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# Circular Economy and Living labs: A multiple case study

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**Abstract:** Circular Economy (CE) emphasis minimizing resources and waste generation by transforming traditional take-make-dispose value chain into various circular value chains. Living lab approach has been suggested as a promising innovation approach for developing and testing CE solutions. However, in-depth analysis of what kind of co-creation and testing methods CE related living lab projects are applying is somewhat uncharted. By applying qualitative document analysis and in-depth interviews approaches, this multiple-case study is mapping living lab methods across the different CE value chain and innovation process phases among five companies participating in European Commission H2020 funded CIRC4Life-project. Visual matrix tool including eight CE value chain phases and six innovation process phases is generated to illustrate the evolution of living lab activities during the various innovation process phases.

**Keywords:** Circular economy; living lab; multiple case study; document analysis; innovation process; value chain

## 1. Introduction

Lately, Circular Economy (later also CE) has gained increasing interest among various stakeholders including companies across the different industry sectors, scholars, public authorities and policy makers. The popularity of the CE is expected to increase further due the new actions plans such as The European Green Deal (European Commission, 2019), thus making it one of most the significant innovation management topics in the coming decades.

CE is grounded on the idea of minimizing resources and waste generation, utilizing cleaner technologies as well as maintaining the value of the products, materials and resources in the economy for as long as possible (Andersen 2007, European Commission 2015). CE is often described by using “R principle”. Depending on the source, R principle is grounded on three to nine R-letter words, in which the original 3R framework consisted Reduction, Reuse and Recycle terms (Ghisellini, et al. 2016; Kirchherr et al. 2017; Joshi et al. 2006; Van Buren et al. 2016). In European Union the 4R framework is utilized where the added the fourth R represent ‘Recover’ term (European Commission, 2008). Various nationwide CE strategies has been adopted to seek out macro-level CE solutions, but only few of them appears to be effective (Marino and Pariso; 2020). Numerous strategies can be applied across the CE value chain (Kalmykova et al. 2018). However, developing CE Business Models (later CEBMs) requires ecosystem-wide orchestration and seamless collaboration between diverse groups of actors across the CE value chain (Parida et al. 2019). Many challenges at meso-level have been identified relating the development and implementation of the CE (e.g. Bressanelli et al. 2019; Franco, 2017). Thus, novel and effective innovation management practices supporting the transition towards circularity are in high demand.

Living lab is a hybrid approach integrating user-centered research and open innovation approaches (Leminen et al. 2012) to develop and test in a co-creative manner new solutions at different phases of innovation process while utilizing various R&D and testing methods in a systematic manner (European Network of Living Labs, 2020). In Europe, living lab approach has been applied to develop CE solutions for various industrial settings especially in Europe's biggest Research and Innovation programme Horizon 2020 (Santonen et al. 2017). However, in-depth analysis of what kind of co-creation and testing methods CE related living lab projects have been applying during the different CE and innovation process phases is somewhat uncharted. In all, living lab studies focusing on CE is relatively novel phenomenon and so far studies have mainly focused on analyzing urban living lab settings instead of e.g. investigating development of private sector CEBMs (e.g. Aguilar, 2019, Cuomo et al. 2019, Amenta et al . 2019, Puerari et. al 2018). Therefore, this multiple case study focuses on mapping and describing living lab methods across the CE value chain and innovation process phases in context of EU funded project consisting five different demonstration cases from four different industries.

## 2 Theoretical Foundations of Circular Economy and Living Labs

### *2.1 Circular economy value chain in brief*

**Definition of Circular Economy.** The concept of CE is in its infancy and development of CE until lately has mainly been driven by practitioners, while a scientific basis for the CE has been scattered and without coherent definition (Korhonen, et al. 2018). So far, the most extensive effort to define CE as a term was conducted by Kirchherr et al. (2017) who gathered 114 circular economy definitions from peer-reviewed journals and non peer-reviewed publications. The study highlighted that out of those 114 definitions, only three of them covered all 3R-framework dimensions (i.e. Reduction, Reuse and Recycle) while the definition proposed by van Buren et al. (2016, p.3) was argued to be written with greatest clarity. As a result of their analysis, Kirchherr et al. (2017) identified 17 different dimensions for CE and proposed the following lengthy one sentence CE definition, which summarises their coding framework:

*A circular economy describes an economic system that is based on business models which replace the 'end-of-life' concept with reducing, alternatively reusing, recycling and recovering materials in production/distribution and consumption processes, thus operating at the micro level (products, companies, consumers), meso level (eco-industrial parks) and macro level (city, region, nation and beyond), with the aim to accomplish sustainable development, which implies creating environmental quality, economic prosperity and social equity, to the benefit of current and future generations.*

**Cycles and Main Phases in Circular Economy.** The traditional linear economy value chain is grounded on take-make-dispose (also referred as take-make-consume-dispose) approach whereas in circular value chain materials and products are used repeatedly by utilizing recycling. Most recycling in fact is argued to be downcycling (i.e. recycled solution has lower value than original) while upscaling (i.e. recycled solution has higher value than original) should be preferred if possible due minor need for energy and virgin materials (Sung and Sung, 2015). CE systems can include multiple different cycles, while the naming of the cycles are varying (Jørgensen and Pedersen, 2018; O'Brien et al. 2018). *Sharing or renting cycle* is referring to *peer to-peer-based activity of obtaining, giving, or sharing the access to goods and services, coordinated through community-based online services* (Hamari et al. 2016) and is covering renting, industrial symbiosis, peer-to-peer models and product-service-system (Codagnone and Martens, 2016). *Repairing or refurbish* cycle focuses on correcting specified faults in a product and includes maintenance and fixing at-home and in shops activities (King et al. 2006). *Re-use cycle* refers to *any operation by which products or components that are not waste are used again for the same purpose for which they were conceived* (Directive 2008/98/) consisting collection, re-distribution and reselling. *Re-manufacturing cycle* refers to collection, rebuild and renew processes in which used products are brought back to at least same performance level and giving equivalent warranties as new products (King et al. 2006). *Recycling cycle* refers to *any recovery operation by which waste materials are reprocessed into products, materials or substances whether for the original or other purposes* (Directive 2008/98/) including collection, sorting, processing and utilizing of discarded materials in the production of new products.

This study focuses on mapping living lab methods across the different CE value chain and innovation process phases. Kalmykova et al. 2018 and European Commission (2014) suggested relatively similar division of CE main phases as presented in Table 1.

**Table 1.** Examples of division of Circular Economy main phases

| *Kalmykova et al. 2018* | *European Commission (2014)* |
|---|---|
| 1. Material sourcing | 1. Raw materials |
| 2. Design | 2. Design |
| 3. Manufacturing | 3. Production, remanufacturing |
| 4. Distribution & sales | 4. Distribution |
| 5. Consumption & use and sharing | 5. Consumption, use, reuse, repair |
| 6. Collection & disposal | 6. Collection |
| 7. Recycling & recovery | 7. Recycling |
| 8. Remanufacturing | 8. Residual waste |
| 9. Circular inputs | |

Grounded on Table 1 naming and phase division, for our research purposes CE main phases are divided and named as follows: (1) material sourcing including raw and recycled materials, (2) design, (3) manufacturing and re-manufacturing, (4) distribution, re-distribution, sales and re-sales, (5) consumption, use, re-use, repair and sharing, (6) collection, (7) recycling, (8) residual waste. In this study, circular input is understood as linkage or connection between different CE phases, not as not as an actual phase. Therefore, this phase is omitted in the CE phase division.

### *2.2 Living lab innovation process in brief*

Living lab and other related user centric co-creation approaches such as testbeds, citizen science and community-based participatory research (Santonen, 2018) has gained interest among innovation scholar and practitioners. Santonen and Julin (2019) defined living lab as follows:

*Living lab user-centered research and open innovation approach operates in a real-life or real-life kind of environments in which diverse groups actors are together developing and/or testing in a co-creative manner new solutions at different stages of innovation process while utilizing various research, development and testing methods via systematic methodology*.

According to European Network of Living Labs (2020), the core components of a living lab consist (1) multi-stakeholder participation, (2) user-centered innovation process, (3) operating in real-life or simulated settings, (4) utilization of systematic multi-method approach via (5) iterative co-creation process. In context of living labs, multi-stakeholder participation has typically been defined by using quadruple helix model – the successor of triple helix model (Etzkowitz and Leydesdorff, 2000) – which extent university-industry-government relations by adding civil society as fourth dimension (Carayannis et al. 2012). However, the Quintuple helix model should be adopted instead, since it acknowledges also “natural environments of society’ as a dimension and highlights environment as a key driver and stakeholder for innovation. User-centered requirement refers to an innovation process in which products or services are co-created with the users (Arnkil et al. 2010) by offering various possibilities for users to give feedback and influence the outcome of the developed solution. Real-life and simulated settings is a peculiarity characteristic of a living lab approach emphasising a need to create realistic usage situations and environments for user encounters (Dell’Era and Landoni, 2014). Multiple methods research criteria refers to combinations of methods that include in a substantive way more than one data collection procedure (Fetters and Molina-Azorin 2017). Iterativeness is referring to a process, where an initial idea is iteratively elaborated and refined into the final solution by using findings from the previous rounds (Bergvall-Kareborn, and Stahlbrost, 2009).

There is a clear consensus among researchers that living lab process is a multi-staged innovation process, but ambiguity about what and how many phases there are (Santonen, 2020). Santonen (Ibid.) summarized the suggestion from various living lab, innovation and design literature and proposed the division for living lab innovation process. The classification presented in Table 2 is adopted for this study.

**Table 2.** Living lab innovation process phases

| *Main level names* | *Sub level names* |
|---|---|
| 1. Need, challenge and opportunity identification | Discover |
| | Define |
| 2. Idea generation and idea testing | Co-create |
| | Idea selection |
| 3. Concepting and prototyping | Co-create |
| | Proof-of-concept test and protyping |
| 4. Detailed product and service development | Detailed development and design |
| | Small-scale real life test and piloting |
| 5. Validation and impact assessment | Impact evaluation and large-scale piloting |
| 6. Market launch and post-market | Market acceptance |

## 3 Research design

### *3.1 Sample selection*

The five companies (a.k.a. demonstrators) participating in European Commission H2020 funded CIRC4Life-project (No: 776503) formed the sample group for this multiple case study. The CIRC4Life-project main aim was to develop CEBMs along the product value chain in the following industrial areas and countries: (1) domestic LED lighting from Spain, (2) industrial LED lighting from UK, (3) meat supply chain from Spain, (4) recycling from Spain and (5) vegetable farming and food from UK. The overview of each sample company, demonstrated CEBM and related initial living lab plans at the beginning of the project are available at CIRC4Life-project website (https://www.circ4life.eu/). The project started in May 2018 and was originally planned to end at April 2021. However, the project duration was extended by 6 months due COVID-19, which prevented close social contacts.

Due the CIRC4Life-project setting, the case companies development and demonstration activities were partially interlink and common for all participants, thus not fully representing a standalone company case example. When generalizing the result of this study, the project setup should be notified as a limitation. The common nominator between the project partners was the development of eco-costs and eco-credits scheme to support and reward eco-friendly buying behaviour (Su and Peng, 2020). Furthermore, project consisted also a series of living lab activities, which were either organized together or were providing information for more than one case company. The initially planned recycling activities for meat supply chain were omitted during the project and replaced by biowaste recycling. Since there was no a direct link to the demonstrator, these activities are omitted in this study even they were a part of the CIRC4Life-project.

### *3.2 Data collection and analysis*

Qualitative document analysis (Bowen, 2009) was conducted to identify the utilized living lab methods during the various project stages. Documents consisted the official

CIRC4Life-project documentations relating living lab implementation plans and results as well as other relevant documents having a linkage to prior living lab documents. Furthermore, the data and method triangulation (Denzin, 1970) was applied by interviewing the key stakeholders from each company and the university responsible for orchestrating and facilitating the living lab actions during the project excluding vegetable "farming and food" company. The main aim of the interviews was to clarify the objectives, activities, outcomes, satisfaction, possible surprises and challenges relating each individual living lab activity. Overall view at the beginning of the project and at the time of the interview, when most of the living lab activities were conducted, was also evaluated to investigate which expectations come true. Visual matrix tool including eight CE value chain phases and six innovation process phases was generated to illustrate the evolution of living lab activities during the various innovation process phases.

## 4 Findings

### *4.1 Utilized living lab methods during the project*

In Appendix Table 1 the utilized living lab methods during the CIRC4Life-project are listed and shortly described in generalized format. In Figure 1 to 6 demonstration specific and generic (i.e. covering more than one demonstrator) living lab activities are presented on the basis of the defined visual matrix tool consisting circular economy and innovation process phases. The green-yellow-red colour coding is representing finished (green), planned (yellow) and cancelled (red) activity.

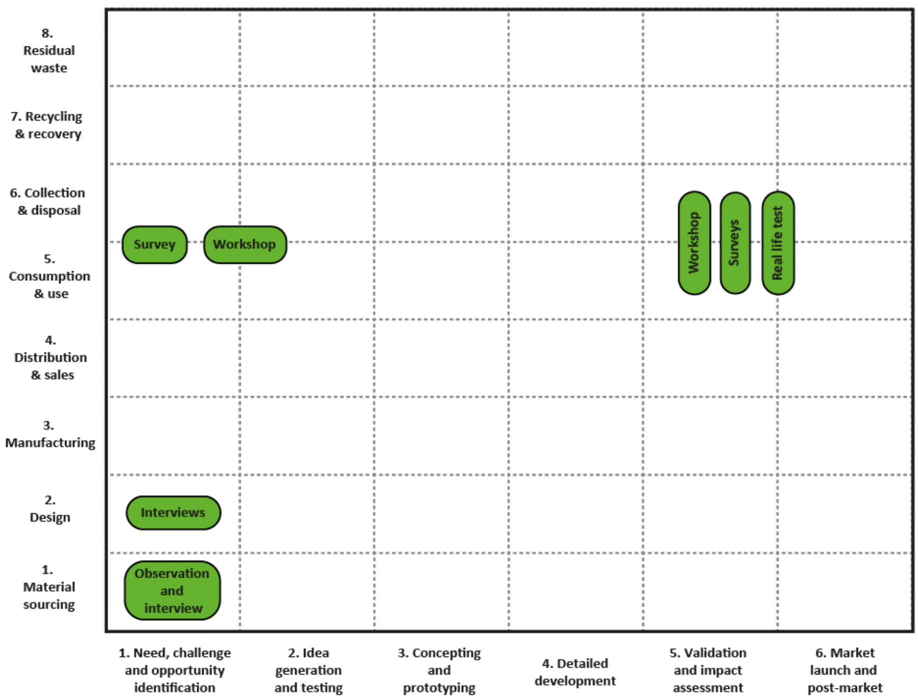


**Figure 1.** Domestic LED lighting

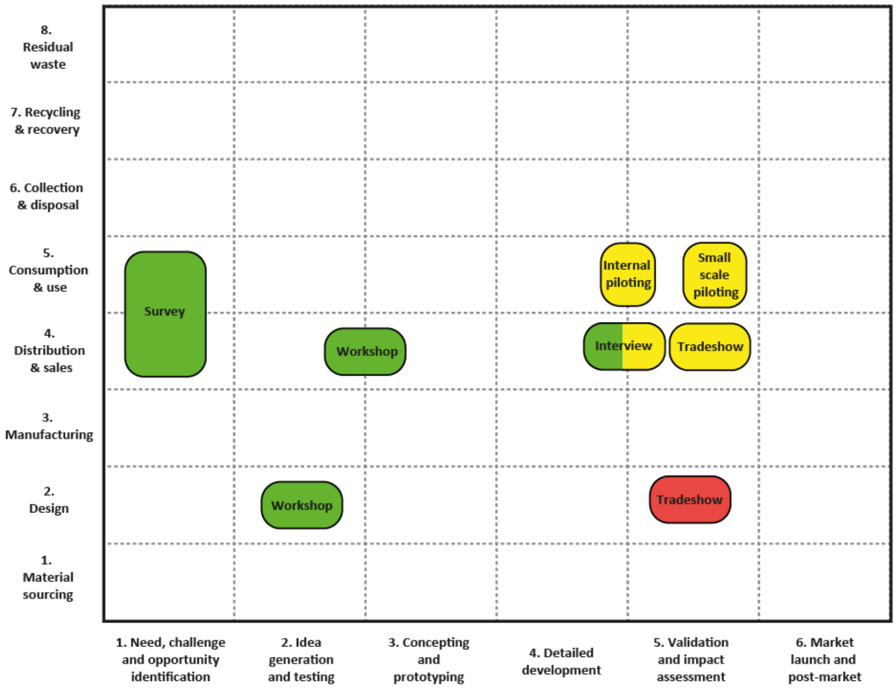


**Figure 2.** Industrial LED lighting

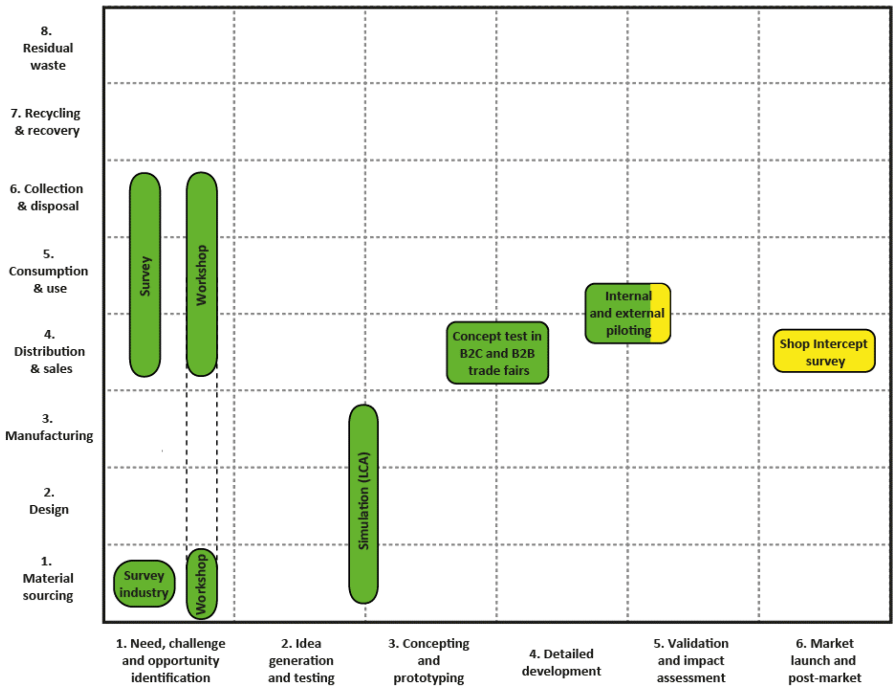


**Figure 3.** Meat supply chain

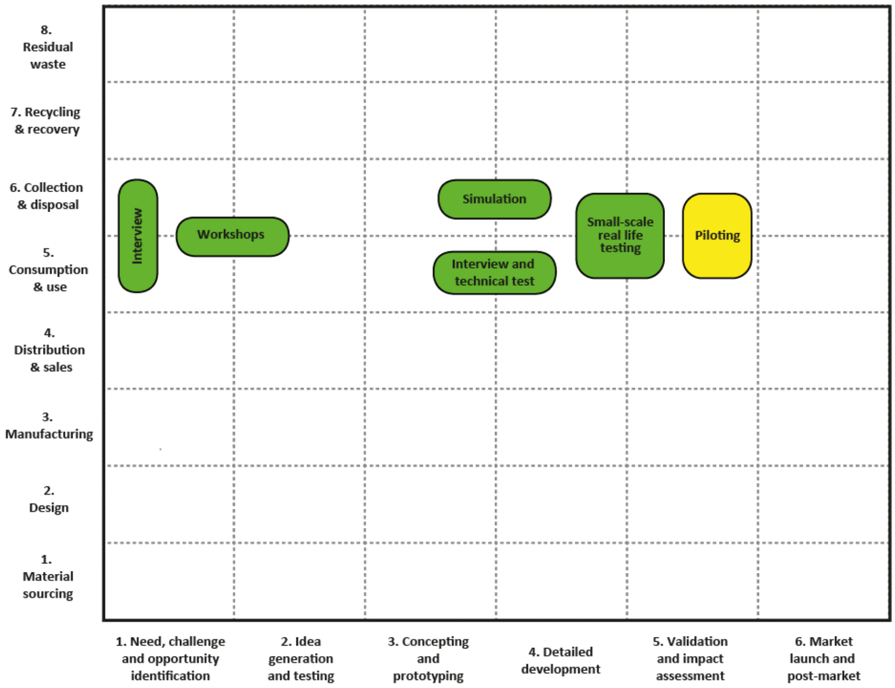


**Figure 4.** Recycling value chain

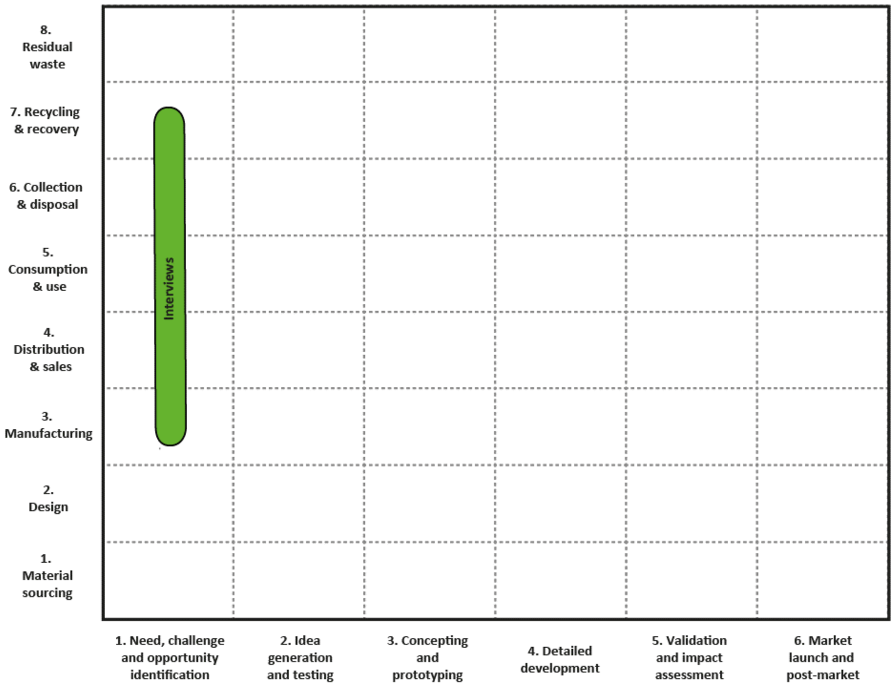


**Figure 5.** Vegetable farming and food

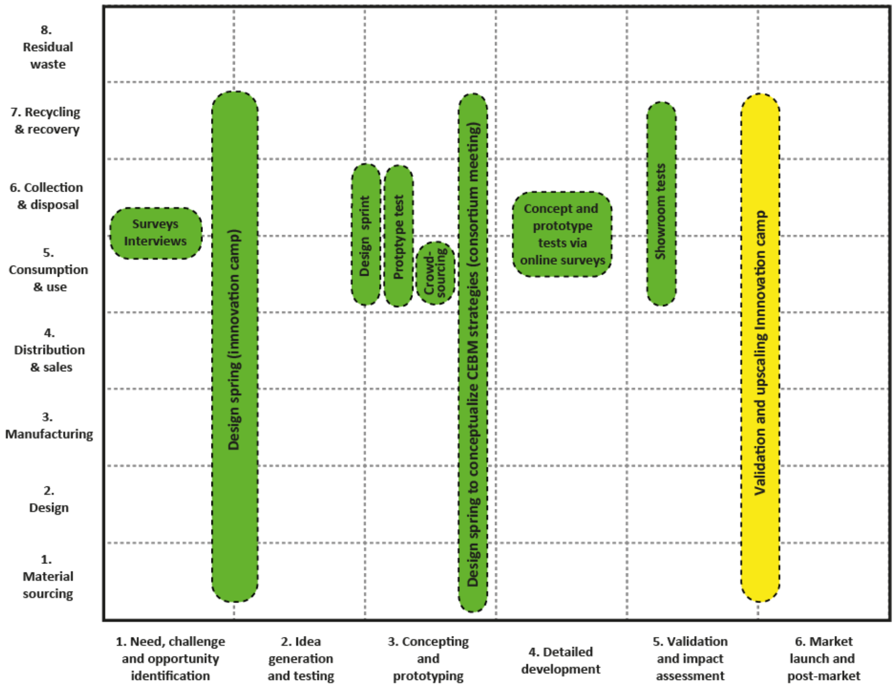


**Figure 6.** Generic activities covering more than one demonstrator

## 4. Discussion

The key components of living lab project consist multi-stakeholder participation, user-centered innovation process, real-life or simulated setting, systematic multi-method approach and iterative co-creation process (e.g. European Network of Living Labs 2020, Santonen, 2020). The detailed evaluation of CIRC4Life-project living lab activities verified the existence of the key components and their relation to applied methods as follows.

**Multi-stakeholder participation** occurred in many forms, while the combination of the participants varied greatly between the activities and demonstrations. Both one-way (e.g. survey) and interactive (e.g. workshop, design sprint) methods were utilized to engage relevant stakeholders depending on the information need and innovation process stage. The one-way methods were emphasised especially during the need, challenge and opportunity identification stage (Innovation Process (IP) stage 1) as well as during the detailed development (IP4) and validation/impact assessment (IP5) stages due transnational scalability and cost effectiveness. Importantly, multi-stakeholder participation could occur in one event (e.g. in workshop or design spring) or by conducting multiple events in series (e.g. via workshop series with different stakeholder groups such as consumers vs. public authorities).

**User-centered innovation process** is a process in which end-users can influence how a design/innovation takes shape. Both *design for users* and *design with users* approaches were utilized (Bergvall-Kåreborn et al. 2010). During *design for users* activities, users are consulted, but they do not have an actively role in development activities. This approach was more evident in IP stage 1 for collecting users preferences (e.g. via survey or interview) and in IP stage 4 and 5 to test different solution versions (e.g. in trade fair, via survey). During *design with users* activities, a solution is co-created by developers and end-users consisting primary user, secondary, and/or tertiary users. Primary and secondary users are distinguished by usage frequency while tertiary user refers to users who are affected by the solution or have an influence on making the decision relating the solution (e.g. public authority). *Design with users* activities were emphasized during the idea generation/testing (IP stage 2) and concepting and prototyping (IP stage 3). Typical methods in these cases included workshops and design sprints.

**Real-life or simulated settings** refers to realistic usage situations in which real-users are interacting with real or real like solutions in real-life or simulated physical or digital environments. This requirement was evident mainly during later innovation process stages (i.e. IP stage 3, 4, and 5) focusing on testing and piloting the proposed solutions (e.g. in trade show, usability testing with real solution but in simulated environment). During the IP stages 1 and 2, real-life requirement was more harder to obtain, but not impossible. For example, observation method was utilized to identify opportunities for material sourcing in IP stage 1. Anyhow, based on demonstrator interviews it was evident that early phase data collection focusing on end-user needs and preferences via survey without genuine real-life or simulated setup is also highly valuable approach and could lead to changes significant changes. Thus, it is suggested that living lab process requirements should be assessed as a whole. Even if some to of the individual actives might not full fill all the living lab requirements at once, satisfactory results can be obtained by combing multiple research approaches.

**Systematic multi-method approach**. As presented in visual matrix tool illustration, a series of consecutive living lab activities were conducted for each demonstration cases as well as for joint project activities. The plans were updated periodically to react to the collected feedback. However, none of the plans were executed as initially planned. In year 2020 COVID-19 pandemic drastically changed the operating environment and prevented close social contacts. This caused significant challenges for the living lab activities, which are heavily grounded on the social interaction. Mitigation activities consisted e.g. online based testing by using storyboards and surveys. Furthermore, cancellation of international tradeshow events were partially replaced by arranging showroom event in university premises in a country, which had less restrictions for close contacts. Obviously, the replication of the real-life setting was impossible to fully achieve. Some of the changes were also caused by external stakeholders (e.g. due delays to get decisions, not able engage required participants) and demonstrators (e.g. no resources or timing issues). It is highlighted that in a long duration living lab project requires adaptive management and willingness change plans based on user feedback.

**Iterative co-creation process** is grounded on an idea of elaborating and refining the developed solution throughout the multiple rounds. Three types of iteration was occurring including proceeding to next IP stage, repeating the same stage and going backwards. In an ideal iteration process, the executed living lab activity validates the assumptions and decision to proceed next IP stage is made. However, during the project especially eco-costs and eco-credits scheme and related mobile application required multiple usability and user acceptance test rounds during IP stage 4, since user acceptance was not gained in testing. Since the mobile application was shared service among multiple demonstrators, it had also direct impact on their development activities. Finally, the project focus also changed partially due collected feedback, leading to amendment request according to European Commission defined procedure. As being European

Commission funded H2020 projects, it was relatively long process to get the amendment request agreed among consortium members and accepted by European Commission authorities. Thus, is argued that the currently H2020 funding system is not as compatible with iterative co-creation process as e.g. in privately funded projects where decision can be made by single company.

When evaluating living lab activities thru CE value chain phases, it is apparent that *distribution &sales*, *consumption & use* and *collection & disposal* were more favourable to conduct living lab activities. Evidently, those are the phases where the end-users have a direct interaction with the developed solutions defined by CIRC4Life-project thematic focus. In many cases the conducted living lab activities consisted two CE-phases and/or two innovation process phases. Furthermore, sometimes it was difficult to define exact innovation (or CE phase), due multiple topics or interlinks. However, in practical work this was not causing problems. The amount of the covered activities are should be defined by notifying time restrictions for user engagement.

Demonstrators were also indicating that living lab process was laborious, which could be partially explained by demonstrators prior low experience on living lab approach. Furthermore, the solution limitations highlighted by end-users in tests were not always resolved for the next iteration round e.g. due resources or technical limitations. Nevertheless, the project activities needed anyhow proceed, thus “optimal” solution was not always deliver to next phase. Importantly, some of the conducted activities (e.g. large scale design sprint, for more information see Santonen et al., 2019) would be out of reach for SMEs conducting living lab project by themselves individually. Finally, it is highlighted that individual demonstrator illustration are providing only partial understanding, since the generic activities presented in Figure 6 provided valuable insight for cases especially for meat supply chain and recycling demonstrations.

## 5 Conclusions

By applying qualitative document analysis and in-depth interviews approaches, this multiple-case study described living lab methods across the different CE value chain (Kalmykova et al. 2018), and innovation process phases (Santonen, 2020) among five companies participating in European Commission H2020 funded CIRC4Life-project. Visual matrix tool was generated to illustrate and map the evolution and method selections with in the project. Method selections were compared to the key of living lab project requirements in order identify the following commonalities. Multi-stakeholder participation requirement were achieved in one event or by conducting multiple events in series. *Design for users* approaches were more often emphasised at the beginning of innovation process and in testing and validation phases, whereas and *design with users* approaches were highlighted in idea generation/testing and concepting/prototyping stages. Real-life requirement was more prominent during the prototyping, detailed development and validation stages, while methods omitting real-life requirement were considered also valuable by demonstrators. None of the planned activities were executed as initially planned, which was only partially caused by COVID-19, thus highlighting adaptive planning. All iterative feedback process variations occurred including gradually proceeding to next IP stages, repeating the same stage multiple times and going backwards in the innovation process. When conducting public funded iterative process, one should be prepared to long decision making process, if collected feedback is indicating a major change needs for the project goals or activities. Finally, CE value chain process phases focusing on *distribution &sales*, *consumption & use* and *collection & disposal* were more favourable to conduct living lab activities. However, this finding is partially caused by CIRC4Life-project thematic focus. Finally, some of the applied living lab activities were possible only due H2020 funded project and therefore not applicable at the same scale e.g. for individual SME.

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## Appendix

**Table 1.** Identified living lab methods

| *Method name* | *Description* |
|---|---|
| Survey | A technique of gathering data by asking questions from a group of people who are thought to have desired information (i.e. representative sample group). A formal list of questions are prepared and statistical methodologies are used for analysing the results. Online, telephone and street/mall intercept survey were utilized. |
| Interview | A structured one-on-one conversation where one participant (an interviewer) asks questions, and the other (an interviewee) provides answers. Unstructured, structured, semi-structured face-to face, and phone interviews were utilized. |
| Focus group | A moderator conducts a collective interview and make sure that the discussions focuses on the research questions. Typically focus group consist 6 to 8 participants who represent a sample of a target group. |
| Workshop | A facilitated a group activity to find solutions for a specific problem by gathering insights from workshop participants while using variety of methods. Durations for short workshop from 45 minutes to 90 minutes, medium-length from 90 minutes to 3 hours, and long-workshop from 3 hours to 1 day. |
| Hackathon and design sprint: | Typically 2-5 day event in which group of people will develop a solution to the predefined challenge by using a variety of co-creation methods. The outcome of the co-creation activity (i.e. the solution) can range from low-fidelity to hi-fidelity prototypes, mock-ups or written concept description for a product or service. |
| Crowdsourcing | A process where a task or tasks are delegated (i.e. outsourced) via an open call by using internet to a large group of people (i.e. crowd) who complete the task according to task description. A specific crowd solving process (i.e. Design challenge) was utilized where a well-defined problem (i.e. eco-label visualization) was defined and crowd proposed actual solutions instead of ideas. |
| Simulation | A technique creating an environment and predefined simulation scenario allowing participants to experience a representation of a real event and location in a risk-free and safe environment and to gain understanding of tested solution and related human interactions. |
| Trade show/fair or showroom | An exhibition open to the public (i.e. consumers) and/or industry professionals (i.e. company representatives) to showcase and demonstrate their latest products and services, meet partners and customers, study rivals and/or identify new opportunities and trends. A showroom is a space where developed solutions or information about the solutions are displayed for users to test and explore them. |
| Observation | A short-term research technique involving a direct observation of phenomena and people in their natural environment and reporting what people actually do. Non-participant and participant observation methods were utilized. |

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**Table 1 (continues).** Identified living lab methods

| *Method name* | *Description* |
|---|---|
| Idea testing / selection | A process where feedback is collected from a target group (i.e. real end-users and other relevant stakeholders) to a group of predefined high-level ideas via quantitative and/or qualitative data collection methods (e.g. interviews, surveys, workshop) in order to identify improvement suggestions and/or select the best ones for further development. |
| Prototyping and proof-of-concept tests | A process where feedback is collected from a target group (i.e. real end-users and other relevant stakeholders) to a predefined from low-fidelity to hi-fidelity concepts/prototypes via quantitative and/or qualitative data collection methods (e.g. sketches, paper interfaces, storyboards, role-playing) in order to demonstrate its feasibility, practical potential, acceptance, and/or make a decision which concept(s) is going to be further developed. |
| Small-scale real life testing and piloting | A process where feedback is collected from a target group (i.e. real end-users and other relevant stakeholders) to fully or nearly fully functional solution in real-life or simulated settings via quantitative and/or qualitative data collection methods (e.g. usability testing, integration testing, user acceptance testing) in order to validate whether the solution is working as intended, identifying comparing actual and expected outputs and user reactions and/or make a decision is solution ready for large scale testing. |
| Impact evaluation and large scale piloting | A process executed on real-life environment at system level with real end-user and fully working solution in order to validate the solution value promise, reliability and scalability. |