This paper was presented at the XXXVII ISPIM Innovation Conference, held in Granada, Spain on 07 June to 10 June 2026. ISBN 978-952-65771-2-8.

Art, Co-Creation and Living Labs for Sustainable Innovation

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Abstract: Co-creation is widely recognized as a key mechanism for sustainable innovation, yet its depth varies significantly across living lab environments. This study examines 40 living labs, including virtual, hybrid, and place-based settings, to analyze patterns of co-creation and the role of artistic practices. Using qualitative analysis, the research develops a structured framework assessing co-creation depth, actor diversity, and stage involvement. The findings identify three modes of co-creation—technical, participatory, and strategic—and show that sustainability-oriented labs exhibit deeper and more inclusive engagement. Artistic and design-led practices are consistently associated with higher co-creation depth, particularly in early-stage processes such as problem framing and ideation. Rather than establishing causality, the study highlights how art operates within broader socio-technical configurations that enable reflexive and inclusive innovation processes. The paper contributes a typology of co-creation and offers insights for designing more effective living lab environments.

Keywords: Living Labs; Co-Creation; Sustainable Innovation; Virtual Living Labs; Art Thinking; Responsible Innovation; Digital Twins; Open Innovation; Stakeholder Engagement; Circular Economy

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1 Introduction

Living Labs (LLs) and Virtual Living Labs (VLLs) are increasingly used to address sustainability and innovation challenges. These environments are designed to enable multi-stakeholder collaboration, integrating users, firms, researchers, and public actors into co-creation processes embedded in real-life or digitally simulated contexts. Despite their promise, an emerging concern in both practice and research is that many VLLs exhibit limited depth of co-creation. Participation is often restricted to downstream activities such as testing, validation, or data provision, rather than involving stakeholders in early-stage problem framing, value negotiation, and strategic decision-making. This "instrumental participation" constrains the transformative potential of living labs, particularly in sustainability contexts where innovation requires not only technological solutions but also societal alignment, behavioural change, and long-term legitimacy.

At the same time, a growing body of work in design, art, and innovation studies suggests that artistic and design-led practices may offer alternative pathways for deepening co-creation. Such practices emphasize exploration, imagination, and meaning-making, enabling participants to engage with complex socio-technical challenges beyond purely functional or technical perspectives. In living lab contexts, artists and designers can act as boundary spanners, facilitating dialogue between heterogeneous actors and surfacing tacit knowledge, values, and future imaginaries.

However, empirical research on the role of artistic practices in living labs—particularly in virtual or digitally mediated environments—remains limited. Existing studies often focus on single cases, conceptual arguments, or physical living labs, while comparative analyses across multiple cases are scarce. Furthermore, there is little systematic understanding of how co-creation varies across different types of living labs, and under what conditions artistic practices are associated with deeper forms of collaboration. This study addresses these gaps through a comparative analysis of 40 living labs, including virtual, hybrid, and place-based environments operating in domains such as smart cities, sustainability, circular economy, and responsible innovation. The study adopts a qualitative methods approach, combining desk-based case analysis with a structured scoring framework assessing co-creation depth, actor diversity, and stage involvement across the innovation process.

This paper conceptualizes LLs as heterogeneous co-creation environments that vary significantly in purpose, governance, and participation intensity. This perspective allows us to compare virtual and non-virtual labs within a unified analytical framework, focusing on co-creation patterns rather than technological form alone.

The study is guided by the following research questions:

- How does co-creation vary across different types of LLs (virtual, hybrid, and place-based)?
- What patterns of co-creation depth, actor diversity, and stage involvement can be identified across cases?
- Under what conditions are artistic and design-led practices associated with deeper co-creation processes?

2 Conceptual Foundations of Living Labs and Co-Creation

2.1. Open Innovation, Living Labs and Virtual Living Labs

LLs are widely understood as user-centered, open innovation ecosystems integrating research and innovation processes within real-life contexts (Müller, 2026, Leminen et al., 2012). They enable multi-stakeholder collaboration and iterative experimentation, involving users throughout the innovation lifecycle. Building on this concept, VLLs extend co-creation into digitally mediated environments, using tools such as digital twins, simulation platforms, and collaborative online infrastructures. A Virtual Living Lab can be defined as a digitally enabled co-creation ecosystem in which stakeholders collaboratively design, test, and evaluate innovations in simulated or hybrid real-world contexts (Ballon et al., 2018; Schuurman et al., 2015). By leveraging digital infrastructures such as platforms, simulations, and digital twins, VLLs expand participation across geographical boundaries and enable scalable experimentation (Nambisan et al., 2017). However, they also raise important conceptual and practical challenges. In particular, recent studies suggest that many VLLs function more as testbeds or validation environments than as fully developed LLs. Participation is often limited to technical users, and engagement tends to be concentrated in later stages of the innovation process, such as testing and evaluation (Schuurman et al., 2015; Ballon et al., 2018). This observation echoes broader critiques in open innovation research, which highlight that user involvement is frequently instrumental and constrained rather than genuinely participatory (West and Bogers, 2014). Consequently, a critical question emerges: to what extent do such environments fulfil the core principles of LLs, particularly with regard to deep user involvement and real-life contextualization (Leminen et al., 2012, Müller, 2026)? Rather than treating all LLs as equivalent, this study adopts a continuum perspective, consistent with recent calls for more nuanced conceptualizations of LLs (Lakatos, 2024). This perspective distinguishes between: instrumental or testbed-oriented environments, characterized by limited co-creation; hybrid LLs, combining technical experimentation with participatory elements; and transformative LLs, enabling deep, multi-stage co-creation and stakeholder involvement across the full innovation cycle.

The concept of Open Innovation, introduced by Henry Chesbrough, has significantly reshaped the understanding of how organizations generate and commercialize innovation. In contrast to traditional closed innovation models, open innovation emphasizes the permeability of organizational boundaries and the strategic integration of external knowledge sources in the innovation process (Chesbrough, 2003; Chesbrough, 2006). Firms increasingly collaborate with external actors—including universities, startups, users, and public institutions—to access diverse knowledge bases and accelerate innovation development (Bogers et al., 2017; West & Bogers, 2014).

Within this paradigm, user involvement has become a central mechanism for innovation generation. Research on user innovation by Eric von Hippel demonstrates that users are often important sources of novel solutions, particularly in contexts where experiential knowledge plays a key role (von Hippel, 2005). Building on these ideas, LLs have emerged as collaborative innovation environments designed to facilitate user-driven innovation in real-life contexts.

LLs are typically defined as user-centered, open innovation ecosystems integrating research and innovation processes within real-life communities and settings (Almirall et al., 2012; Leminen et al., 2012). According to the European Network of Living Labs, LLs enable the co-creation, prototyping, and evaluation of new products, services, and societal solutions through multi-stakeholder collaboration. They provide experimental environments where public institutions, firms, research organizations, and citizens jointly develop and test innovations (Schuurman et al., 2015). Recent developments in digital technologies have expanded the scope of LLs toward VLLs, where digital infrastructures enable distributed collaboration, remote experimentation, and large-scale user engagement (Ballon et al., 2018). VLLs extend the reach of open innovation by allowing geographically dispersed actors to participate in co-creation processes. However, despite their collaborative potential, many VLLs remain primarily technology-oriented and often rely on users mainly as testers rather than active co-creators. This limitation raises important questions regarding how co-creation processes in VLLs can be deepened and made more transformative.

2.2. Co-Creation in Innovation Processes

Co-creation is a central concept in both open innovation and living lab research. It refers to collaborative processes in which multiple stakeholders jointly contribute to the creation of value, knowledge, or solutions (Chesbrough, 2003; Prahalad and Ramaswamy, 2004; Leminen et al., 2012). However, prior research shows that co-creation varies significantly in depth, scope, and stage involvement (Voorberg et al., 2015; Schuurman et al., 2015). Existing literature often distinguishes between different levels of co-creation intensity: shallow co-creation, where users primarily provide feedback or data; intermediate co-creation, involving co-design and ideation; and deep co-creation, characterized by shared decision-making and co-governance (Arnstein, 1969; Voorberg et al., 2015; Bovaird and Loeffler, 2012). Empirical studies indicate that co-creation depth is strongly influenced by factors such as actor diversity, governance structures, and the nature of the problem addressed (Voorberg et al., 2015; Bogers et al., 2017). In particular, sustainability-oriented LLs tend to involve broader stakeholder networks and more deliberative processes, especially in early stages such as problem framing and scenario development (Schuurman et al., 2015; Leminen et al., 2017; Lakatos, 2024). However, systematic comparative frameworks for assessing co-creation across cases remain limited, as most existing studies rely on single-case analyses or qualitative descriptions (Voorberg et al., 2015). This gap motivates the development of the structured analytical approach used in this study.

2.3. Responsible Innovation and Societal Alignment

Alongside the rise of open innovation, increasing attention has been paid to the societal implications of technological development. This has led to the emergence of the concept of Responsible Innovation, which emphasizes the need to align innovation processes with societal values, ethical considerations, and sustainability objectives. Responsible innovation frameworks developed by scholars such as René von Schomberg and Richard Owen highlight the importance of anticipatory governance, reflexivity, inclusion, and responsiveness in innovation processes (Owen et al., 2013; von Schomberg, 2013). These

principles aim to ensure that technological development addresses societal challenges while minimizing unintended consequences.

Responsible innovation has become particularly relevant in the context of grand societal challenges such as climate change, digital transformation, and sustainable development. Scholars argue that addressing these complex challenges requires innovation systems that are more inclusive, participatory, and reflective (Stilgoe et al., 2013). In this regard, LLs offer promising institutional environments for operationalizing responsible innovation because they embed innovation processes in real-life contexts and facilitate interaction among diverse stakeholders. Nevertheless, participatory innovation initiatives frequently encounter difficulties in achieving meaningful stakeholder engagement. Participation may remain limited to consultation or feedback rather than genuine co-creation (Schuurman et al., 2015). Consequently, there is a need to explore alternative approaches capable of expanding the creative and participatory dimensions of innovation processes.

2.4. Art Thinking and Creative Approaches to Co-Creation

One promising approach to enhancing participatory innovation is the integration of artistic practices and creative methodologies into innovation processes. This perspective is often referred to as Art Thinking, which emphasizes the role of artistic exploration, imagination, and critical reflection in generating novel ideas and alternative perspectives. While Design Thinking has become widely adopted as a user-centered innovation methodology (Brown, 2008), art thinking extends this approach by emphasizing the exploration of new questions rather than the immediate search for solutions (Verganti, 2017). Artistic practices encourage experimentation with ambiguity, aesthetic exploration, and the reinterpretation of existing assumptions.

Research on art-based innovation highlights the potential of artistic approaches to facilitate interdisciplinary collaboration and stimulate creative thinking in organizational contexts (Berthoin Antal, 2015; Johansson-Sköldberg et al., 2013: Berthinier Poncet et al., 2025). Artists often function as boundary spanners who challenge established perspectives and enable participants to explore new meanings and experiences. In living lab contexts, artistic practices can enhance co-creation processes by introducing new forms of knowledge and engagement. Creative experimentation, participatory art installations, and speculative design practices can encourage participants to reflect on societal values, ethical implications, and future possibilities. Such practices can therefore contribute to deeper forms of collaboration and more reflexive innovation processes. In LLs, such practices may contribute to expanding the scope of participation, engaging non-traditional actors, and enabling early-stage co-creation and value exploration. However, empirical research on the role of art in LLs remains fragmented and largely case-based. There is a lack of comparative studies examining how artistic practices relate to co-creation patterns across different types of labs.

2.5. Integrating Theoretical Perspectives

Bringing together open innovation, responsible innovation, and art thinking allows for a richer conceptualization of innovation processes in VLLs. By integrating these perspectives (Table 1), the paper conceptualizes LLs—both virtual and non-virtual—as

heterogeneous co-creation environments in which different configurations of actors, tools, and practices produce varying levels of co-creation depth.

Table 1 Theoretical perspectives

Perspective	*Core contribution*
Open Innovation	expands innovation boundaries and enables collaboration
Responsible Innovation	ensures societal alignment and ethical reflection
Art Thinking	deepens creativity, imagination, and participatory exploration

Source: authors contribution

Within VLLs, artistic practices can expand the co-creation space by enabling stakeholders to move beyond incremental problem-solving toward more exploratory and reflexive innovation processes. Artists and designers often act as boundary spanners, facilitating dialogue between disciplines and helping participants articulate tacit knowledge, emotions, and values that are difficult to capture through conventional innovation methods. This role becomes particularly important in sustainability-oriented innovation, where technological solutions must be integrated with social practices, cultural meanings, and long-term societal goals.

Based on the literature, the study adopts a three-mode conceptualization of co-creation (Figure 1).

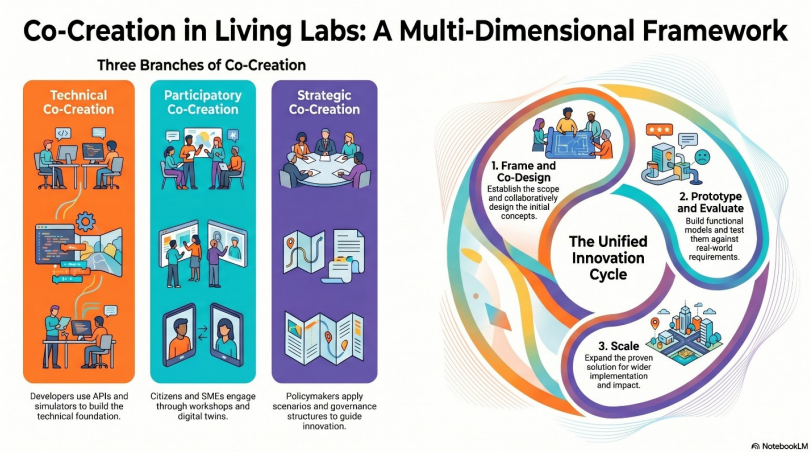

Figure 1. A three-mode conceptualization of co-creation

3 Methodology

This study adopts a qualitative, comparative research design to examine how co-creation varies across different types of LLs and to explore the conditions under which artistic practices are associated with deeper forms of co-creation. Given the exploratory nature of the research and the lack of standardized, cross-case frameworks for assessing co-

creation in LLs, a structured comparative approach was selected to enable both analytical both analytical consistency and sensitivity to contextual differences. .

The empirical basis of the study consists of a dataset of 40 LLs (Appendix 1). A purposive sampling strategy was employed to ensure maximum variation across two key dimensions: (1) type of living lab (virtual, hybrid, and place-based) and (2) domain of application (e.g., smart cities, sustainability transitions, circular economy, digital innovation and creative industries). This variation-oriented sampling enables the identification of recurring patterns across diverse contexts rather than statistically representative generalisation. Cases were identified from three primary sources: (1) living lab networks (e.g., the European Network of Living Labs), (2) academic literature and (3) publicly available project documentation, including institutional reports, project websites and policy materials.

To ensure analytical consistency, cases were included based on the following criteria: a clearly defined innovation objective, evidence of multi-stakeholder participation, the presence of a structured innovation or experimentation process, identifiable user groups and stakeholders roles, documented user involvement in at least one stage of the innovation process and element of open or collaborative innovation, , operation within real-life or simulated real-life context. Data for each case were collected from multiple sources, including academic publications, project reports, official websites, and institutional documentation. On average, 2-4 sources were used per case to enable triangulation and reduce reliance on single-source interpretations. The final sample reflects the diversity of contemporary living labs and includes fully virtual environments, hybrid socio-technical configurations and physically embedded labs.

The final sample reflects the empirical diversity of contemporary LLs and includes fully virtual, hybrid, and physically embedded labs. Rather than treating VLLs as a discrete category, the study conceptualises virtuality as a continuum, ranging from platform-based environments to integrated physical-digital ecosystems. For each case, qualitative data were extracted and coded according to the nine analytical criteria listed above. Where possible, multiple sources were triangulated to increase reliability.

To enable systematic comparison across heterogeneous cases, a structured analytical framework was developed based on prior literature on co-creation, living labs and participatory innovation (e.g., Voorberg et al., 2015; Schuurman et al., 2015; Leminen et al., 2012). The framework operationalises co-creation along three key dimensions: co-creation depth, referring to the intensity and influence of stakeholder participation, ranging from feedback-based involvement to co-governance and shared decision-making; actor diversity, capturing the breadth of stakeholder groups involved, from narrow (e.g., technical experts only) to broad (e.g., quadruple helix including citizens, firms, public actors, and civil society); stage involvement, reflecting the extent of stakeholder participation across the innovation process, from limited involvement (e.g., testing only) to full-cycle engagement (problem framing, co-design, testing, evaluation, and scaling).

Each dimension was assessed using a three-level ordinal scale (1 = low, 3 = medium, 5 = high). This 1–3–5 scale was chosen to capture meaningful variation while maintaining interpretive clarity and comparability across cases.

The analysis followed a structured coding procedure. First, qualitative descriptions of each living lab were extracted and summarized. Second, the cases were coded along three

dimensions: co-creation depth, actor diversity and stage involvement, based on predefined criteria. Third, coding decisions were iteratively refined through cross-case comparison, allowing emerging patterns to inform adjustments and improve internal consistency. To enhance reliability, coding was reviewed and discussed among the authors and discrepancies were resolved through iterative deliberation. In addition, a subset of cases was revisited after initial coding to ensure stability and consistency of the scoring logic. While the approach remains interpretive, these steps increase transparency and reduce individual bias. A summary of coding results is presented in Appendix 2.

Artistic and design-led practices were operationalised to ensure consistent identification across cases. A LL was considered to include such practices if at least one applied: (1) involvement of artists or designers; (2) use of art- or design-based methods (e.g., installations, storytelling, prototyping); or (3) production of creative outputs for reflection and engagement. This approach captures artistic practices across actors, methods, and outputs, enabling consistent comparison.

Each case was assessed along three key dimensions: a) co-creation depth (1 = feedback-based participation; 3 = co-design and iterative engagement; 5 = co-governance and shared decision-making); b) actor diversity (1 = narrow (e.g., developers only), 3 = mixed (e.g., firms + users); 5 = broad (quadruple helix: citizens, NGOs, policymakers, firms); and c) stage involvement (1 = limited (testing only); 3 = multiple stages (design + test); 5 = full cycle (problem framing → co-design → testing → evaluation → scaling). This scoring enabled cross-case comparison while preserving qualitative interpretation (Appendix 2).

The analysis proceeded in three stages. First, a within-case analysis was conducted to identify key characteristics of each living lab, including its stakeholders, tools, governance structures and co-creation processes. Second, a cross-case comparison was performed using the scoring framework, enabling the identification of patterns and clusters across cases. Third, based on these patterns, a typology of co-creation modes and living lab configurations was developed.

The current study has several limitations. First, the reliance on desk-based data introduces potential bias, as some LLs,, particularly those involving artistic practices, are more extensively documented and publicly visible. Second, the analysis identifies associations between artistic practices and co-creation depth but do not establish causal relationships.. Third, the concept of VLLs remains heterogeneous, and the inclusion of hybrid and place-based cases reflects this ambiguity. While this broad approach strengthens comparative insights, it also introduces conceptual variability. Finally, the scoring framework, although systematic, involves interpretive judgment, and future research could refine and validate these measures through empirical and longitudinal studies.

4 Results

4.1. Co-Creation Patterns Across 40 Living Labs

The comparative analysis of 40 LLs (Appendix 1) reveals substantial variation in how co-creation is conceptualized and operationalized across cases. Rather than representing a uniform model, LLs form a heterogeneous landscape spanning different domains, governance structures, and levels of participation. The analysis identifies six clusters reflecting dominant co-creation configurations: digital/technical labs, urban/hybrid living labs, energy and infrastructure labs, circular and sustainability labs, art/design-oriented labs, and network/policy labs (Table 2). These clusters differ significantly in their objectives, user groups, and modes of interaction, leading to distinct co-creation patterns.

Table 2 Co-Creation Patterns Across 40 LLs

Cluster	*Examples*	*Co-Creation Type*	*Key users*	*Tools /*	*Stages of co-creation*	*Depth*	*Notes*
Digital / Technical Labs	Nokia Living Lab; Ericsson Garage; SAP Experience Center	Technical co-creation	Developers, engineers, firms	APIs, digital platforms, prototyping tools	Prototype → Test → Refine	3.2	Focus on technology development; limited societal engagement
Urban / Hybrid Living Labs	Amsterdam Smart City; Helsinki Living Lab; Smart Kalasatama	Participatory co-creation	Citizens, city actors	Digital platforms, dashboards, IoT	Frame → Co-design → Test	4.0	Strong citizen involvement and real-life experimentation
Energy & Infrastructure Labs	Energy Living Lab Aalborg; Fraunhofer Energy Campus	Technical + participatory	Utilities, researchers, communities	Energy simulations, digital twins	Co-design → Pilot → Evaluate	3.5	Data-driven experimentation in real infrastructure
Circular & Sustainability Labs	Circular Economy LL (Amsterdam); Green Living Lab; Climate-KIC Living Labs	Deep participatory co-creation	SMEs, citizens, NGOs	CE platforms, workshops, data tools	Frame → Co-design → Pilot → Reflect	4.2	High actor diversity; strong sustainability orientation
Art / Design Living Labs	Waag Futurelab; MediaLab Prado; Ars Electronica Futurelab	Participatory + strategic	Citizens, artists, designers	Digital fabrication, interactive media	Frame → Co-design → Reflect	4.5	Meaning-making, inclusion, and reflexivity
Network / Policy Labs	EIT Climate-KIC Deep Demonstrations; European Network of Living Labs	Strategic co-creation	Policymakers, institutions	Platforms, scenario tools	Frame → Scenario → Policy test	3.7	System-level coordination and governance focus

Source: authors contribution

A key finding is the emergence of three recurring modes of co-creation. **Technical Co-Creation.** Primarily observed in IoT and network testbeds, this mode focuses on the joint development and testing of technological systems. Participation is typically limited to developers, engineers, and technical experts. Co-creation occurs mainly through APIs, simulators, and data platforms, and is concentrated in later stages of the innovation process (prototype–test–refine). Co-creation depth is generally shallow to medium. **Participatory Co-Creation.** This mode involves broader stakeholder engagement, including citizens, SMEs, and community groups. It is commonly found in urban, energy, and sustainability-oriented labs. Methods include workshops, co-design sessions, and participatory use of digital twins. Co-creation spans multiple stages, particularly problem framing and solution design, resulting in medium to high depth. **Strategic Co-Creation**. Observed in governance-oriented and policy-driven labs, this mode involves multi-actor collaboration at the level of decision-making and long-term planning. Stakeholders include policymakers, researchers, and institutional actors. Co-creation focuses on scenario building, policy experimentation, and system-level change, often supported by large-scale simulation environments. These three modes frequently coexist within the same lab, forming a multi-layered co-creation structure that spans technical development, participatory design, and strategic governance.

4.2. Co-Creation Depth, Actor Diversity and Stage Involvement

A central dimension of variation across cases is the depth of co-creation, which ranges from feedback-based participation to co-governance. The analysis shows a clear pattern: technical testbeds tend to concentrate co-creation in downstream stages, particularly testing and validation; sustainability-oriented labs engage stakeholders more strongly in upstream stages, including problem framing and scenario development; governance-oriented labs extend co-creation into strategic decision-making, enabling shared ownership and long-term alignment. This pattern is consistent with broader differences in purpose. Labs addressing complex societal challenges—such as circular economy or climate transitions—require deeper forms of engagement, as they involve value negotiation, behavioural change, and systemic transformation.

Another key finding concerns actor diversity. Technical labs typically involve narrow user groups (developers, engineers), while sustainability-oriented labs engage a wider range of actors, including: Citizens and local communities; SMEs and entrepreneurs; NGOs and civil society organizations and public authorities and policy makers. This broader participation is associated with more deliberative and inclusive forms of co-creation, as well as higher levels of legitimacy and acceptance. Importantly, actor diversity is closely linked to co-creation depth. Labs with more heterogeneous stakeholder networks tend to exhibit deeper and more sustained forms of collaboration.

The analysis also highlights how digital infrastructures shape co-creation processes. Different types of virtual environments support different forms of interaction: APIs and data platforms, which enable technical co-creation; Dashboards and real-time data systems, which support behavioural feedback; Digital twins and simulation tools aiming to facilitate shared understanding and deliberation. Digital twins play a crucial role in participatory and strategic co-creation by enabling stakeholders to visualize scenarios, explore trade-offs, and engage in collective decision-making. However, virtual environments alone do not guarantee deep co-creation. Their impact depends on how they are embedded in governance structures and participatory processes.

To summarize cross-case patterns, Table 3 presents average co-creation scores across different lab types. Averages are calculated from the Appendix 2 dataset (n = 40) and rounded to two decimal places.

Table 3 Co-creation scoring summary

LL type	*Average Depth*	*Average Diversity*	*Average Stage Involvement*
Technical / Digital	3.2	3.2	3.8
Sustainability	4.11	4.22	4.00
Art-integrated	4.50	4.50	4.40

Source: authors contribution

4.3. Association Between Artistic Practices and Co-Creation Depth

A key focus of this study is the role of artistic and design-led practices. Across the dataset, such practices are not uniformly distributed but appear primarily in specific types of LLs. Artistic practices are most commonly observed in: Sustainability and circular economy labs; Urban and civic innovation environments and Design-oriented and community-based initiatives. These labs tend to exhibit higher co-creation depth, broader actor diversity, and stronger engagement in early-stage processes. Artistic practices contribute to co-creation in several ways: Enabling sense-making through visual, narrative, and experiential methods; Expanding participation to include non-technical actors; Facilitating value exploration and reflection; Supporting the articulation of alternative futures. For example, participatory installations and speculative design approaches allow stakeholders to engage with abstract sustainability challenges in tangible ways, enhancing understanding and dialogue. Importantly, the analysis does not establish a direct causal relationship between art and co-creation depth. Instead, artistic practices appear as part of a broader configuration of factors associated with transformative LLs, including sustainability orientation, inclusive governance, and participatory methods.

4.4. Toward a Typology of Living Labs

Based on the analysis, LLs can be classified along two key dimensions: 1) Purpose: Technical innovation → Sustainability and societal transformation and 2) Co-creation depth: Shallow → Deep. This results in a typology of five types: Technical Testbeds; Hybrid Urban Labs, Community and Circular Labs, Policy Simulation Labs, Transition Governance Labs (Table 4). Within this typology, art- and design-integrated practices are most strongly associated with the latter categories, which exhibit the highest levels of co-creation depth and societal engagement.

Table 4 Typology of LLs

Type	*Purpose*	*Co-Creation Depth*	*Actor Diversity*	*Example*
Type I – Technical / Digital Labs	Technology development and validation	3.2	3.2	Nokia Living Lab; Ericsson Garage Innovation Lab; SAP Experience Center

Type II – Hybrid Urban Labs	Urban innovation and smart city development	4.0	4.0	Helsinki Living Lab; Amsterdam Smart City; Smart Kalasatama
Type III – Circular / Sustainability Labs	Socio-ecological and sustainability transitions	4.1	4.2	Circular Economy LL (Amsterdam); Green Living Lab; Climate-KIC Living Labs
Type IV – Network / Policy Labs	System-level coordination and policy experimentation	3.7	5.0	EIT Climate-KIC Deep Demonstrations; European Network of Living Labs
Type V – Art / Design / Transformative Labs	Societal transformation and meaning-making	4.5	4.5	Waag Futurelab; DESIS Network; Ars Electronica Futurelab

Source: authors contribution

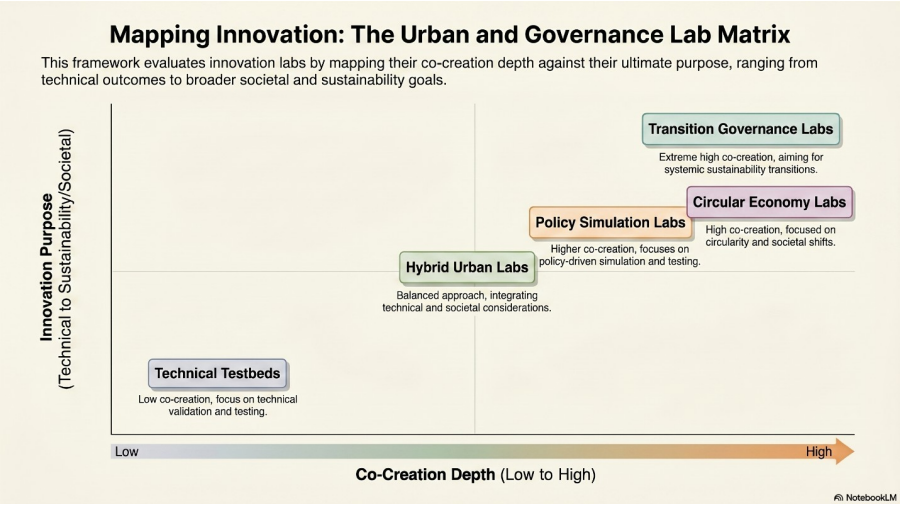

Figure 2. Typology of Living Labs based on co-creation depth and purpose

5 Discussion of the results

5.1. Differentiating Co-Creation Depth in Living Labs

The findings of this study reinforce prior research suggesting that co-creation in LLs is heterogeneous and context-dependent. While early definitions emphasize user-centered, participatory innovation environments (Müller, 2026, Leminen et al., 2012), empirical studies have shown that many LLs operate with limited user involvement, often restricted to testing and validation phases (Schuurman et al., 2015). The predominance of technical co-creation modes in IoT and testbed-oriented environments observed in this study aligns with open innovation literature, which highlights that firms frequently engage external

actors in selective and controlled ways, particularly when innovation processes are technology-driven (West and Bogers, 2014; Bogers et al., 2017). In such contexts, co-creation tends to be instrumental rather than transformative. In contrast, sustainability-oriented LLs in this study exhibit deeper co-creation processes, characterized by broader stakeholder engagement and involvement in early innovation stages. This finding is consistent with Voorberg et al. (2015), who show that co-creation becomes more intensive when addressing complex societal challenges requiring collective problem framing and deliberation. Similarly, studies on urban LLs emphasize that sustainability transitions necessitate inclusive and iterative co-creation processes involving diverse actors (Schuurman et al., 2015; Lakatos, 2024).

The typology developed in this study contributes to this literature by empirically distinguishing between technical, participatory, and strategic co-creation modes, providing a structured framework that captures variations in co-creation depth across LLs.

5.2. Virtual Living Labs as Hybrid Socio-Technical Systems

This study also contributes to the ongoing conceptualization of VLLs. While VLLs are often described as digitally mediated environments enabling distributed innovation (Ballon et al., 2018), the findings indicate that most cases operate as hybrid configurations, combining digital tools with physical experimentation and social interaction. This observation supports the broader literature on digital innovation, which conceptualizes innovation environments as socio-technical systems where digital infrastructures interact with organizational and social processes (Nambisan et al., 2017). Digital tools such as digital twins, dashboards, and simulation platforms do not operate in isolation but shape—and are shaped by—governance structures and participation practices. In particular, digital twins have been identified as enabling shared visualization and collaborative decision-making in urban and sustainability contexts (Maiullari et al., 2024). However, recent research also highlights the risk that digital platforms may reinforce existing inequalities by privileging actors with technical expertise, thereby limiting inclusiveness (Calisto Friant et al., 2023). The findings of this study confirm that virtual environments enable but do not guarantee deep co-creation. Their impact depends on how they are embedded in participatory processes and institutional arrangements, reinforcing the need to move beyond technology-centric perspectives on VLLs.

5.3. Art and Design as Mechanisms of Deep Co-Creation

A central finding of this study is the consistent association between artistic practices and deeper co-creation processes. This observation aligns with research on art-based and design-driven innovation, which emphasizes the role of artistic practices in enabling exploration, reflection, and interdisciplinary dialogue (Berthoin Antal, 2014; Johansson-Sköldberg et al., 2013). Verganti (2009; 2017) argues that innovation is not only about solving predefined problems but also about creating new meanings. Artistic practices support this process by enabling stakeholders to engage with complex issues—such as sustainability transitions—through experiential, symbolic, and narrative forms of knowledge. In living lab contexts, such practices can facilitate sense-making and expand the scope of participation beyond technical actors. This is consistent with research on design-driven LLs, which shows that design approaches can extend co-creation into more exploratory and reflexive domains (Ståhlbröst and Holst, 2012). In sustainability

contexts, this is particularly important, as innovation processes must incorporate social values, ethical considerations, and long-term societal impacts (Stilgoe et al., 2013). However, the relationship between artistic practices and co-creation depth should not be interpreted as causal. Instead, it is better understood as configurational and context dependent. Three explanations are supported by the literature: Selection effects: Sustainability-oriented and socially driven labs are more likely to adopt both participatory approaches and artistic practices (Voorberg et al., 2015; Lakatos, 2024); Reverse causality: Labs that already engage in deep co-creation are more open to interdisciplinary and artistic methods (Johansson-Sköldberg et al., 2013).; Institutional alignment: Governance structures that support inclusiveness and interdisciplinarity enable both artistic engagement and deeper co-creation (Owen et al., 2013; von Schomberg, 2013). This interpretation strengthens the theoretical contribution by positioning art not as an isolated driver, but as part of broader innovation system configurations. Based on the findings, Figure 3 illustrates the role of artistic practices in enabling deeper co-creation.

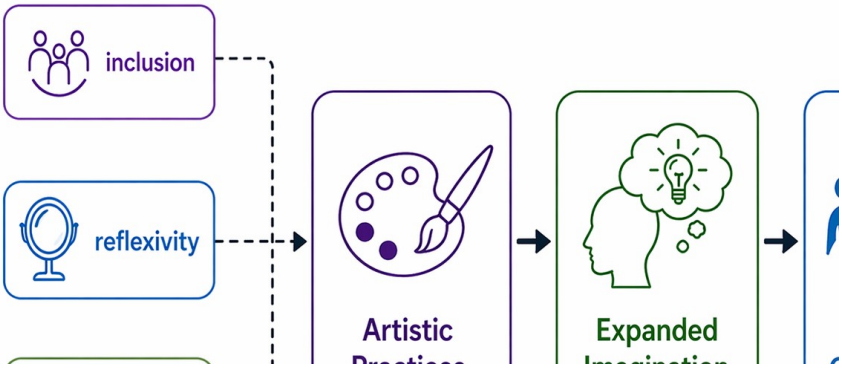

Figure 3. Art & Co-Creation Mechanism

5.4. Implications for Responsible Innovation and Sustainability Transitions

The findings also contribute to responsible innovation literature by providing empirical insights into how co-creation processes support societal alignment. Responsible innovation frameworks emphasize inclusion, reflexivity, anticipation, and responsiveness as key dimensions (Stilgoe et al., 2013; Owen et al., 2013). The results show that LLs differ significantly in their ability to operationalize these principles. In line with recent systematic reviews (Lakatos, 2024), sustainability-oriented LLs tend to exhibit: Higher levels of inclusion, through broader stakeholder engagement; Greater reflexivity, through deliberative and participatory processes; Enhanced anticipation, through scenario building and exploration; Improved responsiveness, through iterative feedback and adaptation.

Artistic practices appear to support these dimensions by enabling stakeholders to engage with innovation processes in more reflective and meaningful ways. This reinforces the argument that addressing sustainability challenges requires not only technological solutions but also cultural and cognitive transformation (Verganti, 2017;

Stilgoe et al., 2013). At the same time, the study highlights the importance of governance. Open innovation research emphasizes that collaboration across organizational boundaries requires appropriate structures and incentives (Chesbrough and Bogers, 2014). Without such structures, co-creation risks becoming superficial or exclusionary.

Although the study focuses on VLLs, the findings suggest that the identified patterns extend beyond virtual environments. Previous research indicates that physical and hybrid LLs provide rich contexts for co-creation, particularly through embodied interaction and real-life experimentation (Schuurman et al., 2015). The results of this study suggest that the role of co-creation depth, actor diversity, and artistic practices is not limited to virtual settings but may be even more pronounced in hybrid or place-based environments. This highlights the need for future research to examine interactions between digital and physical co-creation, and to explore how different configurations influence innovation outcomes.

5 Conclusions

This study set out to examine how co-creation varies across LLs and to explore the role of artistic practices in shaping co-creation processes. Based on a comparative analysis of 40 cases, the findings provide new insights into the diversity of living lab configurations and the conditions associated with deeper forms of collaboration. This study contributes to living lab and innovation literature in three ways. First, it develops a comparative and operationalised framework for assessing co-creation depth across heterogeneous living lab environments. Second, it provides one of the first systematic cross-case analyses of the relationship between artistic practices and co-creation processes in both virtual and hybrid living labs. Third, it advances the conceptual integration of open innovation, responsible innovation and art thinking by positioning artistic practices as configurational mechanisms that enable deeper and more inclusive forms of co-creation.

From a practical perspective, the findings suggest that innovation managers and policymakers should pay greater attention to Early-stage co-creation and problem framing, Actor diversity and stakeholder inclusion; Integration of artistic and design-based methods; Governance structures that enable participation and reflexivity.

Future research should build on this work by conducting longitudinal studies of living lab impact; developing validated metrics for co-creation quality; exploring causal mechanisms through field experiments; investigating hybrid models combining virtual and physical environments. Overall, the study highlights that the transformative potential of LLs depends not only on technological infrastructure, but on the quality of co-creation processes and the capacity to engage diverse actors in meaningful ways.

Acknowledgements

This work is supported by the Erasmus+ Cooperation partnerships in higher education (KA220-HED) project “Developing tomorrow's competences for responsibility, sustainability, digitalization and societal transformation through Art (ArtInnoLab4.0), 03.11.2025 – 2.11.2028

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Appendix 1 Comparative dataset of 40 LLs used in the study

Type	Living Lab	Country	Main Objective	Process	Stakeholders	Core Users	Virtual Environment	User-Centered & Participatory	Context	Open Innovation	Continuous Experimentation
Urban LL	Amsterdam Smart City Living Lab	Netherlands	Urban sustainability and smart city innovation	Open innovation platform with city pilots	Municipality, companies, universities	Citizens, startups	Digital urban innovation platform	Citizen co-creation workshops	Real city infrastructure	Cross-sector collaboration	Pilot projects and iterative testing
Urban LL	Barcelona Urban Lab	Spain	Smart city and urban innovation testing	Public procurement innovation testbeds	City government, tech firms	Residents	Urban digital testing platforms	Citizen feedback loops	Urban public spaces	Public-private collaboration	Real-life prototype testing
Urban LL	Helsinki Living Lab	Finland	Service innovation and urban sustainability	Multi-stakeholder co-creation projects	City, universities, companies	Citizens	Online co-creation tools	Participatory design sessions	Public service environments	Multi-sector collaboration	Iterative service pilots
Urban LL	Eindhoven Living Lab	Netherlands	Smart mobility and energy innovation	Innovation ecosystem orchestration	Industry, academia, city	Residents, commuters	IoT platforms	Living experiments with users	Smart district environments	Industry-academia partnerships	Technology trials
Urban LL	Stockholm Smart City Living Lab	Sweden	Digital sustainability solutions	Collaborative experimentation	Government, startups	Urban citizens	Smart city digital infrastructure	Citizen engagement platforms	Urban infrastructure	Ecosystem innovation	Continuous data monitoring
Urban LL	Dublin Living Lab	Ireland	Urban digital transformation	University-led collaboration	Universities, SMEs	Citizens	Online civic platforms	Participatory urban design	Smart district trials	Cross-sector innovation	Iterative pilot projects
Urban LL	Turin Living Lab	Italy	Smart city innovation and entrepreneurship	Structured city experimentation	Municipality, firms	Residents	Digital urban platforms	Citizen testing communities	Real urban districts	Startup collaboration	Rapid prototyping
Urban LL	Copenhagen Solutions Lab	Denmark	Climate-neutral city innovation	Municipal innovation programs	City, industry	Citizens	Smart city dashboards	Public participation platforms	Real city climate solutions	Cross-sector partnerships	Iterative experimentation
Urban LL	Vienna Living Lab	Austria	Sustainable urban services	Research-driven experimentation	Universities, city	Residents	Online participation tools	Co-design workshops	Smart city districts	Knowledge partnerships	Continuous evaluation
Urban LL	Milan Urban Living Lab	Italy	Urban sustainability projects	City-led innovation pilots	Government, startups	Citizens	Civic innovation platforms	Participatory experimentation	Urban neighborhood pilots	Multi-sector collaboration	Iterative project cycles
Circular LL	Circular Economy Living Lab (Amsterdam)	Netherlands	Circular economy experimentation	Co-creation innovation programs	City, companies	Entrepreneurs	Circular innovation platform	Stakeholder workshops	Circular pilot districts	Industry partnerships	Iterative prototyping
Sustainability LL	Green Living Lab	Netherlands	Sustainable healthcare and urban ecosystems	Research-community collaboration	Universities, hospitals	Patients, citizens	Sustainability monitoring systems	Community participation	Green campus environments	Interdisciplinary collaboration	Living experiments
Sustainability LL	Sustainability Living Lab at UBC	Canada	Campus sustainability innovation	Campus-as-a-lab model	University, city	Students, residents	Sustainability dashboards	Student participation	Real campus infrastructure	Academic-industry collaboration	Continuous pilot testing
Urban LL	Leuven Living Lab	Belgium	Smart city and sustainability	Urban experimentation	City, university	Residents	Urban data platforms	Citizen panels	Smart city districts	Cross-sector networks	Iterative solutions
Network / Platform	Climate-KIC Living Labs	Europe (multi-country)	Climate innovation and decarbonization	Innovation ecosystem programs	EU partners	Entrepreneurs	Digital climate platforms	Co-creation workshops	Regional pilots	Cross-sector networks	Innovation experiments
Network / Platform	EIT Climate-KIC Deep Demonstrations	Europe (multi-country)	Systemic climate transitions	Regional transition experiments	Governments, industry	Citizens	Digital transition platforms	Citizen assemblies	Regional climate initiatives	Multi-sector innovation	Policy and technology testing
Urban LL	Smart Kalasatama Living Lab	Finland	Smart energy and circular city	District-level co-creation	City, energy companies	Residents	IoT and digital dashboards	Resident innovation	Smart district pilots	Industry-city collaboration	Iterative development

								programs			
Energy LL	Energy Living Lab (Aalborg University)	Denmark	Sustainable energy solutions	Research-industry collaboration	University, utilities	Communities	Energy simulation platforms	Community participation	Energy transition pilots	Industry-academic networks	Continuous testing
Urban LL	Urban Living Lab Graz	Austria	Climate-neutral urban development	Urban experimentation projects	City, universities	Residents	Digital urban modelling	Participatory planning	Real urban development sites	Cross-sector collaboration	Iterative planning
Mobility LL	Delft Living Lab	Netherlands	Sustainable mobility innovation	Academic-city collaboration	University, government	Commuters	Mobility data platforms	User feedback	Real transport systems	Research-industry collaboration	Pilot experiments
Research LL	MIT City Science Living Lab	USA	Urban technology and sustainability	Research innovation platform	University, cities	Citizens	Urban simulation platforms	Participatory design	Smart city pilots	Global innovation networks	Rapid prototyping
Research LL	MIT Media Lab City Science Group	USA	Future urban mobility and data-driven cities	Experimental urban research	Academia, startups	Urban residents	Digital twin environments	Participatory research	Real urban mobility contexts	Interdisciplinary innovation	Iterative technology experiments
Energy LL	Fraunhofer Living Lab Energy Campus	Germany	Smart energy systems	Applied research testbed	Research institutes, utilities	Campus users	Energy digital twins	User monitoring	Real energy systems	Research-industry collaboration	Continuous testing
Network / Platform	Open Living Lab Days Network	International	Global living lab collaboration	Network-based innovation	Universities, firms	Citizens	Online collaboration platforms	Community engagement	Multiple regional contexts	Global innovation network	Shared experimentation
Network / Platform	European Network of Living Labs	Europe	Living lab ecosystem development	Multi-stakeholder network	Governments, companies	Citizens	Digital collaboration tools	Stakeholder participation	Real-life innovation settings	International collaboration	Knowledge exchange experiments
Digital / VLL	Living Lab for Digital Innovation (Sweden)	Sweden	Digital transformation	Industry-academic collaboration	Tech companies, universities	Consumers	Virtual testing platforms	User testing panels	Real consumer contexts	Innovation ecosystems	Iterative digital product testing
Digital / VLL	iLab.o Living Lab	Belgium	User-driven ICT innovation	Structured living lab methodology	University, firms	End users	Virtual test platforms	Co-creation workshops	Everyday technology use	Industry partnerships	Continuous testing cycles
Digital / VLL	Nokia Living Lab	Finland	Digital service innovation	Corporate user innovation	Technology firms	Mobile users	App testing platforms	User communities	Real usage environments	Corporate open innovation	Rapid product iteration
Digital / VLL	Ericsson Garage Innovation Lab	Sweden	Digital connectivity solutions	Innovation accelerator	Industry partners	Developers	Digital prototyping tools	Developer participation	Telecom use cases	Open innovation ecosystem	Continuous experimentation
Corporate Lab	SAP Experience Center Living Lab	Germany	Enterprise digital innovation	Corporate innovation labs	Industry partners	Business users	Virtual enterprise platforms	Co-design sessions	Real business workflows	Corporate ecosystem collaboration	Iterative solution testing
Art / Design LL	Ars Electronica Futurelab	Austria	Art-technology innovation	Artist-scientist collaboration	Artists, researchers	Public audiences	Interactive digital environments	Participatory art projects	Cultural technology contexts	Art-science collaboration	Experimental prototypes
Art / Design LL	MediaLab Prado	Spain	Citizen innovation and digital art	Open collaborative workshops	Artists, technologists	Citizens	Open digital labs	Community co-creation	Civic innovation projects	Interdisciplinary collaboration	Iterative prototypes
Art / Design LL	ZKM Center for Art and Media	Germany	Art and digital culture innovation	Research and exhibition labs	Artists, scientists	Visitors	Interactive media installations	Public participation	Cultural experimentation	Art-science networks	Creative experimentation
Art / Design LL	Waag Futurelab	Netherlands	Responsible technology and citizen science	Open maker and design labs	Designers, researchers	Citizens	Digital fabrication platforms	Co-design workshops	Civic technology contexts	Cross-disciplinary collaboration	Rapid prototyping
Design / Social Innovation	DESIS Network Living Labs	International	Design for social innovation	Design-led community projects	Designers, communities	Local citizens	Collaborative design tools	Participatory design	Community sustainability contexts	Global design networks	Iterative social innovation

Art / Design LL	Living Lab for Creative Industries (Amsterdam)	Netherlands	Creative economy innovation	Creative industry collaboration	Designers, startups	Creative professionals	Digital design platforms	Co-creation labs	Creative industry contexts	Cross-sector collaboration	Iterative design experiments
Design / Innovation	Aalto Design Factory	Finland	Design-driven innovation	Multidisciplinary project labs	University, companies	Students	Digital prototyping tools	Project-based learning	Real product design challenges	Industry-academic collaboration	Continuous prototyping
Art / Design LL	MIT Media Lab	USA	Radical interdisciplinary innovation	Experimental research groups	Researchers, artists	Technology users	Advanced digital platforms	Participatory research	Technology innovation contexts	Cross-sector partnerships	Iterative experimentation
STEAM / Education	STEAM Living Lab (various initiatives)	International	Integrating arts with technology innovation	STEAM education ecosystems	Universities, artists	Students	Digital learning environments	Creative collaboration	Education innovation contexts	Cross-disciplinary innovation	Experimental projects
Art / Design LL	Creative Living Lab Copenhagen	Denmark	Creative urban sustainability	Design-led co-creation	Designers, city	Citizens	Digital urban design tools	Participatory design workshops	Urban cultural spaces	Cross-sector collaboration	Iterative urban prototypes

Appendix 2 Coding summary for the 40-case dataset

ID	Living Lab	Country	Type	Domain	Co-creation Depth	Actor Diversity	Stage Involvement
1	Amsterdam Smart City Living Lab	Netherlands	Urban LL	urban sustainability	4	5	4
2	Barcelona Urban Lab	Spain	Urban LL	smart city innovation	4	4	4
3	Helsinki Living Lab	Finland	Urban LL	service innovation	4	4	4
4	Eindhoven Living Lab	Netherlands	Urban LL	smart mobility / energy	4	4	4
5	Stockholm Smart City Living Lab	Sweden	Urban LL	digital sustainability	3	4	4
6	Dublin Living Lab	Ireland	Urban LL	urban digital transformation	4	3	3
7	Turin Living Lab	Italy	Urban LL	smart city entrepreneurship	4	4	4
8	Copenhagen Solutions Lab	Denmark	Urban LL	climate-neutral city	4	4	4
9	Vienna Living Lab	Austria	Urban LL	sustainable urban services	4	3	3
10	Milan Urban Living Lab	Italy	Urban LL	urban sustainability	4	4	4
11	Circular Economy Living Lab (Amsterdam)	Netherlands	Circular LL	circular economy	5	5	5
12	Green Living Lab	Netherlands	Sustainability LL	sustainable healthcare / ecosystems	4	4	4
13	Sustainability Living Lab at UBC	Canada	Sustainability LL	campus sustainability	4	3	3
14	Leuven Living Lab	Belgium	Urban LL	smart city / sustainability	4	4	3
15	Climate-KIC Living Labs	Europe	Network / Platform	climate innovation	4	5	4
16	EIT Climate-KIC Deep Demonstrations	Europe	Network / Platform	systemic climate transitions	5	5	5
17	Smart Kalasatama Living Lab	Finland	Urban LL	smart energy / circular city	4	4	4
18	Energy Living Lab (Aalborg University)	Denmark	Energy LL	sustainable energy	3	4	4
19	Urban Living Lab Graz	Austria	Urban LL	climate-neutral urban development	4	4	4
20	Delft Living Lab	Netherlands	Mobility LL	sustainable mobility	3	3	4
21	MIT City Science Living Lab	USA	Research LL	urban technology / sustainability	3	4	4
22	MIT Media Lab City Science Group	USA	Research LL	future urban mobility	4	5	4
23	Fraunhofer Living Lab Energy Campus	Germany	Energy LL	smart energy systems	3	4	4
24	Open Living Lab Days Network	International	Network / Platform	global living lab collaboration	3	5	3
25	European Network of Living Labs	Europe	Network / Platform	living lab ecosystem development	3	5	3
26	Living Lab for Digital Innovation (Sweden)	Sweden	Digital / VLL	digital transformation	3	4	4
27	iLab.o Living Lab	Belgium	Digital / VLL	user-driven ICT innovation	4	3	4
28	Nokia Living Lab	Finland	Digital / VLL	digital service innovation	3	3	4
29	Ericsson Garage Innovation Lab	Sweden	Digital / VLL	digital connectivity	3	3	4
30	SAP Experience Center Living Lab	Germany	Corporate Lab	enterprise digital innovation	3	3	3
31	Ars Electronica Futurelab	Austria	Art / Design LL	art-technology innovation	5	5	5

32	MediaLab Prado	Spain	Art / Design LL	citizen innovation / digital art	5	5	4
33	ZKM Center for Art and Media	Germany	Art / Design LL	art and digital culture	4	4	4
34	Waag Futurelab	Netherlands	Art / Design LL	responsible technology	5	5	5
35	DESIS Network Living Labs	International	Design / Social Innovation	design for social innovation	5	5	4
36	Living Lab for Creative Industries (Amsterdam)	Netherlands	Art / Design LL	creative economy innovation	4	4	4
37	Aalto Design Factory	Finland	Design / Innovation	design-driven innovation	4	4	5
38	MIT Media Lab	USA	Art / Design LL	radical interdisciplinary innovation	5	5	5
39	STEAM Living Lab (various initiatives)	International	STEAM / Education	arts + technology education	4	4	4
40	Creative Living Lab Copenhagen	Denmark	Art / Design LL	creative urban sustainability	4	4	4

Note: Scores in Appendix 2 are interpretive coding values derived from document analysis (1 = low, 5 = high).