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Urban Living Lab: An Experimental Co-Production Tool to Foster the Circular Economy

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Abstract: In recent decades; the balance of power between institutional and economic actors has radically changed; with a significant impact on the modes and dynamics of governance. In the broad array of experimental practices of co-production; Living Labs (LLs) represent a promising mode of collaboration among public bodies; research centres; private companies and citizens. By means of LLs; public actors aim to co-produce experimental policies; breaking out of traditional policy schemes to find new solutions to collective problems. On an urban scale; such tools have come to be known as Urban Living Labs (ULLs), and they are increasingly used by local governments to tackle complex problems such us stimulating the circular economy to tackle climate change. This paper provides a systematic review of case studies to understand whether and how the ULLs can represent an effective policy tool to foster the circular economy on an urban scale.

Keywords: collaborative governance; urban living labs; circular economy; co-production; policy tools

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1. Introduction

In recent decades, the balance of power between institutional and economic actors has radically changed, with a significant impact on the modes and dynamics of governance (Enroth 2013). In very different ways, the worldwide breakthrough of pro-market influences into politics has laid bare the controversial and uneven transition in public management from an "old public administration" model to a "new public governance" one (Dente 1989; Howlett et al. 2017). In the hierarchical structures of traditional governance, public policies were considered to be fixed combinations of majority decisions taken by political representatives within institutional public arenas and their subsequent implementation by bureaucratic administrations (Belligni 2004). By contrast, in the new governance model, the relevant policy-makers are a large and flexible set of stakeholders, such as territorial interest groups, banks, trade unions, companies, media, churches, banking foundations, and non-governmental organizations, which cooperate in multi-layered networks of interaction (Righettini and Lizzi 2020). As a consequence, public policies are currently based on a steady process of dialogue and negotiation between public and private actors, which leads to a blurring of boundaries among social, environmental and economic issues, and of responsibilities for tackling them (Baldi and Profeti 2020). In an attempt to learn how to deal with new collective problems, in a context of increasing interdependence and uncertainties, many public actors have gradually accepted the idea of revising their traditional modes of action by means of experimental policies. Experimentation in public policies is deemed to be a governance approach that entails a multi-actor trialling of new ways to devise innovative solutions, with the potential to address contemporary challenges (Huitema et al. 2018). Recently, the concept of experiment has become a key component of co-production policies, which are based on the active participation of users, citizens and non-governmental associations in the co-commission, co-design, co-implementation and co-assessment of new ideas, services, and products (Sorrentino et al. 2018).

In the broad array of experimental practices of co-production, Living Labs (LLs) represent a promising tool of collaboration among public bodies, research centres, private

companies, and citizens (Nesti 2017). Born in the academic field as user-centred research methodologies aimed at refining technological solutions, they today consist of real-life setting policy devices in which stakeholders shape public–private–people partnerships (4Ps) intended to create, develop, and validate services, products, and systems (Carayannis et al. 2012). Unlike organizational experiments in real-life settings with purely research objectives, LLs aim at testing public policy or managing innovative public programmes or assets in a collaborative network (Schuurman et al. 2016). Compared with traditional policy tools, LLs differ because starting from site-specific needs of communities, they intend to come up with policy practices or knowledge innovation able to deal with global issues (Habibipour 2020).

On an urban scale, such tools have come to be known as Urban Living Labs (ULLs), and they are increasingly used by local governments to tackle complex problems such as social inequality or sustainability issues generated by urbanisation (Frantzeskaki et al. 2018). Hence, they are most often employed to promote the circular economy (CE) on an urban scale. The CE is deemed to be a positive model of development where natural resources are conserved and enhanced, minimizing systemic risks by handling finite stocks and renewable flows to reduce environmental impacts. In this policy field, ULLs offer unique arenas of citizens' participation in urban policy making, where co-production is identified as the leading approach to provide effective opportunities for the co-design, co-implementation, and co-evaluation of circularity experiments (Engez et al. 2021).

According to Reike et al. (2018), the CE paradigm is based on 10 'Rs' (refuse, reduce, reuse, repair, refurbish, remanufacture, repurpose, recycle, recover, re-mine). Although there is a growing interest in how ULLs can facilitate urban circularity, no research has yet attempted to investigate how such tools can actually put into practice the 10 Rs of the CE. This paper aims to answer this question by providing a systematic review of recent case studies focused on ULLs and CE.

Methods and Analytical Framework

Systematic review of case studies is deemed to be a promising method to investigate the potential of urban experimentations in dealing with complex problems at a city scale (Gerring and Cojocaru 2016; Trein et al. 2019). Such a methodological approach based on seven basic principles (transparency, clarity, integration, focus, equality, accessibility and coverage) is expected to reduce research bias in data collection as well as in analytical processing (Meyer 2022). This method relies on combining literature review with a selection of a limited number of cases that, despite slight differences in terms of timeframe, scale and contextual futures, have adopted common pathways in tackling public problems (Hossain et al. 2019). To dig into the potential of ULLs, this paper applies a systematic review methodology based on three main stages.

First, an electronic database searching is given to provide a comprehensive overview on case studies of ULLs focused on CE. This step involved a preliminary search by using four keywords 'living labs', 'urban experimentations', 'urban living labs', and 'circular economy' on SCOPUS and Google Scholar databases, which resulted in the collection of 153 peer-reviewed articles including scientific papers and contributions in conference proceedings published between 2018 and 2022. Afterwards, a temporary folder was created to shape a first list of the selected works containing basic information, such as year of publication, scale, main findings, and limitations.

Second, a qualitative appraisal was performed to understand whether the articles specifically addressed any of the 10 Rs proposed by (Reike et al. 2018). This phase led to screening the list, resulting in the selection of 34 papers that specifically recounted case studies of ULLs capable of addressing one of the ten facets of the circular economy.

Third, qualitative data extraction was carried out to select the most valuable case studies based on empirical analysis for understanding the real potential of ULLs in stimulating CE. This process entailed the selection of ten exemplary ULLs case studies that thoroughly covered at least one of the 10 Rs of CE proposed by the Reike's model (Reike et al. 2018).

Such cases ensured that the systematic review was enriched through empirical analyses that could offer practical insights into the real potential of ULLs.

For this purpose, the paper is divided into four main sections. Section 1 presents how experimental co-production policy tools became integral parts of the NPG. Section 2 provides a historical overview of the LLs, and identifies the distinctive features that characterize them as policy tools. Section 3 explores the CE, looking at the main currents of thought that have characterized its emergence and integration in institutional policy agendas. Section 4 deals with the topic of cities to unravel why they are considered promising scales of action for facilitating circular transitions, and finally addresses the research question by presenting case studies that demonstrate how ULLs can effectively apply the 10 Rs of the CE on an urban scale.

2. From Policy Studies to Policy Facts

2.1. The Experimental Approach in Policy

In the 1960s, the growing interest in experimenting engendered theories able to attract the attention of governments and institutions still anchored to the Old Public Administration model (OPA). The OPA paradigm had always conceived public policies as the systematic combinations of political decisions, taken by the majority of political representatives within public arenas, with their subsequent implementation by bureaucratic administrations using direct provisions, rules, and input-based tools (Belligni 2004). Nonetheless, due to mismanagement and inefficiency in a vast range of public services, policy-makers started to consider introducing experiments in some of the most discussed policy fields in order to reshape their traditional modes of action. Especially in the USA, this thriving interest launched a twenty-year period—the so-called "golden era'—which is still considered to be unique in the history of policy experiments (Oakley 2007). In the aftermath of the popular protests against militarism, racism and gender inequalities, Campbell (1969) built his "experimenting society" based on the need to change perspective and introduce alternative measures to fix governmental dysfunctions (Huitema et al. 2018). Campbell, who specifically felt the need for structural reforms in the federal apparatus, came up with the idea of introducing experiments into public departments:

> "the United States and other modern states should be ready for an experimental approach to social reforms, an approach, in which new programs designed to solve specific social problems are put to the test in which we retain, imitate, modify, or discard them on the basis of apparent effectiveness".
>
> (Campbell 1969, p. 409)

For the first time, the experimental approach was conceived as an essential part of policy making rather than as a research method or a philosophical tool. In Campbell's framework, public actors would have to play the role of explorers by proposing new paths of policies to design long-term reforms (Butler 2012). In this regard, Campbell highlighted the difference between "experimental administrators" and "trapped administrators", where the former embraced controlled trials as starting points to build broader programmes, whereas the latter accepted experimental evaluations at the end of implementation solely to strengthen or justify their beliefs (Dehue 2001). Campbell's theory was indicative that something was changing in the world of public policies. Since the thoughtless Nixon administration in the 1970s, which implemented the Experimental Technology Incentives Program, experimental policies had apparently been introduced into governmental agendas (Tassey 2014). That programme aimed to encourage practical innovations by testing new patterns of action in government agencies, and it conceived experimental corrective actions as stress tests for reforms, with the ultimate goal of improving the efficiency of the public administration system. After the Watergate scandal (1974), experimental policies maintained a key role in social and employment programmes. At that time, one of the most popular experiments was conducted between 1975 and 1978, when the USA launched the National Supported Work Demonstration: "*a temporary work placement program designed to help workers without*

basic training [. . .] by offering the possibility of work experience and counseling in a protected environment" (LaLonde 1986, p. 605). The intention was to highlight how a temporary innovative measure could create opportunities for real changes in complex policy fields, with the final aim of improving public administration management and employment strategies. However, the experiment remained a circumscribed attempt, and even though experimental policies formally were coming up in many contexts throughout the 1970s, two main knots continued to circumvent their consistency: the risks of instrumentalisation and misinterpretation (Greenberg and Robins 1986).

2.2. Instrumentalisation and Misinterpretation of Experimental Policies

Under the OPA paradigm, many governments considered experimental policies as useful tools of legitimation to strengthen their traditional modes of action (Atkinson 2017). This underlying purpose was evident in one of the most important evaluations of an experimental policy, the one conducted by Gene Kassebaum in 1971. Kassebaum's research concerned assessment of different programmes for prison inmates' rehabilitation, at that time proposed by the California Department of Corrections. The study evaluated the short-run and long-run effects of participation in experimental treatment programmes called "group counseling". To accomplish the goal, Kassebaum compared the post-prison behaviour of inmates assigned to group counselling with that of others who were randomly assigned to the traditional rehabilitation system. The study revealed no meaningful differences in later recidivism rates between the two groups, and suggested that more participative therapies do not produce benefits in terms of recovery and rehabilitation into society. Even if Kassebaum's research suffered from a lack of programme integrity, which inevitably led to the weak outcomes of counselling programmes, it was used as a proof to maintain traditional prison policy in the following years. Experimentation remained a means to symbolically strengthen the OPA model without upsetting the balance of the government and management of public affairs. Moreover, the lack of a straight dialogue between scientific researchers and policy-makers, who were often undertrained and unwilling to explore new policy paths, hampered their extent and effectiveness in practice (Ginsburg and Gorostiaga 2001). Instead of undertaking long-term reforms on the basis of experimental results, policy-makers continued to be sceptical about the effectiveness of public policy evaluation, especially when the analytical assessments were focused on experimental initiatives (Weiss 1977). As a consequence, experimental policies could rarely be translated into practical results, because they were not perceived as yielding valuable information on how to improve public policies (Green and Gerber 2002).

2.3. The Rediscovery of Experimentation in Co-Production Policies

With the shift from the OPA to New Public Management (NPM), competition and contractualisation among big companies became the key pillars of public management, while civil society continued to play a marginal and passive role in policy making (Hood and Peters 2004). NPM was based on the superiority of private-sector techniques over those of OPA (Osborne 2009). Hence, the public administration sought to monitor market-based service delivery performance and imported business-like strategies and criteria into the management of public bureaucracy by means of output-based tools. In stark contrast to traditional models of administration, NPM is based on competition, an open market, and the outsourcing of public services through a wide range of incentivization mechanisms (Lapuente and Van de Walle 2020).

Nevertheless, both OPA and NPM have failed to capture the complex reality of the design, delivery, and management of public services in the twenty-first century. Albeit with remarkable differences across countries, at the turn of the millennium, the growing complexity of society and the crisis of pro-market strategies laid bare the transition from NPM to New Public Governance (NPG). NPG arose from the assumption that NPM had failed to address urgent issues of contemporary society such as entrenched poverty, healthcare dysfunctions, and social disparities (Citroni et al. 2013; Barraket et al. 2016).

New governance regimes aim to create public and social value by means of a fruitful collaboration between public and private actors, in which the government plays the role of the guarantor of public value (Ansell and Gash 2008). Under the NPG paradigm, both scholars and policy-makers have stressed that engaging with stakeholders and citizens in policy making, by enabling citizens to play a legitimate pro-active role as collaborators and creators rather than as passive users or consumers, can lead to more consistent, sustainable, and appropriate policies (Lippi and Profeti 2014). NPG considers experimental policies to be co-production processes that entail the trialling of innovative ways to design, organize and implement solutions with the potential to address contemporary challenges (Howlett et al. 2017). To this end, by means of experimentation, NPG has widened the spectrum of relevant policy actors to engage a large and flexible set of different bodies in public management, such as territorial interest groups, banks, trade unions, companies, media, churches, banking foundations and non-governmental organizations (Deserti et al. 2020).

On the assumption that scientific expertise is not sufficient, and that instead, the commitment of stakeholders' resources is crucial for creating knowledge that is not only scientifically valuable but also socially consistent, co-production aims to create win–win results for all of the actors engaged in it (Turnhout et al. 2020). With the establishment of NPG, co-production has acquired the status of leading practice in reformulating public service delivery (Bartenberger and Sześciło 2016). Through experimental patterns of co-production, different organizations are expected to contribute to testing public policy or managing innovative programmes or assets in a collaborative network. At different scales, governments are currently looking for alternative tools of policies, or new arrangements of the older ones, to fulfil the expectations and needs of the new governance interested in underpinning co-production (Howlett et al. 2017). In this context, the adoption of experimental public policies is crucial for NPG, since it enables the various actors to test new patterns of action and eventually structure long term policies (Ravazzi 2018).

3. The Living Lab

3.1. From Labs to Politics: The Birth of LL

Over the past three decades, the concept of LL has gained attention among policy-makers, academics, and private-sector organisations, taking on very different interpretations according to the context of application (Dutilleul et al. 2010). Along the way, various meanings have marked the emergence of the concept. According to recent literature, LLs can take on different meanings and be interpreted as research methods, learning environments or policy tools (Leminen et al. 2017b). As research methods, LLs provide unique study spaces with real-life settings, allowing scientists to avoid the artificiality of traditional laboratories. As learning environments, LLs ensure inspiring sites where businesses, academies, associations, and public administrations can share valuable knowledge to improve solutions that address place-based needs. As policy tools, LLs are gaining importance for addressing complex problems in real-life contexts. Given the different facets, it is important to provide a brief history of LLs, in order to understand how over time they have gradually emerged as policy devices used at different scales by policy-makers to undertake innovative environmental and social policies.

Theorized during the 1990s in the domains of technology and urban planning, LLs were considered innovative methods of study based on testing prototypes in real-life contexts through various techniques of user involvement (Mulvenna and Martin 2013). As practical user-centric research methodologies, LLs took their first steps in 1999, when William Mitchell at the Massachusetts Institute of Technology (MIT), considered the founding father of the LL, conducted an in-depth study focused on the everyday use of technologies in workplaces and private homes. Mitchell assumed that users could play a key role in designing, prototyping, and assessing complex solutions in heterogeneous and evolving real-life contexts (Eriksson et al. 2005).

In the 1990s, due to the increasing interest in identifying customers' needs expressed by private-sector organisations, the user-centric method traversed academic boundaries

to be applied in market strategies. Multinational corporations in the mobile technologies industry considered the LL a useful tool with which to refine products before their entry into the market. In 2002, together with the Municipality of Helsinki, Nokia decided to promote an LL in the eastern part of the city, focused on testing handsets in a pre-commercial phase to collect users' feedback. Meanwhile, European institutions at various levels began to structure projects, action plans and development programmes built on LL methodology. In 2005 the European Union (EU) launched the Sixth Framework Programme with the purpose of fostering public innovations by means of new modes of action and configurations of governance. When drawing up the Helsinki Manifesto at the end of 2006, the EU explicitly pointed to LL as a promising tool of public policy with which to put institutions and companies in direct communication with citizens and research (European Union 2006). According to European strategies, LLs were innovative forms of a public–private–people partnership (4Ps) where citizens were not only involved in developing products and services but also engaged in co-producing and evaluating policy processes. In that framework, public institutions, academia, companies, and citizens were supposed to furnish different kinds of resources with which to build effective LLs. Public authorities had to promote and create safe conditions for experimentation, providing real-life contexts in full compliance with public space regulation (Leminen et al. 2012). Companies had to spend time and economic resources on taking territorial peculiarities into account, and planning effective strategies of engagement. Academics had to guarantee a reliable assessment of scientific and ethical implications by using the expertise and knowledge resources at their disposal. Finally, citizens were asked to spend their time and knowledge on testing products, co-producing innovative services, and experimenting with unconventional solutions (Mengual et al. 2018). Adopting these lenses, the institutions proposed a new procedural policy instrument potentially able to tackle new policy problems in an experimental way. Nevertheless, its practical implications as well as its theoretical features remained unclear and rarely investigated, attracting the attention of the public policy literature.

3.2. LLs in Europe: The ENoLL Platform

Although still difficult to distinguish and classify, the laboratories started to stimulate close collaborations among European administrations that chose to adopt them in different policy areas. Since the Sixth Framework Programme, as explicitly indicated by the Finnish Presidency of the European Union (2006), chaired by Matti Vanhanen, they began to be considered integral parts of European long-term policies aimed at boosting innovation and sustainable development. At a practical level, they gained momentum on the political agendas relying on the Horizon 2020 funding project proposed by the European Commission to underpin and support local governments in sustainable transitions (Simay 2017). On the wave of the renewed cooperative framework, the ENoLL (European Network of LivingLabs) platform was launched in 2006 as an international non-profit association aimed at collecting experiences and creating partnerships among public and private actors interested in LLs. The ENoLL was deemed to be a fruitful channel for sharing experiences and exchanging information (Kallai 2006). Among its many activities, the association opened up the academic debate on LLs and initiated a process of data collection and mapping of experiences. Even if the database has not included all the living laboratories in the world, it has furnished an interesting picture of LLs dissemination. Since its inauguration, ENoLL has certified more than 440 LLs, creating an intercontinental network capable of crossing European borders. Overall, 17% of the network consists of non-EU countries (Paoni 2017). Focusing on the Old Continent area, there are currently 131 laboratories registered on the platform, well distributed on the territory, with peaks of concentration in France, Spain, and Italy. Having spread throughout the continent, LLs have captured the attention of public policy scholars, who were initially reluctant to interpret laboratories as a topic worthy of study. The term LLs has thus gradually shifted from being perceived as an ambiguous

label alongside innovative private sector projects to becoming an integral, albeit somewhat problematic, part of policies.

3.3. Utilizer, Enabler, Provider and User: The Categories of LL

Due to their heterogeneity, LLs have proved difficult to categorise. Therefore, a though LLs are widespread, the literature has not yet systematized them within a public policies framework. However, scholars are trying to put order between the various experiences classified as LLs. Leminen et al. (2012) proposed a categorisation of LLs based on four variables (organization, action model, outcomes, and implementation period) which led to distinguishing four types of LLs: utilizer-driven, enabler-driven, provider-driven, and user-driven. In Leminen's categorisation, LLs are conceived as measures able to act in several areas of development policy. The utiliser-driven LL is used in the field of technological innovation for private productive sectors. The enabler-driven and the user-driven LLs act on a local scale to solve problems identified by citizens with a territorial character. The provider-driven LL aims to promote innovation in research by offering a development opportunity to universities and research institutes. While this categorisation offers ideal types that in reality are partially disregarded, the theoretical model makes it possible to retrace the key shared characteristics of LLs as identified by (Nesti 2017):

I. the "quintuple helix" or "horizontal" governance pattern (composed of public administration, entrepreneurial sector, research world, citizen consumers/users, and natural environment) as a further enlarged public–private interaction modality compared to the triple or quadruple helix model formulated for innovation policies. In this unique configuration of governance, the natural environment is considered in all respects an actor capable of generating knowledge and stimulating synergies between economy, society, and politics (Baccarne et al. 2016), the strong link with the open innovation concept, which assumes that knowledge is rooted in society and that innovative solutions to contemporary problems should be also based on the expertise of external actors, such as other organizations or civil society. LLs can boost innovation processes, enhance empirical research, temporarily improve users' lives, and support the PA in overcoming routine and refining administrative barrithe
II. The iterative approach to co-production based on a step-by-step development in the conception and innovation of products and services as potentially exploitable to intervene on wider public issues. It entails a systemic and repetitive process of co-design and co-creation with users to enable experimentation with a prototype in real contexts; finally, it entails an evaluation of the impact proposed by the innovation.

As regards the distinctive features that characterize LLs as policy tools, their attitude to multi-directionality seems to distinguish them from the other substantive instruments. The traditional toolkit of substantive instruments is based on unidirectional flows of action with no real user-engagement. Through direct delivery systems, regulations, or proven incentives, governments mobilize material resources and wait for the adopted stimuli to take effect: direct provision offers the unilateral supply of a service, without any response from the users concerned; regulatory tools fix new rules by setting limits and imposing duties, which have to be monitored by judicial authorities; even in the case of incentives and communication campaigns, public actors implement their action top-downwards, in an attempt to steer the market or affect the choices of citizens, businesses and associations (Benkert and Netzer 2016).

With regard to these dynamics, the LLs seem to draw peculiar tools of policy, where all actors are expected to act but also to gain some benefits through a tentative process that incorporates a certain degree of improvisation. Public agencies are supposed to speed up the bureaucratic process and identify suitable types of contract, but exactly how they can do so is not planned a priori. Promoters, enablers or partners are expected to set up some sort of unconventional collaborations, but the form of these collaborations is not set up in advance. Companies are committed to developing devices in a real-life context, with a consequent expenditure in terms of economic and time resources; citizens take action to

co-design, co-implement and co-evaluate the goods and services tested; academics analyse the development of goods and services in the real context and the dynamics triggered by the process. In the meantime, all of the actors involved should gain something from the tentative process. By means of LLs, public institutions have the chance to innovate policy making by incorporating the most promising solutions and enhancing their policy capacities; companies can benefit from a unique market context to refine their prototypes and enlarge their networks; academics can rely on a privileged context in which to conduct research and development activities; citizens can participate more actively in policy making and co-create solutions related to their specific needs (McGann et al. 2021).

Although LLs fall fully within the procedural perspective of co-production, they display properties that qualify them to be considered as instruments in their own right. Differently from other procedural instruments, LLs can achieve meaningful results in terms of policy impact only if user engagement in real-life setting is not merely symbolic, and it takes place in a spontaneous way (Sauer 2012). A genuine process of user engagement within LLs can speed up innovation processes and ensure a deeper understanding of real-life situations where new policy solutions are proposed and tested (Compagnucci et al. 2021). To accomplish this, citizens should see the LLs as an opportunity to take part in formulating and testing policies that can actually respond to site-specific needs. When user engagement occurs naturally, LLs can then represent unique arenas for civic participation where the meaning and boundary of collective problems can be reframed (Leminen et al. 2017a). Moreover, the propensity to accept a certain degree of randomness seems to characterize LLs in that the process, and the expected results are not defined in advance. The PA does not know in advance the quality of the experimentations; nor is it able to forecast the response of citizens or the indications that may emerge from the academic world (Burbridge 2017). In other words, LLs are adopted by public authorities in the hope that a certain degree of randomness may provide fertile ground for entrepreneurial, social, and academic innovation. The tool is somehow a "black box" into which actors can inject inputs without exactly knowing the process and final outputs.

4. The Circular Economy

4.1. A Historical Overview of the CE

On a global scale, the CE is receiving increasing interest as a valuable alternative to the current production and consumption pattern based on continuous growth in terms of exploitation of natural resources, energy demand, and land use (Ghisellini et al. 2016). Because of the huge variety of research fields, stakeholders, and policies associated with the CE, semantic boundaries are not fixed, and many definitions can be given according to the perspective adopted (Ddiba et al. 2020). Although the ambiguity of the term has generated both criticisms at the theoretical level and difficulties in policy making, there is a certain consensus on the roots and principles of the CE (Kirchherr et al. 2017).

According to (Stahel 2020), circularity has always characterized the history of the Earth, expressing itself in two particular forms: nature and mankind. By its nature, the Earth is regulated by a set of cyclical ecosystems where the organic waste of one species can be a source of nourishment for others. Circularity is therefore the basis of any form of life, as a dynamic essential to achieve equilibrium in feeding processes. In a similar vein, the literature has pointed out that circularity in exchanging materials and products has taken place in every form of economy undertaken by mankind throughout history, from ancient societies to the contemporary age. In the barter economy, individuals exchanged raw materials and manufactured products, relying on the necessity to satisfy primary needs (Stahel 2020). In the industrial society, households furnished their labour to firms in order to obtain incomes and enhance their capacity to purchase goods and services (Cardoso 2018). Hence, the production system was interpreted as a cycle, where entrepreneurs and workers were dependent on each other's work.

On examining the historical origins of the CE concept, several authors have traced its roots back to the François Quesnay's "Tableau Economique" (1758) and his claim on

surplus value from cyclical inputs (Reike et al. 2018). When agricultural productions were investigated, the tableau model depicted an economic system where equilibrium was achieved normatively by a circular flow of inputs and outputs (Schachter 1991). Quesnay assumed that there is no distinction between productive factors and goods, due to the circularity of a stationary state inter-class system of exchange, where nothing is wasted, and every output is re-injected into the production–consumption process (Bilginsoy and Khan 1994). Other scholars have linked the CE to Thomas Malthus' assumptions on world population growth and responsible management of natural resources (Lacy and Rutqvist 2016). In 1798, Malthus warned that the limited amount of agricultural land could not produce sufficient food to keep up with the exponential growth of the world's population. According to the English cleric, in the long run, governments must revise resource stewardship in order to ensure environmental recovery capacities and preserve humanity's future (Blomsma and Brennan 2017).

Moving beyond the heated debate about historical and philosophical roots, the contemporary literature has pointed out that the CE incorporates different features and arguments from a wide variety of scientific fields that share the idea of "closed loops" (Geissdoerfer et al. 2017). Among the many schools of thought, three seem to have had the greatest influence on the current conception of the CE: ecological economics, cradle-to-cradle theory, and industrial ecology. Because the CE has drawn meaningful aspects from each of them, a brief overview of these fields is required to provide a comprehensive framework. Taking cues from milestones as "The Silent Spring" by (Carson 1962) and "The Economics of the Coming Spaceship Earth" by (Boulding 1966), ecological economists, such as (Turner et al. 1993), have contested the misleading contentions of traditional economists who have always conceived environment and economics as two different and autonomous systems. They have recognized the biophysical limits and natural constraints of the environment to propose an alternative model of economics based on sustainable systems, fair distribution, and efficient allocation of resources (Costanza 1991). Eventually, providing meaningful insights for the development and refinement of the CE concept, they highlighted the necessity to shift from a throughput-based, open-ended economic system to a circular one aimed at preserving biodiversity, preventing climate change, and defending ecosystems (Bruel et al. 2019).

Coined by Walter Stahel in 1976, the expression "cradle to cradle" has been elaborated by McDonough and Braungart (2002) to resume the necessity to shift from eco-efficiency initiatives aimed at cutting down environmental impacts through recycling to "upcycling" practices intended to re-adapt discarded products and increase their use value. From the cradle-to-cradle perspective, designers can play a key role in "paving the way" for a reframing of business strategies on the basis of a guilt-free approach (Bakker 2010). This approach seeks to trigger sustainable manufacturing practices that rely on both preventing waste generation and extending producer responsibility in the recovery and recycling of chemical materials, plastics, glass, and heavy metals.

Industrial ecology was formally born at the end of the 1980s, when the scientists (Frosch and Gallopoulos 1989) metaphorically compared industrial and commercial enterprises to biological ecosystems, in the sense that the outputs of one industry can be used as inputs by another. Ranging from management engineers to materials chemists, scholars engaged in this field of inquiry have sought to understand how industries work, how they are managed, and what their interactions with ecosystems are (Erkman 1997). Industrial ecology studies have focused on investigating and demonstrating the unsustainable levels of industrialized societies' physical metabolism (Schiller et al. 2014). Eco-design tools have been used to consider environmental throughput into product and process design to reduce the costs and environmental impacts (Ghisellini et al. 2016). From a policy perspective, industrial ecologists have supported initiatives of producer responsibility extension, lifecycle planning, and decarbonization, to make industrial systems compatible with the biosphere function.

4.2. Principles of the CE

Nowadays, the CE is usually presented in opposition to the "linear" economy, based on a "make-use-dispose" consumption paradigm. Environmental economists, policy analysts and industrial engineers regard the CE as a way to overcome the post-extractivist society and transition to a sustainable socio-economic system (Savini 2021). The CE is deemed to be a positive model of development where natural resources are conserved and enhanced, minimizing systemic risks by handling finite stocks and renewable flows to reduce environmental impacts (Saavedra et al. 2018). The circular approach entails an alternative economic paradigm in which the production, distribution and consumption phases are designed towards the reduction in environmental impact by closing resource flow loops (D'Adamo 2019). Besides the purely environmental aspect, many authors have pointed out that the circular approach is expected to generate important benefits in social terms by impacting several social policy areas such as food security, employment, social inclusion, and gender equality (Geissdoerfer et al. 2017; Padilla-Rivera et al. 2020).

Nonetheless, the notion of the CE has proved to be controversial and blurred. In order to make it more comprehensible, over time, many authors have attempted to summarise a CE's main operationalization principles (Jawahir and Bradley 2016). To this end, models based on "Rs" principles" have been reformulated several times in many research fields. In explaining what to do, scholars have used a range from 3 Rs to 10 Rs relying on very different hierarchies, which have often created further misunderstandings and controversies between researchers and policy-makers, both engaged in designing common targets (Morseletto 2020). In an attempt to clarify matters, Reike et al. (2018) have provided a comprehensive model of CE based on 10 Rs:

R.0. Refuse: this consists of the preliminary choices made by consumers and designers to use less of a product and design it better in order to avoid waste. For instance, it may concern the rejection of either/both overpackaged products or/and the use of virgin materials.

R.1. Reduce: the cutting down of waste is the starting point as well as the final aim of the CE. Consumers are expected to review their habits to reduce their impact on the environment by using and buying less harmful products. Designers are expected to use less material per unit by 'dematerialising' production processes.

R.2. Reuse: this is the main pillar of the CE. It is to be placed before any initiative that foresees an intervention on the finished product. Consumers may prefer to buy second-hand or share some products to make the most of them and increase their durability.

R.3. Repair: this may concern consumers, producers, and designers as well. Consumers can activate good neighbourhood practices that involve object and knowledge sharing to increase the durability of products through their repair. Producers should ensure reliable repair channels, replacing planned obsolescence with ad hoc repair offers for their products. Designers play a key role in planning the reparability and modularity of products.

R.4. Refurbish: this mainly concerns the construction sector. Renovation using unused or second-hand materials should be facilitated. The modularity of buildings could facilitate this endeavour.

R.5. Remanufacture: this entails industrial practices of disassembling, checking, cleaning, and replacing. It aims at guaranteeing "a better than new condition" of products under treatment. Remanufacturing may generate high-skilled jobs in several sectors, such as automobiles, medical equipment, and restaurant furniture.

R.6. Repurpose: this means reusing materials and products for another function. In some cases, repurposing practices may lead to an upcycling of the product, increasing its use value.

R.7. Recycle: this is based on the industrial treatment of a wide variety of postconsumer and post-producer waste flows. Ranging from mechanical techniques to chemical or feedstock recycling, it relies on technological practices of collecting, shredding,

melting, etc. In the CE framework, recycling is not considered a solution to reduce environmental impact, but rather as the result of a choice made at the design stage and aimed at preserving the use value of the products as long as possible (Ghisellini and Ulgiati 2020).

R.8. Recover: this involves the recovery of energy from discarded products. The most common example being that of waste-to-energy plants able to convert organic waste into methane gas or electricity.

R.9. Re-mine: this concerns the recent techniques for the recovery of discarded materials in landfills. Currently, it is mainly applied on an urban scale to extract metals to be reintroduced into the production process.

Although the above principles have a strong influence on institutional narratives about sustainable transition, the concept of the CE has attracted a great deal of criticism and demonstrated operational shortcomings that need to be addressed to provide a comprehensive overview on the issue.

4.3. Criticisms and Limits of the CE

The growth and spread of the CE concept has induced academia and research institutes to reflect not only on its origins and principles, but also on its weaknesses and limitations (Zink and Geyer 2017). Many authors have pointed out the need to question and problematize the narratives concerning the CE, which is often deemed to be self-celebrating and lacking a critical analysis of the environmental and social problems at stake (Hobson 2020). According to (Korhonen et al. 2018), there are still clear differences and boundaries among research sectors involved in CE studies, with the consequent lack of a holistic approach. Many doubts and questions concern the degree of robustness and maturity of the concept. In an attempt to systematise critical analysis concerning CE, (Korhonen et al. 2018) have identified six main limits: I. thermodynamic limits; II. system boundary limits; III. limits imposed by the physical scale of the economy; IV. limits imposed by path dependency and lock-in; V. limits of governance and management; VI. limits of social and cultural definitions.

First, according to the second law of thermodynamics, every action requires energy and generates wastes and side-products. This implies that in any recovery or recycling initiative there is a dispersion of energy and an increase in entropy, which leave some kind of output in the ecosystems.

Second, the perfect circularity of the production system requires a holistic vision at a spatial and temporal level, which is not possible in contemporary society. Natural resources, as well as the means and knowledge of recovery and recycling, belong to government structures that are not always willing to act in a global perspective. Over time, the extension of product durability can have negative impacts, fuelling the exploitation of non-renewable resources and linear production models.

Third, the rise in circular production systems may cause a rebound effect. Being able to produce the same quantity of products, with less impact in environmental terms, could encourage economies to increase production. Moreover, the circular economy, relying on the reuse and remanufacturing of second-hand materials and products, has a high level of uncertainty. Not being able to rely on stable and quality resources, the economy could jam and create a boomerang effect accompanied by temporal, quantitative, and qualitative supply uncertainty (Goltsos et al. 2019).

Fourth, path dependency could affect the CE because new reuse, remanufacture and redesign models have to cope with conventional recycling chains embodied in market dynamics. This may be an insurmountable barrier in many market sectors, where the pressures and interests at stake to maintain the same production and recycling methods are too strong. A wholesale shift in terms of circularity necessitates deep changes in lifestyles, social interactions and systems of production, distribution, and consumption, which require a strong and genuine support from politicians (Williams 2021).

Fifth, at a global level, there is still a lack of inter-organizational strategies able to ensure sustainable management of the whole production and consumption chain. This creates problems and uncertainties in the distribution of responsibilities, affecting the introduction of circular models (Korhonen and Snäkin 2015). Sixth, on a formal and statistical level, there is still little recognition of categories such as reuse rate, redesign and remanufacturing. This makes it difficult to plan long-term CE policies which could be implemented uniformly in different contexts. For instance, the management of plastic packaging involves very different recycling and recovery cycles according to the different definitions of waste adopted by the institutions (Peiró et al. 2020).

These limitations have had an impact on policies to stimulate the circular economy. At very different scales, interesting initiatives have appeared; nonetheless, there is a lack of a systemic approach to guarantee that the actual environmental outputs of the CE comply with broader strategies of sustainability (Zink and Geyer 2017).

5. Circular cities and Urban Living Labs

5.1. Global Strategies for Circular Cities

Cities are considered to be the main drivers of contemporary economic growth, with disruptive consequences on the environment (Crouch and Le Galès 2012). According to the United Nations (2015), cities are expected to host 66% of the world's population by 2050, generating a continuous increase in consumption and in the amount of resources and materials needed for their sustenance. Nowadays, urban areas generate 70% of the global greenhouse gas emissions, consume 75% of natural resources, and produce 50% of global waste (Chen 2020).

Consequently, institutions around the globe look at cities as key scales of policy action to promote circularity at various levels (Petit-Boix and Leipold 2018). In 2016, the New Urban Agenda of the United Nations, as an extension of the 2030 Agenda for Sustainable Development, officially established the goal of creating circular cities, considered as areas capable of reducing consumption and defending their natural, human, and social capital from underutilisation or waste (Fusco Girard and Nocca 2019). Cities are deemed to be promising contexts in which to design adoptable visions of the future, using experimental approaches, enhancing contextual knowledge about resource management, and engaging diverse stakeholders in circular policies (Prendeville et al. 2018). Despite these shared assumptions, the reality of urban policies supporting the circular economy appears to be very fragmented among continents.

Since the first decade of the 2000s, China has been building an urban circular economy strategy by means of first implementing the "eco-cities program" of the Ministry of Environmental Protection (MEP), which started in 2003, and then the one for "low carbon cities", launched in 2012 by the Ministry of Housing and Urban Rural Development (MOHURD). Through these programmes, the national government has set precise goals to address climate change in cities, increasing the public support for a variegated range of urban experimentation practices (Chang and Sheppard 2013). As a result, in the cities of Dalian, Beijing, Shanghai and Tianjin, several successful pilot projects have been undertaken in recent years. Their focus has been on the reuse of resources and space, reducing consumption, and cutting primary energy demand (Su and Ang 2013).

Owing to the lack of consistent and shared policy strategies among different levels of public institutions, circular policies in North America are rarely turned into practical interventions on a city scale (Veleva and Bodkin 2018). As a result, circularity in the USA and Canada is still mainly promoted by private corporations, which have triggered a proliferation of eco-industrial parks far from urban areas (Winans et al. 2017). Nonetheless, several key players in the US economy, such as Nike and Google, have recently announced their commitment to strengthening collaboration with urban governments in order to promote the circular economy in cities (Stahel and MacArthur 2019). Moreover, the new federal administration, led by Joe Biden, has stated its commitment to promoting the

circular economy, moving beyond green-washing attempts, and maximizing the incentives for closed loop solutions at different scales of policy (Kenway 2020).

In Latin America, the Manizales Manifesto, signed in 2017, declared the shared commitment of 850 urban policy-makers and practitioners to the development of resource-efficient 'Circular Economies and Smart Sustainable Cities' (Wesely 2019). Among the ten main actions envisaged by the Manifesto, one explicitly concerned bringing the circular economy to life on a city scale by improving the efficiency of production, recycling processes, and management of waste. Although there is still a vacuum in terms of concrete national policies to support cities' efforts, the growing interest in the CE has led to the proliferation of urban experimental schemes, such as in Medellin (Colombia), Buenos Aires (Argentina), and Mexico City (Mexico), aimed at combining environmental and social equity objectives (Betancourt Morales and Zartha Sossa 2020). The situation in the African continent is markedly diversified among countries. Urbanization is generating increasing pressure on the water supply, food system, and sanitation services at a city level. However, in most cities, there is no consistent planning of urban circular economy policies, and initiatives to reuse and recycle resources are mainly promoted by NGO programmes. Differently, national governments of some developing countries, such as Nigeria, South Africa and Kenya, have recently recognized in their official strategies the necessity to consider cities as pivotal actors to support appropriate and context-specific circular development. This effort has unleashed a proliferation of urban experiments designed on the basis of urban metabolism concepts and focused on food and water recovery (Oke et al. 2021). In Australia, "the 2018 National Waste Policy" has stressed that local governments are playing a key role in promoting circularity through procurement practices, proposing waste management innovations, and supporting bottom-up initiatives focused on the transition towards a circular economy (Flowers 2021). As stressed by several authors (Bolger and Doyon 2019; Stephan et al. 2020), the city of Melbourne can be considered a model of circular experimentations supported by a robust local strategic plan.

5.2. European Cities in Transition

The circular economy appeared for the first time in European Union policy in 2014, in the 'Communication Towards a circular economy: A zero waste programme for Europe' document, as a development strategy able to combine economic growth with waste reduction (Kovacic et al. 2019). At that time, the concept of circularity was still in its infancy, and no specific space in the document was devoted to the role of cities. Nowadays, European institutions have officially included urban policies within the most recent programmes for transition to the circular economy. From an institutional perspective, European cities are considered the most active players in promoting the circular economy and facilitating changes in urban lifestyles and consumption patterns, generating positive outcomes in terms of economic and employment recovery (Fratini et al. 2019). The circular economy is supposed to reduce waste by 17–24% by 2030, increasing the European Gross Domestic Product (GDP) by EUR 630 billion per year (Lazarevic and Valve 2017). Partly due to their growing dependence on European funds allocated through the Horizon 2020 programmes, circularity has become a primary objective for European cities (Vanolo 2013). To achieve the 2030 Sustainable Development Goals, the European Commission has inserted circular strategies for cities as one of the main pillars of both the European Green Deal and the Circular Economy Package, which aim to make the European Union the first climate-neutral continent by 2050 (Montanarella and Panagos 2021). At the end of 2020, the Green City Accord launched a specific challenge for European cities (European Commission 2020, p. 1):

> "By 2030, cities will be attractive places to live, work and invest in, and will support Europeans" health and well-being. All Europeans will breathe clean air, enjoy clean water, have access to parks and green spaces, and experience less environ mental noise. The circular economy will become a reality and waste will be minimized thanks to greater reuse, repair and recycling."

The Accord invites city governments to pursue five main objectives to transform cities in accordance with CE principles. First, cities are supposed to improve air quality by no longer exceeding EU pollution standards. Second, municipalities should enhance the quality of water management, and strengthen the efficiency of water recovery and purification processes. Third, urban areas should preserve urban biodiversity by extending green areas and regenerating unused spaces through green infrastructures. Fourth, cities should work specifically on circular initiatives of re-use, repair and recycle in the management of waste collection and landfilling. Fifth, cities are required to cut down on noise pollution to comply with standards recommended by the World Health Organization.

Beyond narratives and formal announcements, municipalities across Europe are proposing a broad array of policy tools to embrace circularity. At the urban level, circular economy actions are often confused and overlapped with those related to sustainability, sustainable development, and social innovation (Fusillo et al. 2021). Nonetheless, many urban governments, such as those of Amsterdam, Glasgow, Helsinki, and Lisbon, have announced their ambition to become "circular beacons" and transform their territories into experimental areas open to circularity. To support the transition, cities have begun to renovate their policy portfolios, combining more traditional substantive tools (laws, green public procurements, incentives, etc.) with procedural measures (public–private agreements, public de bates, strategic plans, etc.). To improve their expertise in stimulating circular practices, municipality are increasingly relying on citizen engagement to understand community needs, develop environmental awareness, and propose shared solutions for tackling complex problems (Williams 2019). Indeed, the cultural heritage, knowledge and creativity of citizens are considered key resources for transforming cities in circular perspective (Foster and Saleh 2021).

In this endeavour, some European cities have gradually linked the topic of circularity to co-production tools, in order to test how citizens can actively participate in the creation of circular economy policies on an urban scale.

5.3. Testing Co-Production Tools for Circular Cities

Since the launch of Local Agenda 21 in 1992, city governments have sought to build new institutional approaches to foster sustainability by means of experimental processes based on citizens' engagement (Ningrum et al. 2022). Nowadays, these dynamics have led to the close intertwining on a practical level of two different policy concepts: co-production and urban experimentation. European cities regard new policy tools of coproduction as promising ways to bridge different fields, sectors, and scales, thereby opening up new political opportunities and pro posing unconventional policy patterns (Rocle and Salles 2018). In the realm of the circular economy, the two terms have blended and proliferated in a wide range of demonstrations and pilots. On the one hand, municipalities across European countries assume that co-production can create user empowerment opportunities to improve the quality of services, transforming local policies in a more democratic way (Nesti 2015). Co-production consists of a wide array of processes by which citizens can assume an active role in providing public goods and services (Cataldi 2015). In the field of circular policies, users' participation is expected to broaden the perspective of local governments by suggesting unconventional patterns of production and delivery of services inspired by circularity principles. The recent literature on environmental policies stresses the role of co-production in identifying problems and proposing institutional changes towards the circular economy (Van der Molen 2018). On the other hand, urban experiments are considered to be promising initiatives focused on designing new physical spaces to re-shape problem definitions, question traditional policy making, and revise conventional assumptions on the circular economy (Von Wirth et al. 2019). Urban experiments can stimulate policy learning processes by offering protected niches within which to arrange tools, resources, and stakeholders' dynamics to propose changes, and subsequently assess and learn from those experiences. In this framework, urban governments assume that the innovative potential proposed by community-based associations, start-ups, and

bottom-up initiatives can help to redefine policies related to circularity items ranging from no-consumption mobility and energy use systems, to waste recovering and alternative agriculture (Savini and Bertolini 2019). Consequently, more and more governance and policy experiments are being conducted in cities to explore new arrangements relating to circularity, and to produce broader changes in urban policies (Rocle and Salles 2018).

5.4. Urban Living Labs

In recent years, one of the policy tools that has been deemed to most effectively combine the co-production approach with urban experimentation is the Urban Living Lab (ULL). ULLs are physical sites where co-production initiatives take place, engaging local governments, researchers, private businesses, and users in a real-time process of learning and developing (Steen and Van Bueren 2017). According to (Voytenko et al. 2016), ULLs are emerging as a co-production policy tool able to boost experimentation in ways such to address the circularity challenges and sustainability issues generated by urbanisation. Accordingly, ULLs are deemed to be different from other policy tools in terms of geographical embeddedness, experimentation and learning, and participation and user engagement. First, ULLs have a geographical connotation, being located in defined real-life urban contexts. Through shared or legal agreements, local governments provide public spaces for experimentation in the design of ULLs located in a single neighbourhood or street, or throughout a city. ULLs consist of a wide range of place based initiatives which seek to deal with global issues on a very fine-grained local scale (Marsh 2008). These experiments tackle wicked problems, such as circularity challenges in spatially embedded sites, by seeking to scale up solutions or produce systemic policy impacts (Puerari et al. 2018).

Second, ULLs explicitly experiment with horizontal governance models or unexplored policy paths to address the issue of circularity by means of shared and alternative strategies. In this sense, ULLs propose solutions that are genuinely innovative and bring together urban policy actors in an unconventional way. The experimental governance configuration is expected to trigger learning mechanisms for all the stakeholders involved—local governments, academia, companies, and citizens—thereby generating promising ideas to build long-term circular policies in waste management, space and service sharing, and reuse of products.

Third, ULLs have to offer unique arenas of citizens' participation in urban policy making. Hence, co-production is identified as the leading approach in ULLs to provide effective opportunities for the co-design, co-implementation, and co-evaluation of circularity experiments. ULLs have to be based on user-driven or human-centred methodologies to engage citizens in a participatory process. Accordingly, ULLs are characterized by the proposal of co-production activities as one of the main goals rather than as a simple policy approach. The horizontal governance established with residents and community-based associations is supposed to trigger reflection on the concrete meaning of the circular economy and whether it could be included in the policy agenda.

Finally, ULLs are considered to be experimental devices able to reframe policy problems and propose a broader toolkit of potential solutions to policy-makers (Lewis et al. 2020). Nonetheless, their capacity to overcome consolidated practices and bureaucratic constraints, as well as their systemic impacts on urban long term policies, are still understudied. Therefore, public policy analysis is starting to explore the implications of this tool for circular economy policies through the use of case studies.

5.5. Potentials of ULLs in Circular Transition

ULLs are deemed to be promising test-bed tools with which to adapt and transfer circular principles stemming from Reike's model to the urban scale. According to recent literature, laboratories could support a systemic approach because they are able to activate both consumers and producers in the development of solutions built on the 10 Rs. Based on citizen involvement, several cases of ULLs have been proven to foster refusing, reducing,

reusing, and recovering practices (R0–R3), and to trigger social, economic, and environmental changes in cities (Engez et al. 2021). In Ireland, the Dublin City Council Living Lab has promoted 'The Bike Hangar

Beta Project', which is dedicated to encouraging the use of bicycles, and to spreading the refusal (R0) of polluting means of transport by citizens (Perng and Maalsen 2020). Through a five-month participatory process, citizens designed a multifunctional bicycle hangar considered to be a necessary infrastructure to allow people to easily 'give up' using cars. In Finland, the Forum Virium Living Lab, led by the City of Helsinki, has enabled innovative companies to test practical solutions aimed at reducing pollution (R1) in the Jätkäsaari neighbourhood (Spilling et al. 2019). Through pilots, the Forum Virium has enabled small and medium innovators to develop prototypes focused on environmental impact reduction and, at the same time, propose potentially scalable initiatives. The U-Lab in Bologna (Italy) has launched participatory events in the city's university area to stimulate new practices of adaptive reuse of facilities (R2), alternative management of private spaces, and sharing initiatives among citizens (Giglio 2020). In that context, the U-Lab has underpinned reusing activities as an integral part of the wider strategy of co-design proposed by the Municipality to transform the university area into a cultural, creative, and sustainable district. The European project "RePair" (Resource Management in Peri-Urban Areas) has funded six peri-urban living labs based on experimental design and repair schemes (R3) to foster broader strategies for CE in Amsterdam (the Netherlands), Ghent (Belgium), Hamburg (Germany), Lodz (Poland), Naples (Italy) and Pecs (Hungary). In those labs, the principle of repair has been applied to the building sector, to recover and regenerate unused spaces, avoiding the deployment of new resources for further construction (Cerreta et al. 2020). In Turin (Italy), the ULL of the European project proGiReg (Productive Green Infrastructure for Urban Regeneration) has included the experimentation of seven NBS (Nature Based Solution) in the Mirafiori Sud district. One of them has entailed the refurbishment (R4) of "Casa nel Parco", a pole-functional centre, through the installation of a green roof, which has enhanced the structure's energy performance, improved air quality, and saved resources needed for other types of restoration. The City of Riga (Latvia) has set out re-manufacturing activities (R5) as cornerstones of its strategy aimed at turning the urban environment into an open laboratory for circular economy innovations (Santonen 2016). The proGiReg (productive Green Infrastructures for urban regeneration) ULL in Turin has tested an experimental product, through a 'repurposing' process, namely a 'new regenerated soil', a mixture of excavated earth, compost, and zeolites, able to upcycle waste from the construction sector (Ascione et al. 2021). In Malmö (Sweden), the Stapeln living lab has underpinned a vast range of creative recycling activities (R.7) related to both industrial and craft sectors (Von Wirth et al. 2019). From 2015 until 2019, the City of Copenhagen promoted the EnergyLab Nordhavn—New Urban Energy Infrastructures—which focused on testing an integrated energy recovery system by means of efficient buildings, innovative heating, and electric transport (R.8). Eventually, the Manchester Metropolitan University conducted several experiments in waste management and re-mining (R.9) in order to understand urban gridlocks of waste process, monitor waste flows, and foster recovering activities from landfills.

6. Conclusions

ULLs are emerging as promising experimental co-production tools to tackle a large variety of complex problems on an urban scale. Among the many issues addressed, circularity challenges appear to be one of the policy areas in which such tools can achieve the most satisfactory results. Exploring case studies, this paper has shown how ULLs have stimulated relevant initiatives in all the 10 Rs of the CE, namely, refusing, reducing, reusing, repairing, refurbishing, remanufacturing, repurposing, recycling, re-mining actions. In very different cities, ranging from Dublin to Naples, ULLs have proven to make in practice collaborative configuration of governance able to trigger positive cooperation mechanisms between municipalities, companies, research bodies and local communities. In full compli-

ance with the 10 principles of the CE, they have succeeded in fostering the creativity of a vast array of urban stakeholders interested in reintroducing waste into the production and consumption cycle, reducing the environmental impact on a city-wide scale. Although this systematic review has offered preliminary insights regarding the nexus between ULLs and CE, three main questions still remain open and need further clarification.

First, so far, case studies analysis has focused on describing ULLs without fully investigating whether such policy instruments may generate significant shifts in the ordinary long-term CE policies of municipalities. In this regard, it remains to be seen to what extent the experimental collaborative governance of ULLs can represent a permanent pattern of action capable of influencing policy agendas and institutional strategies. Second, it remains to be understood how far ULLs can represent effective policy devices to contest the traditional economic paradigm and overcome the linear approach of 'take-make-dispose'. In fact, although these instruments are increasingly widespread in many cities, they usually conserve a well-defined spatial connotation within urban boundaries and rarely manage to engage national institutions and large private actors capable of making real changes in production and consumption systems. Third, it seems necessary to more closely examine the extent to which ULLs can foster the participation of citizens and local communities in the construction of circular policies. Citizen engagement in ULLs raises important research questions about the ethical implications of participation. On the one hand, further investigation should be delivered to investigate whether engagement in ULLs is really open to all citizens, or whether some categories remain cut off from the experimental co-production process. On the other, it remains to be understood how much citizen engagement in ULLs is merely functional for temporary experiments, or whether it can truly represent a process of democratic civic participation in the construction of shared policies. Although these issues constitute important gaps in the analysis of the link between ULLs and the CE, they might represent fascinating research fields for public policy analysts. Further explorations on these topics can help to understand the real potential of such policy instruments in promoting genuine CE which explicitly aims at reducing waste in production and consumption.

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