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CONDITIONS OF INTRODUCING CIRCULAR BUSINESS MODELS INTO CRAFT BREWERIES – LCA APPROACH

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Purpose: The objective of the paper is to assess the craft breweries sector with regard to the possibilities of introducing circular economy solutions and especially circular business models.
Design/methodology/approach: The assessment is made with life cycle assessment (LCA) method for single specific case of a craft brewery but the interpretation and conclusions are referred to the whole sector. The approach here is to focus on specific case of existing craft brewery and use its primary data to assess its regular business model and to compare it with possible circular business model (CBM).
Findings: According to the assessment of life cycle stages, the dominating role of internal factors in decision making towards CBM is a feature of production process only. All the other stages require strong commitment of external actors, especially while cultivation processes, packaging production and distribution are concerned. The decision of a single craft brewery itself has rather limited contribution to CBM requirements.
Research limitations/implications: The important limitation of this research is related to the economic outcome of CBM oriented changes that are not considered here. Probably, the decision making process would be much more susceptible to the economic constrains and should be considered once again with regard to current market opportunities of any decision making unit.
Practical implications: Certainly turning into CBM requires wide cooperation with different stakeholders, both from the down and upstream processing. It seems that the only solution is to build up a network of organizations, both from craft brewing industry and from other industries that could use its waste as a secondary raw material, in order to close down the open loops.
Originality/value: The results of the research provide meaningful insight into business circularity issue from the perspective of craft breweries. The results show that small scale of craft breweries operations might be a significant factor determining the possible way towards CBM.

Keywords: circular economy, circular business models, craft breweries, environmental life cycle assessment (LCA).

Category of the paper: Case study.

1. Craft breweries within the economy of circularity

Global economy is nowadays strongly directed towards circularity through legislation and regulation, economic incentives and innovation and conceptual support. The challenge though, is not only to accomplish it in a technical or organizational sense but also to reach it in both economically and environmentally sound manner. The challenge is imposed to all economic sectors as well as consumers and their habits. From the perspective of beer production sector, the circularity challenge should be referred to cultivation of beer relevant crops, malting and brewing processes, distribution modes and practices and consumption patterns, especially with regard to the packing.

Circular economy (CE) refers to the synchronization of forward and backward flows of goods and materials in a way to support the closure of all the loops, through application of different processes, such as reuse, repair and refurbishment, remanufacturing and recycling (EMF, 2013; Zink, Geyer, 2017). CE aims to minimize input materials from fossil or non-renewable sources in a production system and maximize the reuse of these materials within the same system aiming at the elimination of waste streams (Barros, Salvador, de Francisco, Piekarski, 2020; Korhonen, Nuur, Feldmann, Birkie, 2018). CE practices can offer opportunities for reducing emissions and waste generation in all the sectors, including agricultural sector through the circulation of raw materials, agricultural waste, and manure (Jurgilevich et al., 2016). Agricultural sector has by far the biggest potential of developing CE solutions (Barros et al., 2020).

Proposed CE solutions should be also due to environmental, economic or social monitoring that would be capable of not only measuring the degree of circularity of a system but also the extent to which circularity enables the achievement of sustainability goals (Helander et al., 2019). It seems that only by adapting systems perspective CE monitoring could contribute to the identification of the relationship between circular and environmental, economic or social indicators (Rufí-Salís, et al., 2021). Many researchers, accepts a life cycle approach as a systematic evaluation of the environmental impacts and benefits resulting from the implementation of circular strategies in different life cycle stages of a product, system or service (Haupt, Zschokke, 2017; Niero, Kalbar, 2019; Pauliuk, 2018; Sauvé, Bernard, Sloan, 2016). Additionally, life cycle approach could contribute to the detection of cases where circularity does not necessarily result in reduced environmental impact (Niero, Kalbar, 2019). It is also not clear how CE mainstreaming refers to the implementation of sustainability priorities, which represent much wider and more holistic approach towards the development of human kind. The interrelation between sustainability and circularity tends to be treated as a strategic vs. operational approaches, where sustainability is treated as a strategic goals, while circularity as one of the tools to implement it (Harris, Martin, Diener, 2021; Nitkiewicz, 2021).

If we take a closer look at the implementation process of CE we could refer to its key elements (physical changes) and enablers (mental changes). Key elements could be defined as (1) prioritize regenerative resources, (2) use a waste as a resource and (3) stretch the lifetime, while enabling factors are (a) rethink the business model, (b) team up to create joint value, (c) strengthen and advance knowledge, (d) design for future and € incorporate digital technology (Goodwin Brown et al., 2021).

Figure 1 presents the conceptualization of five circular business models as proposed by Lacy et al. (2014). All of proposed variants are at least partially appropriate for craft beer manufacturing. Circular Supplies BM are referring mainly to the cultivation of different types of cereals and hops for beer production, as well as, for beer packaging policy. Resource Recovery BM is most useful while grain and packaging waste is concerned. BM of Product Life Cycle Extension and Sharing Platforms have a very limited usefulness with regard to craft brewing process, with some extension to multiple use kegs, providing its repair and refurbishing systems or sharing production and bottling capabilities between different actors. Finally, Product as a Service BM could be based on switching to serving without packaging system.

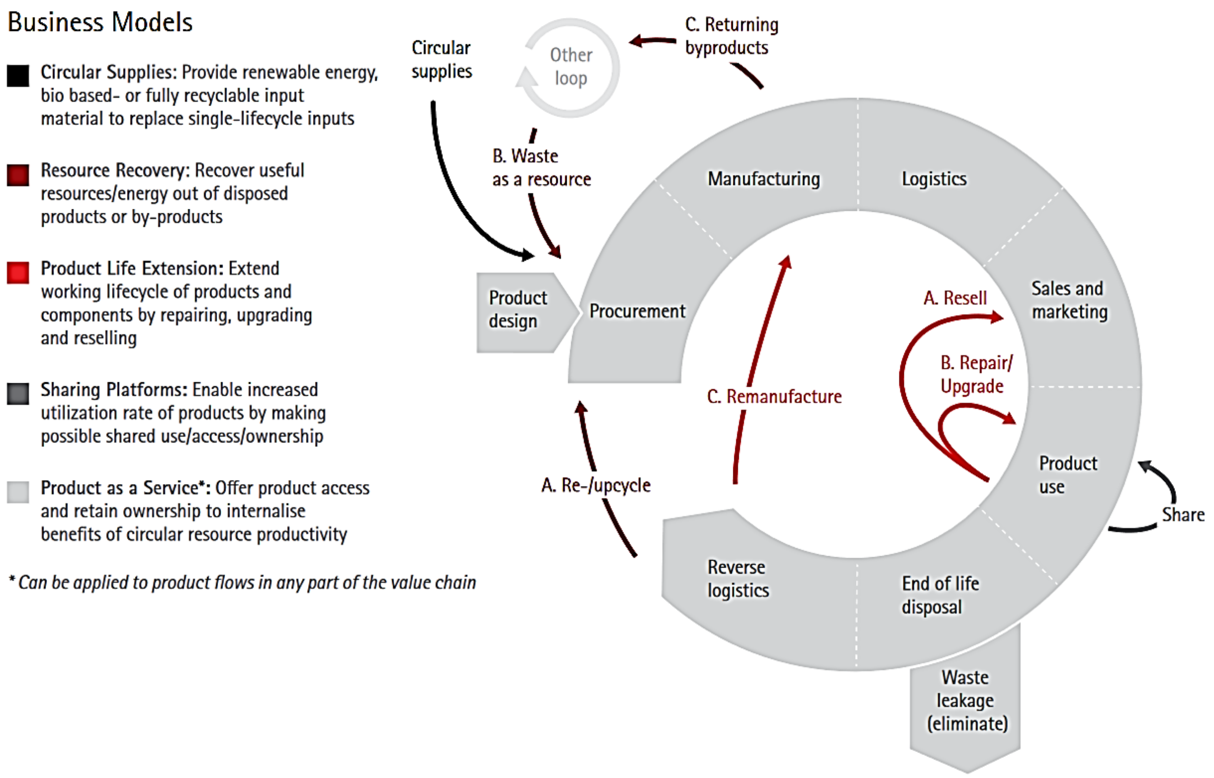

Figure 1. The five circular business models (Lacy et al., 2014).

It seems that the introduction of the circular economy on the ground of brewing industry is very much related to the reduction or elimination of industrial waste, which can enable new circular value propositions and biomass valorization in small breweries' value chains (Bonato, Augusto de Jesus Pacheco, Schwengber ten Caten, Caro, 2022). The approach that could be useful here is a life cycle originating cradle-to-cradle strategy that could assist breweries in implementing circular solutions (Braungart, McDonough, Bollinger, 2007; Niero, Negrelli, Hoffmeyer, Olsen, Birkved, 2016), eventually bringing the benefits for the society (de Pauw, Karana, Kandachar, Poppelaars, 2014).

The studies within the scope of assessment of brewing industry environmental impact and circularity potential have used quite different approaches and focuses. Rajaniemi et al. (2011) have focused on the cultivation process of different types of inputs for brewing process and showed significant differences in environmental impacts between feedstock types. Another process that is assessed to have the highest contribution is packaging and its influence on distribution system (Koroneos et al., 2005; Cordella et al., 2008; Cimini et al., 2016). The different types of beer are also under investigation concerning the environmental impacts. The studies are showing significant differences between the share of brewing processes within overall impacts while different types of beer are concerned (Amienyo, Azapagic, 2016; De Marco, Miranda, Riemma, Iannone, 2016). The brewing stage has been found to be a relatively minor contributor to the overall environmental impacts of beer life cycle (Amienyo, Azapagic, 2016; Cimini, Moresi, 2016) and it is yet confirmed that this is also the case for small scale beer producers that do not have the large scale production volumes (Morgan, Styles, Lane, 2021, 2022).

The objective of the paper is to assess the craft breweries sector with regard to the possibilities of introducing circular economy solutions and especially circular business models. The perspective of the assessment is twofold and consist of decision making process and environmental soundness of possible actions. The craft brewing entity is defined in a way to underline the differences between craft and industrial brewery. The term “craft brewery” is defined as smaller and independent firm that deploy traditional production processes (as opposed to the industrial practices of large scale breweries); emphasize quality, flavor, and diversity; and produce limited quantities (Gatrell, Reid, Steiger, 2018; Gómez-Corona, Escalona-Buendía, García, Chollet, Valentin, 2016; Hieronymus, 2015). The assessment is made with life cycle assessment method for single specific case of a craft brewery but the interpretation and conclusions are referred to the whole sector.

2. Methods

Life Cycle Assessment (LCA) is very well suited method to assess the environmental impacts of sustainability and CE strategies. LCA is a science-based technique for assessing the environmental impacts associated with entire product life cycles, which can provide technical support to decision-makers. LCA procedure enables the assessment of environmental impacts and its trade-offs and may also be applied to identify the most promising CE strategies and options for improving the environmental performance of society's consumption and production patterns (Pena et al., 2020).

In order to support CE decisions, methods for assessing and quantifying the environmental benefits of CE strategies, such as LCA, are thus increasingly challenged by the need to reflect the systemic context of an organization (Schulz, et al., 2020).

Life Cycle Assessment (LCA) is a science-based technique for assessing the environmental impacts associated with entire product life cycles, processes and organizations, which can provide technical support to decision-makers. LCA as a methodological framework seems to be perfectly suited to assess the circular economy solutions as well as circular business models from the perspective of environmental aspects. LCA procedure enables the assessment of environmental impacts and its trade-offs and may also be applied to identify the most promising CBM and options for improving the environmental performance of society's consumption and production patterns (Pena et al., 2020).

In order to support CE development, such methods as LCA are increasingly challenged by the need to reflect the systemic context of an organization (Schulz et al., 2020). LCA finds its multiple uses within food and agricultural sectors, which also includes breweries and its supply chains and operations. There are many studies within the literature that apply LCA for the assessment within different scopes and context. From the perspective of breweries it is important to mention more general holistic approaches (Morgan et al., 2021) or approaches that are focusing on final stage of the beer life cycle (Ashraf, Ramamurthy, Rene, 2021; Bonato et al., 2022) or beer packaging specifically (Morgan et al., 2022).

Since the issue of CE is not only focused on environmental aspects the use of LCA and its scope should be considered as an element of a wider, decision support system. According to Wernet et al. (2016) the allocation of specific end-of-life and side flows, which are directed towards other life cycles, would be a critical issue in CE solutions assessments. Therefore, the combination of "cradle to cradle" definition of system boundaries with small scale consequential approach is the best possible, and very often the only feasible coverage for circular solutions.

2.1. Goal and scope definition

Since the objective of the paper is to assess the craft breweries sector with regard to the possibilities of introducing circular business models the main goal of LCA use is to assess the ecological aspects of such a change. Therefore, the assessment has comparative orientation and shows the possible changes within environmental impacts while CBM is introduced. The approach of the assessment is based on LCA screening and encompasses "cradle-to-cradle" life cycle perspective. The functional unit for the assessment is defined as life cycle of a yearly production of 85 000 liters of craft beer within two scenarios: 1) regular and 2) circular. The basic assumptions of material flows within life cycles, including key differences between the scenarios, are presented at Figure 2 and Figure 3. Black colored arrows represent downstream processing of a craft beer while red and turquoise color represent waste and revers flows respectively. Straight line arrows symbolize flows directly related to the craft beer manufacturing while dotted arrows symbolize indirectly related flows.

The major difference between the scenarios is related to the allocation of the end-of-life processes and side flows. In regular business model scenario (RBM) the "cut-off" rule is used and end-of-life processes and side flows, which are not further affiliated to the craft beer manufacturing process are excluded from the assessment (Figure 2). This is regular practice with LCA, where side processes as a whole cannot be attributed to the primary production. For example spent grain comes out of the craft beer manufacturing process and it is not investigated further concerning its possible processing but is considered as a generic waste stream.

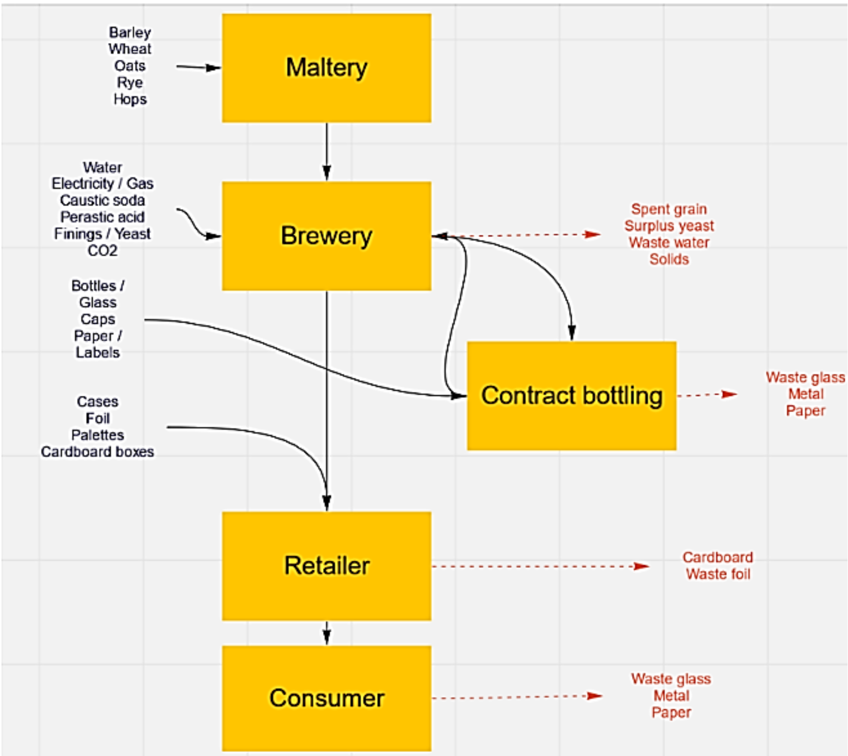

Figure 2. Regular business model scenario of craft beer life cycle.

In circular business model scenario (CBM) the assumption is made that all the flows are totally or partially attributed to the craft beer manufacturing process (Figure 3). All the flows are tracked to the point of its final fate, which is assumed to be recapture of its value and bringing them to the status of usable resources or energy. The CBM takes into account both kinds of contributions: positive environmental impacts related to recovering of the resources (avoided impacts) and negative impacts related to their processing, which is necessary to recover its value. In general, the implementation of circular business model within craft brewery should lead to directing all of the waste flows towards its recovery. The possible treatments and processing of a brewery originating waste flows are very diversified and numerous. Therefore, only the most common treatment with regard to the biggest flows is considered here.

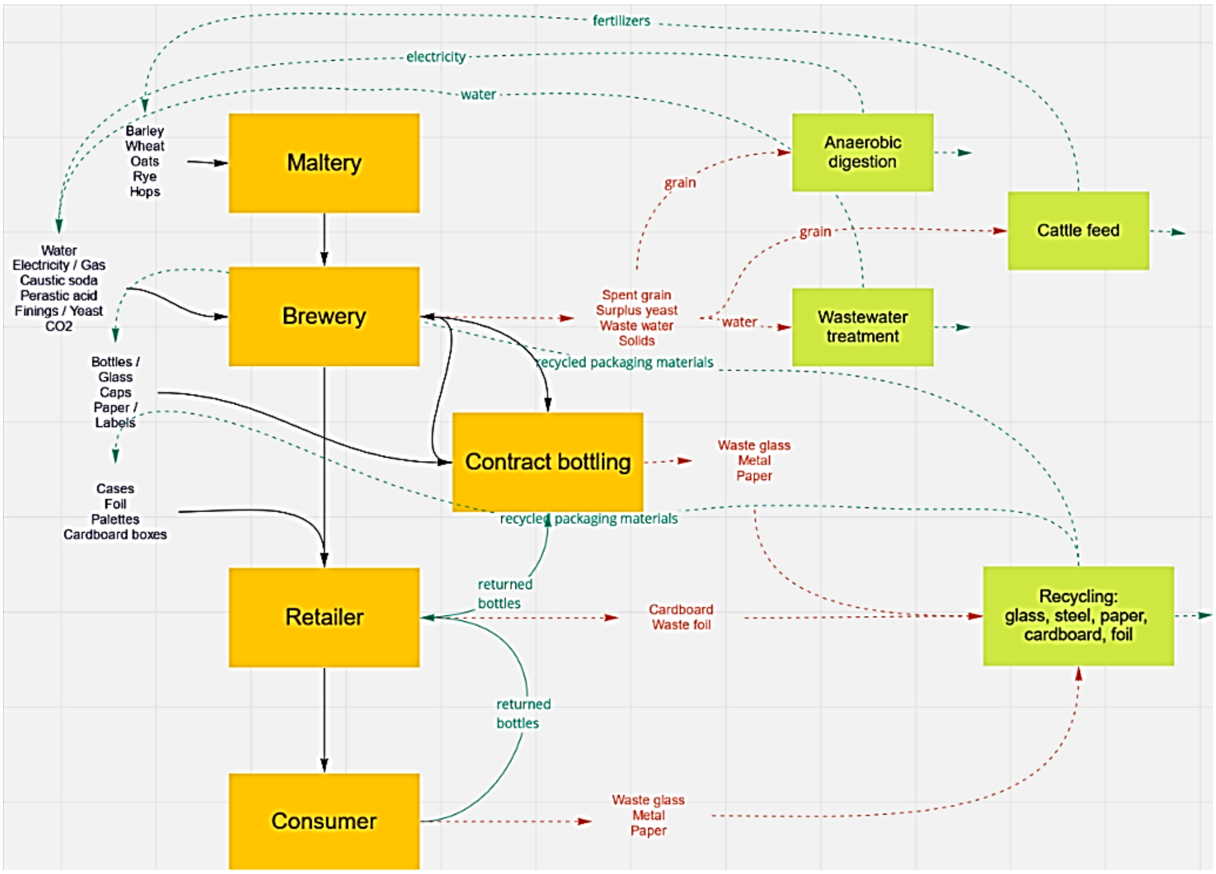

Figure 3. Circular business model scenario of craft beer life cycle.

The difference between the scenarios is visible on the level and type of open flows. In RS the open flows relate to the waste streams or potential secondary material but not processed to serve as one. On the other hand, CS has all the waste flows returned into the functional unit life cycle or to other life cycles as a ready secondary material. The returned flows are not too numerous while craft beer manufacturing process is concerned. It could be a wastewater treatment system, leading to the recovery of water used in brewing process, or packaging, like returnable bottles, that could fulfil its function several times. Most of the waste flow could be recovered but within different life cycle systems, contributing eventually to the original one (i.e. energy produced out of anaerobic digestion could feed the brewing process). While craft breweries are concerned, the scale of operations could be an organizational and economic obstacle in using this reverse flows directly.

The comparison of the two scenarios will bring out the differences in environmental impacts and its potential reasons.

2.2. Life cycle inventory

The analysis of material, energy and waste flows within considered life cycle is based on primary data from a single craft brewery. Primary data covers the brewing process, the distances and means of transport within supply and distribution chains and share of returned flows and recycled materials. All the flows related to the supply, end-of-life treatment and recovery rates are modelled with secondary data from the literature and ecoinvent 3 database. Table 1 presents the inventory data for both scenarios included in the study.

Table 1.
Inventory for craft beer regular life cycle

Specification	Unit	Quantity
Outcome		
Beer	l	85000
Resources		
Water	l	430000
Materials/fuels		
Natural gas, high pressure	m3	83,6077
Heavy fuel oil	kg	0,42075
Biogas, from grass	m3	14,5146
Natural gas, low pressure	m3	4,1837
Diesel	kg	0,12155
Ammonia, liquid	kg	0,6477
Phosphorous chloride	kg	0,000357
Barley grain	kg	15980
Hop, organic, intensive	kg	136
Fodder yeast	kg	50
Ethoxylated alcohol (AE11)	kg	68
Chlorosulfonic acid	kg	25,5
Propyl amine	kg	25,5
Dimethenamide	kg	25,5
Electricity/heat		
Electricity, high voltage	kWh	49500
Emissions to air		
Co(II)	kg	896,6072
Nitrogen oxides	kg	0,41905
Sulfur oxides	kg	0,09265
Emissions to water		
Waste water/m3	m3	15,231405
Organic compounds (unspecified)	kg	77,32638889
Ammonia	kg	0,01275
Organic chlorine compounds (unspecified)	kg	0,0000085
Final waste flows		
Packaging waste, unspecified	ton	1,845605
Production waste	ton	0,0017
Waste to recycling	ton	1,8428
Waste, toxic	ton	0,000127245
Packaging		
Steel, low-alloyed	kg	260
Packaging glass, brown	kg	41600
Transport		
Transport, freight, light commercial vehicle	kgkm	36990
Transport, freight, lorry 3.5-7.5 metric ton, EURO5	kgkm	3398970
Transport, freight, lorry 7.5-16 metric ton, EURO5	kgkm	1815182
Transport, freight, lorry 16-32 metric ton, EURO5	kgkm	7679782

The inventory data presented here is used for all of the scenarios considered but for circular ones is modified in accordance to additional assumptions as presented in the following chapters. The change in data use is also visible at the level of secondary data and its records within ecoinvent database. RBM are modelled with “cut-off” approach while CBM are modelled with consequential approach.

2.3. Methodology for life cycle impact assessment

In order to give full coverage for possible life cycle impacts and include global as well as European perspective the ReCiPe method is used for the assessment. The impacts are calculated with SimaPro software and the endpoint variant of ReCiPe (H) V1.08 indicator. The ReCiPe method has a wide coverage within the literature and it is not furtherly described here (Huijbregts et al., 2017).

3. Results

Figure 4 presents the LCA results for different variants of craft beer life cycle. The results are presented for both scenarios, circular and regular, but for circular scenario one additional variant is created. CBM scenarios take into account different rates of bottles return, namely of 40% and 100%. 100% scenario is a hypothetical one, just to show the change of impacts related to the return rate. In 40% return rate CBM scenario it is assumed that all the remaining glass is recycled. Additionally, the benefits of using spent grain as an animal feed as well as treating waste water are taken into account. Moreover, the closed loop of used bottles needs some additional resources use due to washing process (washing agents, water, energy and heat) as well as additional transportation mass due to heavier bottles (22% heavier than non-returnable bottles) as observed by Morgan et al. (2022).

The processes of malting and brewing have the highest impact within RBM scenario. In the CBM scenario the impact is decreased due to the provision of spend grain as a secondary resource to the market and wastewater treatment for closed circuit. The bottling process has the highest overall impact within RBM and CBM scenarios, but with a significant vulnerability to the return rate of the bottles. When it is settled to 100% the bottling process is turning into the 3rd highest process. It is important to observe the difference between RBM and 40% CBM, which are close to current business practices, which is in favor of RBM scenario. It means that additional pressures that are appearing due to organizing close circuit of returnable bottles are overwhelming the benefits of decreasing the use of raw glass.

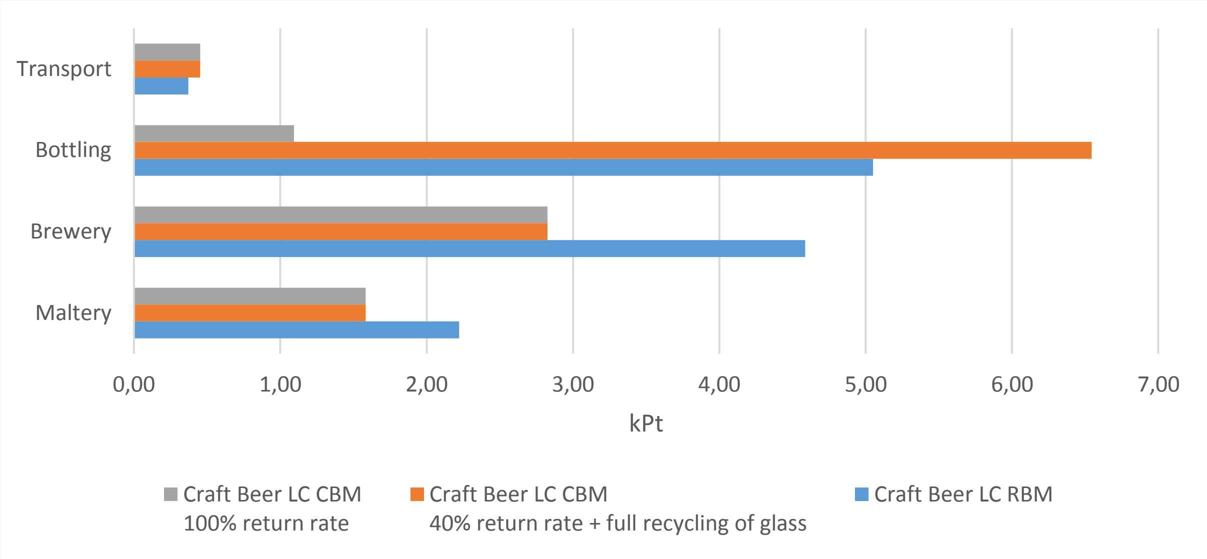

Figure 4. LCA results (ReCiPe single score weighted indicator) for different variants of craft beer life cycle.

Finally, the transportation process has the lowest impact in all of the scenarios but interestingly some more significant within CBM. This is due to some additional transport needed to close down the loops and heavier bottles used to increase their mechanical strength and durability.

4. Discussion

Table 2 presents decision making context for CBM implementation in craft breweries. The key parameter for decision making process is defined with regard to the capability of a single craft brewery to introduce CBM on its own and within its organizational scope (denoted as "Internal") or a necessity to introduce it with cooperation with some other actors from its value chain ("External"). Each life cycle phase could be characterized by different changes or ventures that could turn BM towards circularity. The changes presented in table 2 are examples of circular ventures and characterized with potential change of environmental impact as measured with LCA. The symbol of "+" indicates the positive change of environmental impacts, while "–" indicate negative consequences. The negative consequences that could appear are usually related to the energy use and infrastructure needed for extra processing. The impacts are also taking into account the effect of scale that could undermine some ventures. As an example we could bring out a wastewater treatment installation that could perfectly fit to the industrial scale production facility while for small scale craft brewery it is rather a burden in economic and eventually in environmental scale.

Table 2.
The decision making context for CBM implementation in craft breweries

Life cycle stages	Decision context	Changes towards CBM	Environmental impact (LCA results)
Supply	External	Biological cultivation Local cultivation and supply Verification of suppliers	+ / – + + / –
Production	Internal/External	Closed water circuit Biogas production Animal feed production	+ / –– ++ / – ++ / –
Packaging	External/Internal	Returnable bottles Keg based distribution	+ ++
Distribution/Serving	External/Internal	Seving without individual packaging	++
Consumption	External	Motivation to return packaging	+

According to the assessment of life cycle stages, the dominating role of internal factors in decision making towards CBM is a feature of production process only. All the other stages require strong commitment of external actors, especially while cultivation processes, packaging production and distribution are concerned. The decision of a single craft brewery itself has rather limited contribution to CBM requirements.

5. Conclusions

The results of the study show also limited possibilities of small scale breweries to achieve major breakthrough towards CBM and its direct operationalization. While for large industrial breweries the effects of scale are justifying the closures of material loops, for craft breweries it is undeniably more difficult. Firstly, the investment costs of waste treatment infrastructure are simply not bearable or feasible by small scale breweries. Secondly, relatively small streams of recoverable waste are not large enough for potential business partners.

The important decision is not only determined by scale of operations but also on the distribution model. Craft breweries could be organized in a different ways and turning into CBM could also mean changing the operational form into on-site serving ones such as brewpub or taproom brewery.

Certainly turning into CBM requires wide cooperation with different stakeholders, both from the down and upstream processing. It seems that the only solution is to build up a network of organizations, both from craft brewing industry and from other industries that could use its waste as a secondary raw material, in order to close down the open loops.

Finally, it is worth to notice that most of the circular loops proposed to craft breweries are quite demanding while additional processing is concerned. It is not a problem if the processing installations already exist and are easily reachable by craft breweries. But if it is also an issue of not existing infrastructure or distant connections, possible environmental benefits could be easily consumed by the necessary environmental burdens. The important limitation of this research is related to the economic outcome of CBM oriented changes that are not considered here. Probably, the decision making process would be much more susceptible to the economic constrains and should be considered once again with regard to current market opportunities of any decision making unit.

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