) at least for now • Procurement procedures do not always consider green alternatives	• Increasing demand for low carbon building materials • Potential higher margins on carbon neutral products • Creating a competitive edge *Source:* *Findings from Wool2Loop and URBCON*

4 Discussion

Based on the macro trends listed above, and of particular importance for the construction and building industry, several scenarios of evolution of new value chains can be described (Fig. 2). We can assume that in the future, the local sourcing of materials will become of greater importance, due to reduced transportation distances and associated emissions, as well as minimisation of supply chain risks. Moreover, the circularity of materials will increase, thereby decreasing CO_2 emissions to achieve carbon neutrality and reduce material footprints. Furthermore, the share of low-carbon products in the markets will substantially expand due to increased producers' social responsibility and higher demand from the customers. Such shifts in market behaviour are likely to have a significant impact on the competitive structure within the construction and building industry [16] as this is likely to result in shorter and more local (domestic or regional) and more diversified value chains and final products. The local context and availability of secondary raw materials will results in local solutions driven also by the need to take advantage of local industrial symbiosis. The time of 'one-size-fits-all' will come to an end.

Fig. 2. Scenarios for evolution of new value chain.

5 Conclusions

In this study, we reported the preliminary findings from the ongoing projects Wool2Loop and URBCON. While certain barriers exist, examined opportunities associated with the use of SRM in geopolymer concrete production indicate a positive outlook for this technology to be adapted within industrial symbioses. Future research will explore further the subject of barriers and opportunities for the transition towards a circular economy within the construction and building industry. Further value chain scenarios will be examined, and relevant circularity indicators will be developed following the progress of URBCON and WOOL2LOOP projects

References

1. Ellen MacArthur Foundation, *Circular Economy Towards the Economic and Business Rationale for an Accelerated Transition* (2013)
2. J. Kirchherr, D. Reike, and M. Hekkert, Resour. Conserv. Recycl. **127**, 221 (2017)
3. P. Ghisellini, C. Cialani, and S. Ulgiati, J. Clean. Prod. **114**, 11 (2016)
4. IPCC, Ipcc - Sr15 **2**, 17 (2018)
5. J. Rogelj, M. den Elzen, N. Höhne, T. Fransen, H. Fekete, H. Winkler, R. Schaeffer, F. Sha, K. Riahi, and M. Meinshausen, Nat. 2016 5347609 **534**, 631 (2016)
6. UNEP, *Building Back Better with Natural Resources* (2021)
7. WWF, *Living Planet Report 2018: Aiming Higher* (2018)
8. Global Footprint Network, National Footprint Accounts, 2016 Edition (2016)
9. T. O. Wiedmann, H. Schandl, M. Lenzen, D. Moran, S. Suh, J. West, and K. Kanemoto, Proc. Natl. Acad. Sci. U. S. A. **112**, 6271 (2015)
10. D. Ioannidou, G. Meylan, G. Sonnemann, and G. Habert, Resour. Conserv. Recycl. **126**, 25 (2017)
11. IEA, *Energy Technology Perspectives 2020* (2021)
12. European Commission, Communication from the Commission. The European Green Deal (2019)
13. WOOL2LOOP Homepage, https://www.wool2loop.eu/en/

14. URBCON - By-Products for Sustainable Concrete in the Urban Environment | Interreg NWE, https://www.nweurope.eu/projects/project-search/urbcon-by-products-for-sustainable-concrete-in-the-urban-environment/
15. J. L. Provis and S. A. Bernal, Annu. Rev. Mater. Res. **44**, 299 (2014)
16. European Commission, https://ec.europa.eu/growth/sectors/raw-materials/areas-specific-interest/critical-raw-materials_en
17. T. Bauer, FIEC Letter to EU Commission-Price increase construction materials (2021)
18 World Economic Forum, *The Global Risks Report 2022 17th Edition* (2022)
19. Wool2Loop project, *Survey among industrial partners in Wool2Loop D3.6* (2022)
20. Saint Gobain, *Saint-Gobain carbon neutrality: leading towards sustainable Building and Industry* (2020)
21. M. E. Porter, Harv.Bus. Rev. **86**, 25 (2008)