Received: 13 June 2023 | Revised: 25 November 2023 | Accepted: 17 January 2024

DOI: 10.1002/eet.2097

RESEARCH ARTICLE

Environmental Policy and Governance

WILEY

Contextualizing and generalizing drivers and barriers of urban livings labs for climate resilience

Laura Quadros Aniche[1] | Jurian Edelenbos[1] | Alberto Gianoli[1] | Rochelle Caruso[2] | Marta Irene DeLosRíos-White[3] | Charmae Pyl Wissink-Nercua[1] | Asier Undabeitia[4] | Elena Marie Enseñado[1] | Salem Gharbia[5]

[1]Institute for Housing and Urban Development Studies (IHS), Erasmus University Rotterdam, Rotterdam, the Netherlands

[2]ERINN Innovation, Dublin, Ireland

[3]European Network of Living Labs (ENoLL), Brussels, Belgium

[4]Naider, Bilbao, Spain

[5]Centre for Environmental Research Innovation and Sustainability CERIS, Department of Environmental Science, Atlantic Technological University, Letterkenny, Ireland

Correspondence
Laura Quadros Aniche, Institute for Housing and Urban Development Studies, Erasmus University Rotterdam, Burgemeester Oudlaan, 50, Mandeville Building, 14th floor, 3062 PA Rotterdam, the Netherlands.
Email: quadrosaniche@ihs.nl; lauraquadros@gmail.com

Funding information
European Climate, Infrastructure and Environment Executive Agency (CINEA), Grant/Award Number: 101007142

Abstract

Urban Living Labs are open innovation ecosystems that integrate research and innovation activities within urban communities. However, while solutions co-created and tested in the Urban Living Labs must be contextualized and tailored to each city's uniqueness, broader impact requires generalization and systematic replication across geographical, institutional, and sectoral boundaries. This article examines nine Living Labs in European coastal cities, identifying several barriers and drivers for mainstreaming and upscaling solutions to increase climate resilience through the Living Lab Integrative Process. Our analysis focuses on three main categories. First, social and cultural aspects highlighted include stakeholder engagement and awareness, communication, and dissemination. Second, we assess institutional and political aspects, such as silos, bureaucracy, and resources. Last, we investigate technical factors as knowledge and experience, technical and internal capacity, data availability and accessibility, climate-related policies and actions, and long-term perspective. The results suggest that while some barriers and drivers are common across the cases, providing generalizable patterns, there are also specific differences requiring tailored solutions at the local scale. Nonetheless, the diversity in drivers indicates the potential for sharing knowledge across cases to translate, embed, and scale solutions, enhancing the transition toward climate resilience. Learning and innovation in real-life contexts are fundamental in the Living Lab approach, and our findings demonstrate that cross-case learning can enhance an iterative process of contextualizing and generalizing innovative climate solutions.

KEYWORDS
climate resilience, coastal cities, diffusion process, living lab, stakeholder, transition

1 | INTRODUCTION

Coastal cities face severe impacts from climate change, including storm surges, flooding, and cyclones (Balica et al., 2012; IPCC, 2022; Torabi et al., 2018). They are both highly vulnerable to climate risks and vital sources of innovation for climate-resilient development (Glavovic et al., 2022—IPCC CCP2.2). Cities seek innovative holistic approaches to become more resilient and tackle climate hazards and impacts. *Urban resilience* can be defined as "the capacity of individuals, communities, institutions, businesses, and systems within a city to survive, adapt, and grow no matter what kinds of chronic stresses and acute shocks they experience" (Resilient Cities Network, 2021). Coastal cities enhance resilience through innovative processes, continuous learning exchanges, long-term strategic planning regarding the impacts of climate change, and effective engagement of urban stakeholders like planners, communities, and industry (Torabi et al., 2018).

The *Living Lab* (LL) approach is highly relevant in this context. (Urban) Living Labs encompass innovation and learning, multi-method approach, user engagement, multi-stakeholder participation, co-creation, and real-life context (Alexandrakis, 2021; Bulkeley et al., 2016; Malmberg et al., 2017; McCormick & Hartmann, 2017; Nesti, 2018; Schuurman et al., 2015; Sharp & Salter, 2017; Steen & van Bueren, 2017; Westerlund & Leminen, 2011). In our research, we define *Urban Living Labs* (ULLs) as open innovation ecosystems in urban environments based on a systematic user co-creation approach that integrates research and innovation activities in communities, actively involving all related stakeholders to co-create, implement, test, and evaluate innovations in real-life situations, to address different issues (Stibe et al., 2017). Such integration of actors from government, industry, civil society, and academia in ULLs is known as a quadruple helix model of partnership (also called as "PPPP" or "4Ps") (Aversano et al., 2016; Bulkeley et al., 2016; Lupp et al., 2020; Lupp et al., 2021; Malmberg et al., 2017; McCormick & Hartmann, 2017; Nesti, 2018; Schuurman et al., 2015).

LL activities occur in nonlinear iterative phases (Alexandrakis, 2021; Malmberg et al., 2017; Sharp & Salter, 2017; Ståhlbröst et al., 2018; Vollstedt et al., 2021). Within the *Living Lab Integrative Process* (Mastelic, 2019), based on Design Thinking, the phases go from empathizing (understanding the local setting and integrating stakeholders) and defining (uncovering barriers), to ideating (co-designing solutions), prototyping (piloting an intervention), and testing (evaluating performance). The LL process ensures the experiments are tailored and contextualized to their specific settings.

On the other hand, a recurring question regarding ULLs is whether and how solutions co-created, implemented, and tested in Living Labs, and thus on a local scale, can have an impact on a broader scale, in the larger political, economic, and strategic context of sustainability transitions (Bradley et al., 2022; Bulkeley et al., 2015; Fuenfschilling et al., 2019; Newton & Frantzeskaki, 2021; von Wirth et al., 2019). We consider a broader impact if it goes beyond the ULL's borders by allowing deep learning, broad replication in a different context, and scaling up by institutional embedding (Ståhlbröst et al., 2018). This requires a certain level of generalization for learning and systematic replication across geographical, institutional, and sectoral borders.

The literature (Bulkeley et al., 2015; Ståhlbröst et al., 2018; Von Wirth et al., 2019) presents a gap in understanding the concrete strategies and practices that allow *diffusion processes* that go beyond the specific ULL, with its results being embedded, translated, and scaled up. There is a need to empirically identify the ULLs' potential in creating a broader impact, accelerating transformative change, inducing sustainability transitions, and formalizing learning across different contexts and actors.

Furthermore, although there is a vast literature on the barriers and drivers to climate adaptation (see e.g., Biesbroek et al., 2013; Eisenack et al., 2014; Lee et al., 2022; Valente & Veloso-Gomes, 2020), the literature is limited on climate resilience, and even less on resilience within the context of Living Labs or sustainability transitions, which is the focus of this article.[1] Additionally, in the literature, there is no systematic overview and understanding or universal categorization of barriers and drivers concerning climate resilience.

Lastly, there is no detailed cross-case comparison in the literature to explore similarities and particularities among multiple cases with similar climate resilience goals as a pathway for a flexible generalization of contextualized approaches toward sustainability transitions.

To address these gaps, this research uncovers barriers and drivers in coastal ULLs (Coastal City Living Labs, referred as CCLLs) fostering climate resilience as a proxy to understand the simultaneous duality of *contextualization* at the ULL or niche level, considering the particularities of each case, and *generalization* at the regime level, given similarities across cases, answering the following research questions:

- What barriers (to be avoided) and drivers (to be encouraged) emerge from the Living Lab Integrative Process?
- To what extent are these barriers and drivers similar (converge and diverge) across the CCLLs contexts, demonstrating the duality between contextualization and generalization?

For that, we analyze the empirical cases of nine CCLLs within the European Union's Horizon 2020 research and innovation project "SCORE—Smart Control of the Climate Resilience in European Coastal Cities." The cases present similarities in climate hazards, impacts and goals, and geographical context, allowing rich case comparison.

In the following sections, we discuss drivers and barriers for mainstreaming and upscaling solutions to increase climate resilience through the Living Lab Integrative Process in the context of sustainability transitions. Then, we will explain the methodology used in this

[1]Climate adaptation and climate resilience are related but different concepts. "Adaptation, in response to current climate change, is reducing climate risks and vulnerability mostly via adjustment of existing systems. Many adaptation options exist and are used to help manage projected climate change impacts, but their implementation depends upon the capacity and effectiveness of governance and decision-making processes. These and other enabling conditions can also support climate resilient development" (IPCC, 2022, p. 18). At the same time, "climate resilient development integrates adaptation measures and their enabling conditions with mitigation to advance sustainable development for all" (IPCC, 2022, p. 28). Therefore, barriers and drivers to increase climate resilience may include, but are not limited to, climate adaptation aspects.

study, followed by the results and discussion. Lastly, we conclude with our main insights.

2 | THEORY

2.1 | Drivers and barriers to climate resilience

Barriers can be defined as "social factors and conditions [that] hamper our ability to adapt proactively to future environmental changes" (Biesbroek et al., 2013, p. 1119). Barriers are often complementary and interlinked, indicating that an integrated approach is needed to tackle them (Aktürk & Dastgerdi, 2021). Barriers, however, can be overcome with enough political will, resources, innovative approaches, institutional change, community support, and effort (Mendizabal et al., 2018). These are *drivers* or opportunities.

We address the lack of a systematic overview and universal categorization of barriers and drivers related to climate resilience in the literature, which presents different names for similar driving and restraining factors. Appendix A illustrates this variety with a non-exhaustive list of examples. For this study, we propose overall categories, linking and combining overlapping (sub-) categories from the literature for a more systematic analysis: *social and cultural; institutional and political; and technical aspects*.

Among barriers (Table A1), we see issues related to stakeholder participation and collaboration, education and awareness, behaviors, short-term thinking, and communication within *social and cultural barriers*. *Institutional and political barriers* include a lack of a shared vision and agenda, resistance to change, lack of will and commitment, and issues in funding, coordination, and regulations. *Technical barriers* include a lack of a cross-cutting, integrated, flexible, and long-term planning, as well as limited capacities, data, and monitoring.

On the other hand, the literature indicates drivers (Table A2) related to: learning, communication, and stakeholder participation (*social and cultural aspects*); collaboration, co-responsibility, leadership, and informed multi-level governance (*institutional and political aspects*); and an innovative and integrated approach, appropriate regulatory framework, as well as education and awareness (*technical aspects*).

In the following sections, we explain how we uncovered barriers and drivers in an in-depth multiple case analysis, using a Living Lab approach, and explored similarities and particularities to address contextualization and generalization simultaneously.

2.2 | Uncovering barriers and drivers through the ULL approach to transition toward climate resilience

A paradox arises in contextualization and generalization; the "pilot paradox" (van Buuren et al., 2018) reflects the challenge of balancing internal success (reaching its main goal) with external impact (wider impact and more enduring change in the system). Factors like distance from parent organizations, innovation safeguarding, participatory processes, and small scale, beneficial for internal success, often hinder external success. This paradox can be addressed through careful experimentation design.

Experimentation through ULLs allows the creation of networks, alliances, shared visions, and learning activities essential for *sustainability transitions*, which are processes of institutional change and regime shifts, institutionalizing new and more sustainable and desirable arrangements (Fuenfschilling et al., 2019). ULLs have gained recognition as a shared governance pathway to policy and service delivery in EU Horizon-funded projects addressing transitions and environmental concerns (Lupp et al., 2020; Mahmoud et al., 2021). They are increasingly seen as a means to attain sustainability goals in European cities, bridging the gap between academia and practice (Bulkeley et al., 2016; McCormick & Hartmann, 2017; Mitić-Radulović & Lalovic, 2021; Steen & van Bueren, 2017). ULLs are touted in the literature as a creative and collaborative response to climate change, addressing low carbon emissions (Alexandrakis, 2021; Barrett et al., 2017; Sharp & Salter, 2017; Stibe et al., 2017; Voytenko et al., 2016) and climate adaptation and resilience (Ståhlbröst et al., 2018; Vollstedt et al., 2021).

The systemic ULL approach offers flexible and transparent decision-making, considering diverse knowledge and stakeholders required for complex environmental issues. This perspective aids in pattern identification and replication (DeLosRíos-White et al., 2020). It is crucial as meaningful experimentation necessitates monitoring, evaluation, translation, and scalability of outcomes and lessons to other contexts (Bulkeley et al., 2015; Fuenfschilling et al., 2019).

We use a *multi-level perspective* to position the diffusion processes of *embedding* (adopting and integrating the approach into the local context), *translating* (replicating the solution elements in another geographical, institutional, or sectoral context), and *scaling up* (experiment growth in content and remit) into a larger conceptual framework. Within this perspective, there is a nested character between three levels: (a) the niches at the micro-level, where innovations are developed within their specific context of problems, rules and capacities; (b) the socio-technical regimes at the meso-level, which relates to the stability of current technologies and trajectories, and where innovation takes place incrementally; and (c) the socio-technical landscape at the macro-level, an external structure that changes more slowly (Geels, 2002). Adapting and scaling experiments from niche to regime contexts poses a challenge but is essential for transformative change and sustainability transitions (Bradley et al., 2022; Bulkeley et al., 2015; Newton & Frantzeskaki, 2021; Von Wirth et al., 2019).

Our conceptual framework (Figure 1) assesses the barriers and drivers faced by CCLLs in mainstreaming and upscaling climate resilience solutions, reflecting the duality of contextualization and generalization. While ULLs excel in creating tailored niche solutions, opportunities for diffusion processes of embedding, translating, and scaling to regime level can be identified by contrasting multiple cases. Understanding this relationship offers insights into contextualizing and generalizing solutions across different urban contexts and actors, contributing to the literature with evidence-based strategies and practices.

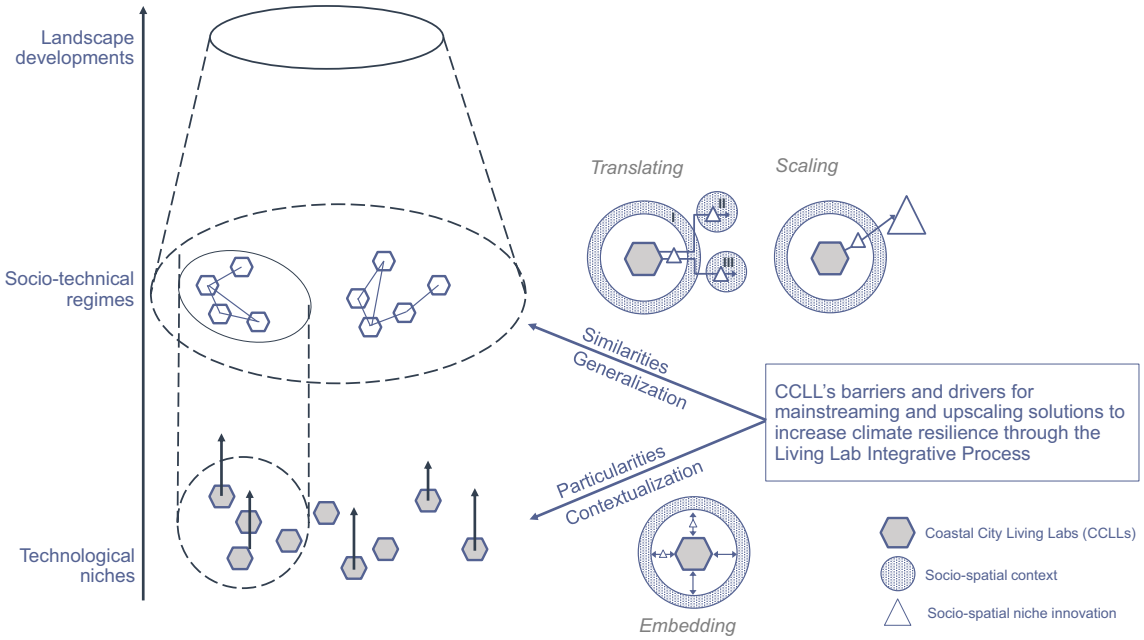

FIGURE 1 Conceptual framework: contextualizing and generalizing drivers and barriers of urban livings labs for climate resilience (author). (1) diffusion processes (embedding, translating, and scaling) adapted from von Wirth et al. (2019); (2) levels based on the multi-level perspective, adopted from Geels (2002).

3 | METHODS

The research strategy chosen was a qualitative multiple case study, as we aim to find particularities and similarities, as well as patterns, among different cases. The case study method focuses on a limited number of real-life situations and goes into detail and depth. It fully explores, describes, and explains a phenomenon in its context, aiming for a rich and qualitative understanding (Mohajan, 2018; van Thiel, 2014). In parallel multiple case studies, several cases are taking place and are studied simultaneously (Mohajan, 2018). In multiple case studies, the researchers aim to grasp differences and similarities among the cases by analyzing the data across their settings, allowing strong and reliable evidence to valuably contribute to the literature (Gustafsson, 2017). That is aligned with our objective to find particularities and commonalities among cases as a proxy to understand the potential of contextualizing and generalizing (diffusing) solutions developed at the ULL level.

This article analyses nine European ULLs in coastal cities (CCLLs), in Ireland—Sligo (SL) and Dublin (DU), Slovenia—Piran (PI), Turkey—Samsun (SA), Italy—Massa (MA), Spain—Vilanova i la Gertru (VI), Benidorm (BE), and Basque Country (Oarsoaldea, OA), and Portugal—Oeiras (OE)—see Figure 2. The cases were selected to allow rich case comparison due to similarities in coastal climate hazards and impacts and European geographical context. Furthermore, all CCLLs aim to increase long-term climate resilience by designing, developing, monitoring, and evaluating adaptation measures that integrate ecosystem-based approaches and smart technologies. At the same time, each CCLL has its unique local setting, vision, strategic goals, and internal capacities. The cases are part of the European Union's Horizon 2020 research and innovation project "SCORE—Smart Control of the Climate Resilience in European Coastal Cities." (SCORE, 2023).[2] Climate hazards faced by the CCLL include land and coastal flooding, coastal erosion, and storm surge. Impacts refer to damage to commercial and residential buildings and other civil infrastructure, tourism and cultural heritage risks, loss of habitats and wetlands, local economy risks, and agricultural stress. Appendix B presents more details about the cases (Table B1).

Data collection comprised a multi-method approach following the steps from the Living Lab Integrative Approach (adapted from Mastelic, 2019). The different data collection methods are detailed in Figure 3. First, two open-ended questionnaires were conducted with each of the CCLLs core teams in June 2020 and January 2022 to understand the local contexts concerning climate resilience. Second, focus groups were done in person in each CCLL between March and May 2022. The focus groups aimed to discuss in depth the questionnaire results and validate the CCLL core team responses with a broader range of local stakeholders, with participants ranging from 4 to 37 people in each session. The CCLL core teams are composed of five different roles (developed by ENOLL, based on Habibipour

[2]We would like to note the authors' positionality. "The term positionality both describes an individual's world view and the position they adopt about a research task and its social and political context" (Holmes, 2020, p. 1). Seven of the nine co-authors are researchers involved in the SCORE project, which provides an inside view of the cases studied. However, none of us is part of any of the CCLL teams, also bringing an outside view. To avoid any bias, a few measures have been taken: (1) we have rigorously followed the same data collection steps and methods within all cases; (2) focus groups were always facilitated in pairs and different organization partners were involved in each CCLL; (3) reports with the results were peer-reviewed by other facilitators and project partners external to facilitation; (4) each CCLL also reviewed the results and provided feedback in writing and via the online validation meetings; (5) two co-authors outside the project were included and reviewed all data analysis. Credit author and (non-) conflict of interest statements were submitted to the journal.

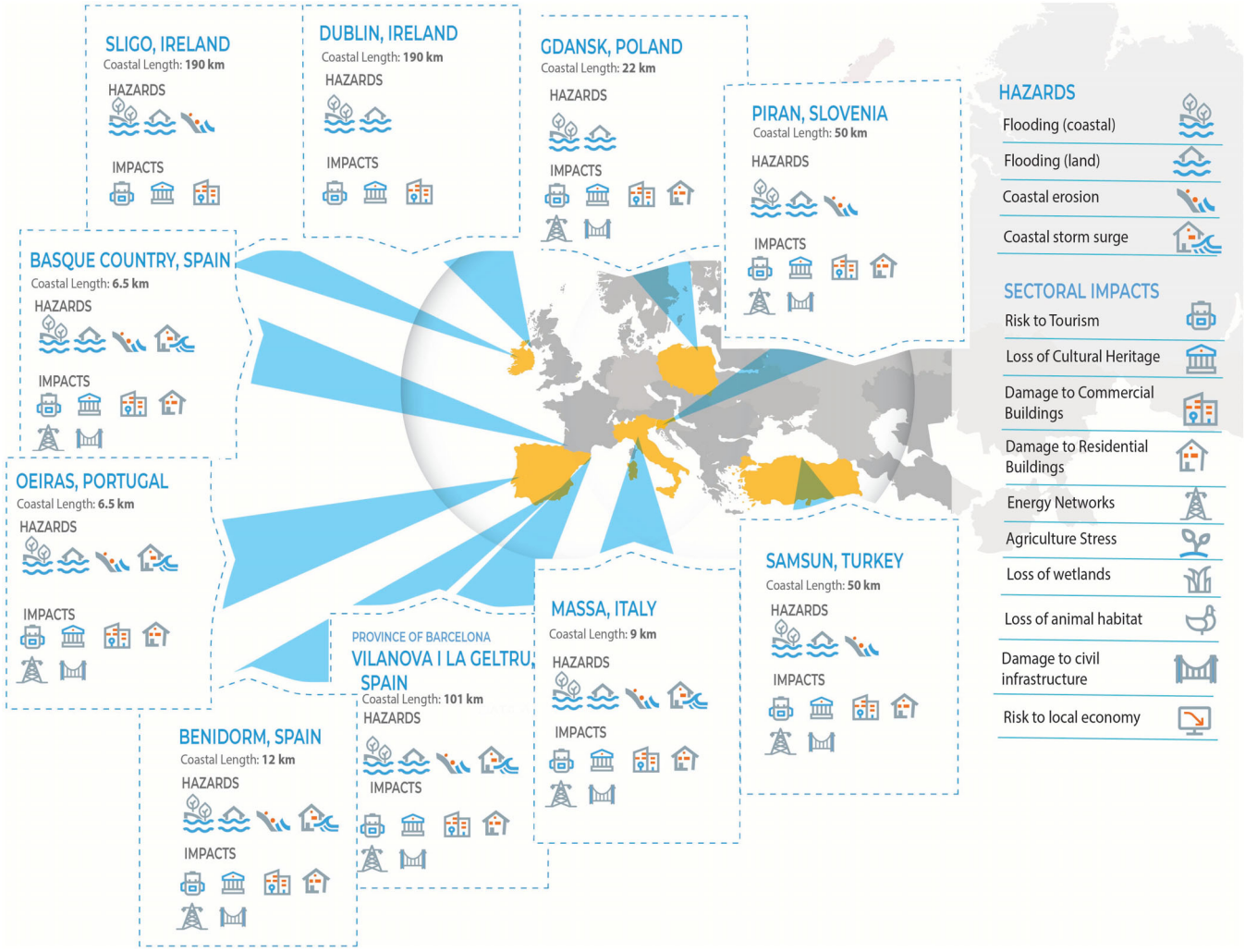

FIGURE 2 Map of the Coastal City Living Labs (CCLLs) within the SCORE project (SCORE 2022).

et al., 2020; Ståhlbröst et al., 2015), namely: Living Lab manager, human interaction specialist, community manager, pilot manager, and project manager. These roles are occupied by experts from the partner organizations in each CCLL, mostly universities and local governments in the studied cases. Key stakeholders were invited by the CCLL teams and included representatives from public entities (from diverse departments, such as planning, environment, and civil protection), private companies, academia, and civil society. Each participant signed an ethics consent form. The activities were facilitated in pairs by experts within the SCORE project.

The focus groups were structured based on the Living Lab Integrative Process steps, with each step having a discussion facilitated via an interactive tool (see Figure 3). Applying of the same tools in all nine cases enhanced the case comparison, keeping the discussion focused on the same basis and creating similar visual outputs. The several tools and discussion outputs, in combination with the questionnaires' results, allowed a systematic cross-case analysis looking for similarities (convergences) and particularities (divergences) among the barriers and drivers faced by the cases. Thirdly, online meetings were held with each CCLL in May 2022 to validate the results compiled by the researchers. One report per city contained the main findings from the questionnaires and focus groups. These documents were peer-reviewed by the other focus group facilitators and shared with the CCLL teams for feedback.

The reports per city were then finalized and uploaded on the software ATLAS.ti for data analysis. Coding was conducted following an abductive approach. "Abductive research is neither data-driven nor hypothesis-driven but conducts parallel and equal engagement with empirical data and extant theoretical understanding (…) to find the most logical solution and useful explanation for phenomena" (Thompson, 2022; p. 1411). Appendix E provides the details of the coding process and presents an overview of the codes and occurrences per report (CCLL). The last step was an analysis of the co-occurrence of findings among CCLLs. The text result within each category was coded again using an automated script. In identifying these co-occurrences, we followed two analytical steps. First, we analyzed identical findings

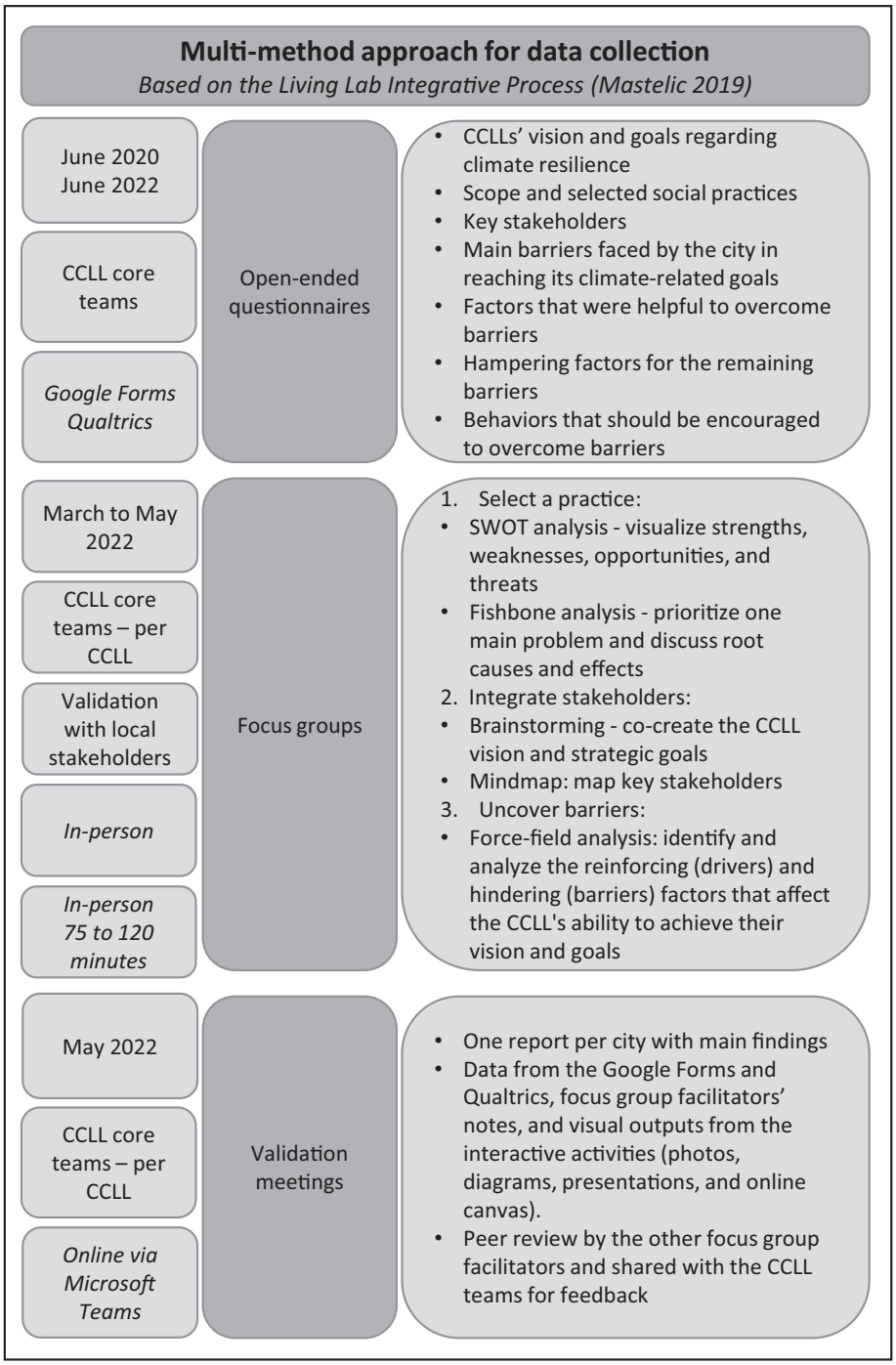

FIGURE 3 Multi-method approach for data collection (author).

of drivers and barriers across pairs of cases. Then, we identified similarities between identical barriers but differences in identified drivers or solutions. This final step in the analysis allows us to find interesting combinations of cases that would point to possibilities of learning exchange between CCLLs dealing with similar barriers to climate resilience and of generalization (via translation, replication, or scaling) of solutions at a higher level in the system.

The section below presents the main findings, organized within the defined themes (or categories of barriers and drivers) from Section 2.1.

4 | RESULTS AND DISCUSSION

4.1 | Dealing with the intrinsic duality between contextualization and generalization: Particularities and similarities among CCLLs

We contribute to the existing body of knowledge on ULL by detailing and categorizing barriers and drivers through the cases studied. Moreover, through the identification of recurring and, therefore, potentially generalizable (sub-categories of) barriers and drivers,

we enhance ULL knowledge, especially in coastal areas, and their potential impact on transitioning toward climate resilience. These results are presented in Sections 4.2 and 4.3, structured as per Section 2.1. Detailed findings are presented in Appendix D, including the CCLLs which identified each barrier or driver.

The relative importance of each barrier and driver is presented in three ways:

I. In Section 4.1, we conduct a co-occurrence analysis to identify patterns.
II. Sections 4.2 and 4.3 reveal commonalities and differences within sub-categories.
III. Appendix D provides tables highlighting which CCLLs encountered each barrier or driver.

Our cross-case analysis identifies barriers and drivers particular or shared among the nine cases, serving as a proxy for the contextualization-generalization duality (refer to the conceptual framework in Figure 1), which are illustrated by the co-occurrence analysis below.

4.1.1 | Similarities, denoting generalization

Several similarities emerge across cases. Notably, co-occurrence analysis reveals high overlaps. For example, regarding barriers (Table C1), the highest co-occurrence was between the CCLLs Vilanova + Benidorm, followed by Sligo + Oeiras, and Benidorm + Oeiras and Sligo + Piran. Within drivers (Table C2), there were even more overlaps, with the highest between the CCLLs Samsun + Oeiras, Samsun + Benidorm, and Vilanova + Samsun, followed by Benidorm + Oeiras and Vilanova + Oeiras.

To illustrate the similarities, there were some factors mentioned by all CCLLs (or all but one). In terms of barriers, these forces were a lack of human resources, limited data availability and accessibility, and excessive bureaucracy. Regarding drivers, the most common forces were relevant knowledge and experience, the existence of climate studies in the region, and communication and awareness opportunities. The similarities within challenges and opportunities among the multiple cases highlight the potential for synergies and diffusion processes, as well as for generalization and a systematic approach.

4.1.2 | Particularities, denoting contextualization

On the other hand, solutions must be contextualized and tailored to the unique situation of each city. The particularities of each CCLL emerge from the research results, with 124 unique barriers and 90 drivers (Table C3), expanded upon in Sections 4.2 and 4.3.

Interestingly, pairs with the most barrier overlaps may not share the same drivers, indicating distinct specificities (co-existence of similarities and particularities) within pairs. For example, the pairs Oeiras + Benidorm, Vilanova + Oeiras, Vilanova + Benidorm, Vilanova + Samsun, and Vilanova + Sligo have many overlaps both in barriers and in drivers. However, that is not the case among Piran + Oeiras, Piran + Benidorm, Samsun + Oeiras, Samsun + Piran, Samsun + Massa, Sligo + Oeiras, Sligo + Piran, Sligo + Benidorm, Vilanova + Piran.

The co-occurrence of similar barriers with different drivers among CCLLs (exemplified in Table 1) suggests the potential for deep learning and diffusion of solutions across (geographical, institutional, sectoral) contexts, facilitating a larger impact at the regime level and contributing to sustainability transitions. Based on the empirical data, there are unique driving forces that can be translated from one case to another. These drivers should then be once more embedded, now in the new case, tailoring solutions to the existing local practices and structures. The experiments may also grow beyond the initial geographical region, domains, actors, and resources, meaning they would scale up.

The results are in line with the literature, such as Bulkeley et al. (2016), that indicates it is crucial that LLs are seeing beyond their specific terms and context but rather part of a larger phenomenon of a transition in how we address and govern sustainability. Furthermore, as stated by von Wirth et al. (2019, p. 251), "the transformative potential of ULL will be realized when applying their lessons across sectors, actors, and geographical boundaries. To achieve transformative change, ULLs must navigate the duality between place specificity and replicability, which could benefit from interactive exchanges among ULLs. Learning is at the core of both climate resilience (Torabi et al., 2018) and ULLs (Bulkeley et al., 2016; Mahmoud et al., 2021; Sharp & Salter, 2017; Steen & van Bueren, 2017).

4.2 | Barriers

We used the three overall categories: "social and cultural," "institutional and political," and "technical" barriers. Within the first one, the most recurrent barriers refer to the lack of a shared vision and awareness among stakeholders and difficulties in keeping them engaged, also in connection with the uncertainty around climate change issues and communication problems. In the second category, the highest similarities relate to the culture of working in silos, excessive bureaucracy, limited financial and human resources (with special attention to the prioritization among many urban issues and time availability), and external socio-economic issues. Lastly, in the third category, some crucial barriers regard lack of specific technical knowledge and experience, such as on smart technologies, ecosystem-based approaches, or implementing a Living Lab. Also, issues regarding data accessibility and availability were frequently mentioned. The barriers are further explained below.

4.2.1 | Social and cultural barriers

Within the first category, "social and cultural barriers" (Table D1), two main sub-categories emerged from the empirical cases. The first one is "stakeholder engagement and awareness." Similar barriers faced by the CCLLs are a lack of a shared vision among the different stakeholders, who hold diverse (and sometimes conflicting) interests and priorities, mis-integration among different government levels, and

TABLE 1 Examples of opportunities for knowledge exchange among the CCLLs (author).

Pair of CCLLs	Example of a similar challenge identified	Example of a particular opportunity identified
Piran + Oeiras	Difficulty to keep stakeholders engaged and committed	Engaging with existing active community groups (PI) Providing certification for activities as incentives (OE)
Piran + Benidorm	Restricted access to certain data from public institutions	Making use of good teamwork, organization, and internal communication (BE) Being willing to learn and share with each other (PI)
Samsun + Oeiras	Use of jargons that are difficult to grasp by actors	Encouraging dissemination among different groups of stakeholders (OE) Reinforcing the presence of different public agencies (SA)
Samsun + Massa	Difficulty to think and plan in the long-term	Increasing interaction among knowledge actors with public sector and communities to bring collaboration into practice (MA) Stimulate collaboration between different public agencies (SA)
Samsun + Piran	Data spreading	Working with a multidisciplinary team (PI) Making use of ongoing collaborations with universities and public departments (SA)
Sligo + Oeiras	Difficulty in coordinating with different levels of government entities, with diverse competences	Being part of relevant networks (OE) Understanding different forms of incentives required by actors (SL)
Sligo + Benidorm	Limited experience with citizen science	Disposing of good contacts (BE) Working with a diverse team (SL)
Sligo + Piran	Resistance to new ideas	Providing concrete evidence of the problems (PI) Making use of specific groups with more interest, such as the youth (SL)

difficulty in keeping stakeholders engaged and committed in the long-term. Also, lack of awareness and interest in climate impacts are common. Unclear expectations, lack of trust, and a feeling of being powerless or not represented as citizens are similar barriers. Other common challenges include citizen fatigue with many projects and overall resistance to new ideas and to change the business-as-usual lifestyle. Examples of particular barriers identified in the cases include issues in identifying the stakeholders or engaging with specific groups of actors, hierarchical organizational culture, and lack of dissemination of best practices. Temporary visitors as tourists might lack understanding of the issue and contribute to negative climate-related impacts. Other restraining forces were unclear success criteria and a longer decision-making process due to a lack of consensus.

The second sub-category is "communication and dissemination." Similarities referred to a lack of a common space for synergies among stakeholders, which might not be all included in communication efforts. A common challenge is the lack of adequate language and design and the use of jargon and terminologies that are difficult to grasp by actors. The cases also pointed to a delay until the solutions reach maturity and results are communicated, resulting in a lack of information about the solutions' benefits. Particular barriers mentioned include issues in communication strategies in terms of channels, limited financial resources to conduct dissemination activities, and resistance to working with foreign experts and organizations. Also, there are problems with disseminating best practices and knowledge retention, limited learning from previous results, lack of visibility of immediate results, and lack of feeding project results into policymaking.

Our findings are consistent with the literature, which identifies limited stakeholder participation and collaboration among actors (Aktürk & Dastgerdi, 2021; Fu & Li, 2022; Rijke et al., 2021), conflicting agendas and values (Aktürk & Dastgerdi, 2021), lack of awareness and communication issues, such as use of proper terminology (Aktürk & Dastgerdi, 2021; Mendizabal et al., 2018), and behavioral issues (Mendizabal et al., 2018). There were some specific barriers from our empirical cases that we did not find explicitly in the literature on barriers to climate resilience. These include, for example, feelings of no empowerment and representation among citizens, citizen fatigue, lack of clear success criteria, issues in communication design, and resistance to working with foreigners.

CCLLs under the spotlight

"There is a potential fatigue among citizens. They are always the same ones who participate in projects." (DU)

"There is climate fatigue leading to inaction." (PI)

"Powerless feeling from the individual: "I will let someone else do it." (SL)

"There are differences in criteria to see and accept success in solutions" (MA)

"Communication materials are without adequate language and design" (DU)

"Communications strategy is not clear (whom, when, how, where)." "Communication lacks a language that covers all the groups" (SL)

"There is resistance to experts coming from the outside to inform and share knowledge. There are resistance and fear about the extent of the problems and working with external foreigners, as well as linguistic issues" (PI)

4.2.2 | Institutional and political barriers

Within the category "Institutional and political barriers" (Table D2), three main sub-categories emerged from the empirical cases: (i) "institutional"; (ii) "resources"; and (iii) "political and external factors." In the "institutional" sub-category, there are two main types of barriers. The first one regards to a culture of working in silos. A common barrier to the CCLLs is the fact that local authorities work in silos and lack communication among departments. There are difficulties in coordinating with the different levels of government entities, which have diverse competencies and processes. The second type refers to bureaucracy, which was mentioned to all but one CCLL. Excessive and slow bureaucratic procedures are seen as hindering factors. Bureaucracy affects how data is accessed, shared, and published. Another similar barrier mentioned was an unclear internal governance structure and roles within the CCLL. In terms of particularities, CCLLs mentioned jurisdictional barriers, spreading of resources among local authorities, difficulty in implementing large projects that require multi-disciplinarity, and problems in aligning policy-strategic and operational levels. Also, that bureaucracy can limit innovation and co-design among stakeholders. Internal CCLL bureaucracy and lack of empowerment were also raised.

In terms of "resources," in the view of all the CCLLs, limited resources are a crucial barrier to reaching their climate-related goals. Common barriers related to financial resources include issues with limited or uncertain funding for certain project phases (research, implementing solutions, and monitoring), issues with public funds, and a "competition" among many issues and projects to be prioritized. Available funding might not be sufficient for conducting training and capacity-building activities. Barriers concerning human resources were also cited by all CCLLs, with only one exception. Time availability, in general or specifically within the CCLL team, is a common issue and can hamper the achievement of the CCLL objectives. This can be related to working on too many projects simultaneously. Understaffing is an issue in some local authorities. Another similarity among the cases was a concern that a lack of resources at the end of the project could endanger the CCLLs' sustainability in the long run and the willingness of stakeholders to commit. Particularities mentioned in this sub-category include a lack of a dedicated budget to tackle climate matters and limited or uncertain funding for specific activities (e.g., communication, stakeholder participation, and implementing solutions such as sensors, maintenance, and scaling up). Other specific barriers were for instance difficulties in accessing EU funds for climate action, staff changes, and a high workload at local authorities which can lead to work delegation and limiting knowledge retention.

The last sub-category is "political and external factors." Here, we found barriers related to political, external socio-economic, and urban infrastructure aspects. Common barriers are political resistance, lack of political support and commitment, and uncertainty after elections. External factors such as increasing inflation, war, and economic recession are also similarities. Lastly, lack of technical equipment and restricted access to land to implement climate solutions were mentioned. As for examples of particularities, we identified the establishment of goals at one government level and action at another, diminishing or aging population, and limited infrastructure in certain sectors.

The findings are highly consistent with the literature, which also highlights the issue of a fragmented and siloed governance, both in terms of scale and sectors (Fu & Li, 2022; Mendizabal et al., 2018), mining the collaboration required for resilience planning and a systemic perspective (Fu & Li, 2022). Issues with limited funding, resources prioritization, and limited sharing of best practices are also cited (Aktürk & Dastgerdi, 2021). Policy inertia, resistance to change, and lack of political and long-term commitment will be highlighted by some authors (Leichenko et al., 2018; Mendizabal et al., 2018). There is also acknowledgement of the influence of external stressors faced by cities, as poverty and inequality (Fu & Li, 2022). Although our cases showed a high importance of bureaucracy as a barrier, it was not so present in the reviewed literature. Regarding human resources, we did not find much on practical aspects as time limitation or understaffing.

CCLLs under the spotlight

"It is difficulty to align many authorities and to navigate their long, complex and bureaucratic process to implement the project." (OA)

"High bureaucracy hampers interaction with external stakeholders. Too much bureaucracy in the public limit co-design." (MA)

"There are complex and bureaucratic process to proceed with innovative ideas from technical staff due to the uncertainty of the effectiveness of new solution, which is "new for proof"." (OE)

"There are difficulties in accessing data due to difficult procedures in getting the formal permissions from the relevant institutions (public, private, universities, etc.)." (SA)

"Local authority is understaffed and has to delegate some of the work to external consultants, limiting the knowledge retention at the end of projects" (DU)

"The CCLL team members are working on several projects at the same time." (PI)

"There is limited time availability of full-time staff, chiefs and decision-makers and personnel in general" (BE)

4.2.3 | Technical barriers

Within the category "technical barriers" (Table D3), four main sub-categories emerged from the empirical cases: (i) "knowledge and experience; (ii) "technical and internal capacity"; (iii) "data availability and accessibility"; and (iv) "long-term view and uncertainty." First, we have "knowledge and experience." As similarities, the CCLL teams have identified some internal barriers in terms of climate change

expertise and in setting up and managing a LL. Particularities raised include difficulty in grasping the scale of climate issues, lack of experience with climate-related financial risks, as well as lack of clarity on what constitutes a risk and how to manage it. Specific issues with limited knowledge of communication and stakeholder engagement strategies were also identified.

Secondly, barriers relate to "technical and internal capacity" were commonly mentioned, such as limited knowledge and experience with smart technologies, citizen science, digital twins, socio-economic assessment, ecosystem-based approaches, and nature-based solutions. Examples of particularities in this sub-category are lack of local people or reduced team size, internal miscommunication, and limited knowledge on specific topics such as modeling, impact measurement, or setting up operational plans.

Thirdly, relevant barriers for all CCLLs regard "data availability and accessibility." The problems include data being scattered among different organizations, lack of a common database, and lack of a compatible platform or homogeneous data. The lack of open-access datasets is an essential barrier to some CCLLs, as well as restricted access to specific data from some public institutions, which can pose bureaucratic and lengthy procedures. There is a lack of real-time, digital, and monitoring data on climate change effects, which might also not be at the appropriate scale. Some particularities were also identified in the cases. For example, low coherence between existing studies, making data integration difficult, or restricted access to certain data from some private or knowledge institutions. Specific constraints mentioned include also limited collaboration among stakeholders who possess data, unclarity on the role of nonexperts concerning data accessibility, and lack of sensors and tools. Lastly, there might not be enough data about the benefits of the proposed solutions.

Lastly, we have "long-term view and uncertainty" barriers. Here, similarities include difficulty thinking and planning in the long-term and engaging and committing stakeholders due to the uncertainty around climate matters. While there is an urgent need for short-term actions, some actors might not be interested. It was also common in some cases that resources are limited for long-term actions and that there is a limited understanding of the timescale of climate events. For some CCLLs, these can affect their sustainability in the future. Particularities raised in this sub-category referred to the unpredictability of climate impacts, which are going faster than predictions and are not fully quantified. There is a lack of capacity building concerning climate change at local administrations, as well as limited ability to implement long-term actions. Also, some seek a quick win or might not perceive long-term actions as needed.

These findings are highly aligned with the literature, which recognizes the deep uncertainty around climate change, which is nonlinear and complex and creates difficulty in planning for the long-term and establishing a proper range of scenarios and affects the copying capacity of a city (Aktürk & Dastgerdi, 2021; Fu & Li, 2022). Also, the lack of a shared understanding and operationalization of resilience challenges cross-disciplinary communication (Fu & Li, 2022). Furthermore, an integration of an overarching vision of climate change, synergies and trade-offs between climate adaptation and mitigation, and a common operationalization of the resilience concept are lacking (Fu & Li, 2022). The absence of a cross-cutting approach is largely mentioned in the literature (Aktürk & Dastgerdi, 2021; Fu & Li, 2022; Rijke et al., 2021), as well as issues with methodologies, staff, and expertise (Aktürk & Dastgerdi, 2021; Fu & Li, 2022; Mendizabal et al., 2018). Other common barriers relate to lack of proper monitoring (Aktürk & Dastgerdi, 2021; Mendizabal et al., 2018), lack of data accessibility and availability (Aktürk & Dastgerdi, 2021; Mendizabal et al., 2018; Rijke et al., 2021). Lastly, limited technology (Mendizabal et al., 2018) and low capacity to respond to climate events (Rijke et al., 2021), as well as a flexible and systemic approach (Fu & Li, 2022), were consistent findings. One interesting finding from the cases that was not highlighted in the literature was the lack of knowledge on stakeholder engagement and communication, which can be crucial for decision-makers dealing with holistic and participatory approaches.

CCLLs under the spotlight

"The CCCLL team has limited knowledge on stakeholders' engagement methodology." (BE)

"The CCLL team has limited skills and expertise in communication." (VI)

4.3 | Drivers

We have organized the drivers within the three overall categories based in the literature. First, there are "social and cultural drivers." The most recurrent drivers in this category refer to stakeholder awareness and engagement through active groups, partnerships, and networks, of collaborative and proactive actors. Promoting communication and dissemination activities were also recurrent drivers. Second, we have "technical drivers." The most mentioned driving forces relate to having technical knowledge and experience, good teamwork, and being involved in networks and collaborations. Existing climate policies, programs, and actions, as well as data availability and accessibility, are very relevant. Last, a cross-cutting and multidisciplinary team and approach facilitates innovation. The third category is "institutional and political drivers." The major similarities here related to funding sources at different administrative levels and in combining climate-related solutions with other social-cultural co-benefits. The drivers are further explained in the following sub-sections.

4.3.1 | Social and cultural drivers

Within the first category, "social and cultural drivers" (Table D4), two main sub-categories emerged from the empirical cases: (i) "stakeholders"; and (ii) "communication and dissemination." Within the first sub-category, the CCLLs identified driving forces related to

stakeholders' engagement, acceptance, and awareness. In some cities, there is great community awareness of climate challenges, with stakeholders committed to solving environmental issues and therefore are interested in the CCLL ambitions. In other cases, awareness is rising and becoming a priority. Having stakeholders who are willing to work together and are proactive were drivers highlighted. CCLL teams have good contacts and are part of relevant networks. CCLLs mentioned existing partnerships with private, public, and research organizations. There are various active community and technical groups which bring opportunities for engagement with CCLL activities. Other common drivers are a citizen participation culture, having environmental education programs in schools and with citizens, and concrete evidence of the problems. They mentioned the importance of being explicitly open to all people and ensuring stakeholders are met as equals, regardless of their background or hierarchical position. Being good listeners and respectful to all are behaviors to be encouraged, the same as being transparent in information sharing. Particularities in this sub-category included involving specific groups more sensitive in the context (e.g., the youth), the presence of an ambitious and experienced group of stakeholders, and experience with citizen science. Other specific drivers were providing diverse forms of stakeholder incentives and using existing LLs that make people more familiarized and interested in the approach.

Concerning the second sub-category, driving forces related to promoting communication and raising awareness of climate issues were mentioned by almost all CCLLs, with one exception. Similarities include having strong media and public relations, which can be an advantage to promoting climate communication to all sectors of society and the existence of tools and initiatives related to environmental awareness that can be linked with CCLL goals. Examples of particularities mentioned are establishing a physical meeting place, training and capacity-building activities, and using tourists to spread information. Also, reinforcing communication between different public agencies and their presence brings opportunities for funding and visibility. There were also particularities regarding the private sector, which could be more involved in climate-relate issues, adopt more climate-friendly practices, and promote good behavior. The piloting and dissemination of innovative, respectful, and cost-efficient solutions can produce synergies among partners, increase accountability and credibility, and expand networks.

The literature also highlights the importance of stakeholder participation and collaboration (Aktürk & Dastgerdi, 2021; Fu & Li, 2022; Mendizabal et al., 2018), good and effective communication, and learning from the past (Fu & Li, 2022; Mendizabal et al., 2018). This is very much aligned with the Living Lab approach, used by the cases studied, in which stakeholders from government, academia, industry and civil society engage throughout the LL phases in a Quadruple Helix Model, contributing to innovation with their knowledge, needs, and interests (Lupp et al., 2020; McCormick & Hartmann, 2017; Ståhlbröst et al., 2018).

4.3.2 | Technical drivers

Within the category "technical drivers" (Table D5), three main sub-categories emerged from the empirical cases. The first sub-category is "knowledge and experience," highlighted by all CCLLs. Technical knowledge is an enabling force for the CCLLs, such as having capacities with technologies, models, and data management and analysis. Some CCLLs have in common the presence of good ICT (Information and Communications Technology) infrastructure, sensor networks, and monitoring systems, and a good use of technology in society. Other similarities include knowledge and experience with the LL approach, climate issues and projects, including risk and vulnerability assessments and ecosystem-based approaches. Working in a diverse, multidisciplinary, organized, and committed team and possessing research skills are seen as advantages. Common drivers are also disposing of good contacts, being part of networks, and possessing a solid territorial intelligence. All CCLLs have identified synergies and opportunities for knowledge exchange. There are ongoing collaborations among different stakeholders, such as universities, industry, public departments, and local organizations, to share information and data on climate-related issues. The CCLLs can link to these existing networks to boost their goals. There are potential synergies with different existing and new projects dealing with similar topics. The CCLLs expressed willingness to share and learn with each other and beyond. Synergies and knowledge exchange can result in the replication of the interventions. Particularities identified in this sub-category include the presence of technical communities, powerful and knowledgeable institutions in the team, or relevant digital platforms. Specific knowledge on certain areas was also mentioned, such as climate-related impacts, parameters, water literacy, climate adaptation, and citizen science. Some CCLLs also mentioned strategic experiences, as with European Commission projects, proposal writing, or resource management.

The second sub-category is "climate-related policies, programs, and actions." The existence of climate studies is an advantage to the CCLLs' goals, as mentioned in all cases but one. They cited relevant climate projects, plans, programs, and activities to which the CCLLs can be linked and involved. The studies and frameworks are available at multiple levels. Research institutions are present in the territories, engaged with sustainability and climate change. Some CCLLs perceive an increasing prioritization of climate action. Others see the opportunity to focus on smart strategies for the long term while bringing climate action to the short-term discussion. Additional shared drivers are data availability and accessibility, especially open-access data, and good territorial knowledge of the geographical area. The existence of studies and data can provide concrete proof of the problems. Working in close collaboration with institutions and stakeholders is valuable in getting information and data. Particularities referred, for example, to the existence of initiatives that can provide relevant data, report, and knowledge on relevant topics, previously implemented solutions that can be monitored, and data standardization. Adequate data and information might give weight to administrations in the decision-making, as well as in a greater involvement of all parties to achieve the CCLL objectives.

The third sub-category is "innovation and practice." As similarities, for the CCLLs, the innovative plans require a cross-cutting approach, with a multi-disciplinary team and cross sectoral support. It

is important to bridge knowledge actors with the public sector and communities, increasing this interaction to bring collaboration into practice. Having clear and recent examples, and a leadership attitude from actors are also helpful. Examples of particularities include openness to trialing potential solutions with clear Key Performance Indicators, a collaboration between specific types of stakeholders, and making use of proper channels of communication and having a proactive environment.

The literature also highlights the importance of cross-cutting, systemic, long-term, and collaborative climate plans (Fu & Li, 2022; Mendizabal et al., 2018). The Living Lab approach is also relevant to promote innovation (Mendizabal et al., 2018). Education and awareness activities, especially data-related, is also cited in the literature (ibid). "To improve future plans, planners can consider non-climatic factors and link existing stressors to climate change impacts, improve horizontal and vertical coordination to build adaptive capacity through collaboration, embrace the deep uncertainty of climate change, promote no- or low-regret adaptations, and emphasize social equity in the coping and adaptive process" (Fu & Li, 2022, p. 318). Our findings highlighted the importance of linking to existing networks, policies, plans, and projects, which is not so much discussed in the literature.

CCLLs under the spotlight

"There are relevant climate related plans at the national and regional level under implementation, that the CCLL can get involved. We have access to many relevant data reports, and good links to sustainable energy and climate action plans, climate change adaptation and resilience plans." (OA)

"Public institutions have already knowledge, models, maps, plans and solutions on climate change related problems. These are local and regional and can be compared and there's availability of monitoring data." (SA)

"Existence of previous studies and analysis of the climate problem of the territory available through the external stakeholders." (VI)

4.3.3 | Institutional and political drivers

Within the category "Institutional and political drivers" (Table D6), two main sub-categories emerged from the empirical cases: (i) "resources" and (ii) "political and external factors." For the first subcategory, the CCLLs have identified potential funding sources as enablers to reaching their goals. In addition to funding from the project, CCLLs mentioned the availability of funds in general and at different administrative levels, from local, regional, national, and European. Other similarities are having experience in fundraising and developing networks. Particularities include opportunities when involving private and industry partners. Common political drivers were identified within the second sub-category, such as having climate issues as a priority and a good alignment between the local administration political vision for urban development, the climate agenda, and the CCLL objectives. As coastal cities, some CCLLs see the opportunity to improve their cities' image while increasing climate adaptation and increasing tourism activities, which can improve municipal finances to invest in climate actions. Raised particularities include a green approach by the local party, trust in the local authorities, opportunities in government change, and sensitivity to politics. Also, The LL integrative Approach can be "easy to sell" to politicians, who are now attracted to participatory approaches. Climate adaptation can bring opportunities for increasing mental health, becoming a smart destination and a green city, and gaining the reputation of being a frontrunner.

Political drivers are also mentioned in the literature, such as co-responsibility, leadership, and adaptive multi-level governance (Mendizabal et al., 2018). Strategic internal drivers, as experience in raising funds, alignment with local political visions, and "selling" a participatory approach were not discussed in the reviewed literature and could be further explored.

CCLLs under the spotlight

"The Living Lab methodology is "easy to sell" to politicians, as participatory approaches are attractive to them at the moment." (OA)

"There is available experience in proposal writing and fundraising the CCLL team." (SA)

"We have experience in external funding raising." (MA)

"There is an alignment between political vision for the urban development of the city and the objectives of the CCLL." (OE)

5 | CONCLUSION

This article provides insights into the barriers and drivers encountered by multiple ULLs in coastal areas (CCLLs) pursuing climate resilience. A comprehensive cross-case analysis was conducted using a multimethod approach for data collection. Focus groups played a pivotal role in transparently and interactively gathering perspectives from CCLL teams and local stakeholders. Using structured tools throughout the Living Lab Integrative Process ensured that the discussions remained comparable among different groups. This participatory methodology enhances the field of ULL science and enriches the collection of empirical evidence from a wider array of participants.

The CCLLs aim to co-create innovative climate resilience solutions through a cross-cutting and data-driven approach while engaging and empowering diverse stakeholders. We have addressed the knowledge gap of understanding the specific strategies employed by

ULLs which potentially foster a broader impact through diffusion processes involving learning, embeddedness, translation, and scaling across various cases.

Categorizing and understanding the various challenges and opportunities helped us pinpoint recurring and significant issues. By identifying both commonalities and unique characteristics among the drivers and barriers in CCLLs, we have demonstrated that a dual approach of contextualization at the niche level and generalization at the regime level can be achieved through an iterative exchange of lessons learned from multiple parallel cases. This approach allows for synergies to be explored and harnessed through knowledge exchange and diffusion processes among cities, contributing to transitioning toward climate resilience.

Our findings show recurring barriers and drivers deserve further attention, while offering fresh empirical insights into the current state-of-the-art literature and avenues for future research. In the "social and cultural" category, the most common aspects refer to stakeholder awareness and continuous engagement. While limited stakeholder participation, lack of a common vision and communication issues are studied in the literature (Aktürk & Dastgerdi, 2021; Fu & Li, 2022; Mendizabal et al., 2018; Rijke et al., 2021), our research contributes to this literature by pointing out that responsively adopting participatory methods can enhance climate resilience. In particular, our findings highlight the value of empowering citizens, ensuring inclusivity and representation, establishing clear and shared success criteria, mitigating citizen fatigue among several projects, and reducing resistance to change.

Within "institutional and political" aspects, the most recurrent factors relate to silos versus cross-cutting culture, excessive bureaucracy, and limited resources. Most findings from this study are aligned with existing literature, such as fragmented or multi-level governance, funding issues, and political commitment (Aktürk & Dastgerdi, 2021; Fu & Li, 2022; Mendizabal et al., 2018). We add insights regarding the practical strategies in ULLs, recognizing that bureaucracy via rules, protocols and tight procedures may impede their innovation capabilities in different ways. Additionally, we show challenges for diffusion arise from limited human resources, including time constraints and understaffing, and opportunities in enhancing the capacity to secure funding, aligning with local political visions, and branding a co-creation approach.

Lastly, in the "technical" category, shared aspects regard specific technical knowledge and experience, data availability and accessibility, existing climate policies, programs, and actions, and involvement in networks and collaborations. Many drivers and barriers that we have found are in line with the literature, such as the need for a cross-cutting approach, available and accessible data, relevant methodology and expertise (Aktürk & Dastgerdi, 2021; Fu & Li, 2022; Mendizabal et al., 2018; Rijke et al., 2021). We advance our understanding by showcasing the importance of ULL teams possessing overall knowledge of stakeholder engagement and communication methods, beyond their experiments' thematic and technical focus. We also point to the relevance of aligning ULL climate solutions with existing policies, plans, and networks, exploring synergies.

In conclusion, our research highlights the significance of various factors contributing to the effectiveness of ULLs in pursuing climate resilience. These factors encompass social and cultural elements, institutional and political dynamics, and technical considerations. Based on our most promising results, we suggest four points for future research: (1) the adoption of participatory methods to include, empower, and represent citizens, while reducing fatigue and resistance to change; (2) the capacity building among ULL members and decision-makers on stakeholder engagement and communication strategies; (3) the multiple facets of bureaucracy in relation to ULL processes and innovations; (4) the significance of linking ULL solutions to existing climate policies, plans, and networks. This agenda will enable us to further understand and unravel the duality of contextualization and generalization, linking niches to regimes in fostering climate resilience.

Looking ahead, the solutions experimented with in the scale of CCLLs can potentially be extended to other geographical locations, domains, funds, and stakeholders. However, to assess the extent of this diffusion within the CCLLs' lifecycle and beyond, longitudinal studies are necessary. These studies, which we plan to conduct in future research, will shed light on whether the potential for diffusion is realized.

ACKNOWLEDGMENTS

The authors are grateful to all members of the SCORE—Smart Control of the Climate Resilience in European Coastal Cities—project, particularly to the Coastal City Living Lab teams and partners from NAIDER, the European Network of Living Labs (ENoLL), the Institute for Housing and Urban Development Studies (IHS), ERINN Innovation, and Atlantic Technological University.

FUNDING INFORMATION

The research presented in this article was conducted within the project "SCORE—Smart Control of the Climate Resilience in European Coastal Cities," which has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 101007142. This output reflects the views of the authors, and the European Commission is not responsible for any use that may be made of the information contained therein.

ORCID

Laura Quadros Aniche https://orcid.org/0000-0003-0275-6920
Charmae Pyl Wissink-Nercua https://orcid.org/0000-0002-5155-9176

REFERENCES

Aktürk, G., & Dastgerdi, A. S. (2021). Cultural landscapes under the threat of climate change: A systematic study of barriers to resilience. *Sustainability*, *2021*(13), 9974.

Alexandrakis, J. (2021). Cycling towards sustainability: The transformative potential of urban design thinking in a sustainable Living Lab. *Transportation Research Interdisciplinary Perspectives*, *9*, 100269.

Aversano, P., Baccarne, B., & Schuurman, D. (2016). D3.3—Implementation Living Lab methodology. Project deliverable, CreatiFI: Leveraging the

Future Internet for the Creative Industries project. Available online at https://cordis.europa.eu/docs/projects/cnect/5/632905/080/deliverables/001-D33ImplementationLivingLabMethodology.pdf.

Balica, S. F., Wright, N. G., & Van der Meulen, F. (2012). A flood vulnerability index for coastal cities and its use in assessing climate change impacts. *Natural Hazards*, *64*, 73–105.

Barrett, L., Galik, G., Hristova, D., Cowie, P., & Caro, F. (2017). Challenges and opportunities in the iSCAPE Cities. Project report, Improving the Smart Control of Air Pollution in Europe (iSCAPE) project, European Community's H2020 Programme. Available online at https://www.iscapeproject.eu/resources-2/.

Biesbroek, G. R., Klostermann, J. E., Termeer, C. J., & Kabat, P. (2013). On the nature of barriers to climate change adaptation. *Regional Environmental Change*, *13*(5), 1119–1129.

Bradley, S., Mahmoud, I. H., & Arlati, A. (2022). Integrated collaborative governance approaches towards urban transformation: Experiences from the CLEVER Cities Project. *Sustainability*, *14*(23), 15566.

Bulkeley, H., Breitfuss, M., Coenen, L., Frantzeskaki, N., Fuenfschilling, L., Grillitsch, M., Hartmann, C., Kronsell, A., McCormick, K., Marvin, S., Mai, Q. L., Sauer, A., van Steenbergen, F., & Voytenko, Y. (2015). Theoretical framework: Working paper on urban living labs and urban sustainability transitions. Project Deliverable 1.1.1, Governance of Urban Sustainability Transitions (GURST) project, JPI Urban Europe. Lund University.

Bulkeley, H., Coenen, L., Frantzeskaki, N., Hartmann, C., Kronsell, A., Mai, L., McCormick, K., Marvin, S., van Steenbergen, F., & Voytenko Palgan, Y. (2016). Urban Living Labs: Governing urban sustainability transitions. *Current Opinion in Environmental Sustainability*, *22*, 13–17.

DeLosRíos-White, M. I., Roebeling, P., Valente, S., & Vaittinen, I. (2020). Mapping the life cycle co-creation process of nature-based solutions for urban climate change adaptation. *Resources*, *9*(4), 39.

Eisenack, K., Moser, S. C., Hoffmann, E., Klein, R. J., Oberlack, C., Pechan, A., Termeer, C. J., & Rotter, M. (2014). Explaining and overcoming barriers to climate change adaptation. *Nature Climate Change*, *4*(10), 867–872.

Fu, X., & Li, C. (2022). How resilient are localities planning for climate change? An evaluation of 50 plans in the United States. *Journal of Environmental Management*, *318*, 115493.

Fuenfschilling, L., Frantzeskaki, N., & Coenen, L. (2019). Urban experimentation & sustainability transitions, *European Planning Studies*, *27*(2), 219–228.

Geels, F. W. (2002). Technological transitions as evolutionary reconfiguration processes: A multi-level perspective and a case study. *Research Policy*, *31*, 1257–1274.

Glavovic, B. C., Dawson, R., Chow, W., Garschagen, M., Haasnoot, M., Singh, C., & Thomas, A. (2022). Cross-chapter paper 2: Cities and settlements by the sea. In H.-O. Pörtner, D. C. Roberts, M. Tignor, E. S. Poloczanska, K. Mintenbeck, A. Alegría, M. Craig, S. Langsdorf, S. Löschke, V. Möller, A. Okem, & B. Rama (Eds.), *Climate change 2022: Impacts, adaptation and vulnerability. Contribution of working group II to the sixth assessment report of the intergovernmental panel on climate change* (pp. 2163–2194). Cambridge University Press. https://doi.org/10.1017/9781009325844.019

Gustafsson, J. (2017). Single case studies vs. multiple case studies: A comparative study. Available online at https://www.diva-portal.org/smash/get/diva2:1064378/FULLTEXT01.pdf.

Habibipour, A., Ståhlbröst, A., Zalokar, S., & Vaittinen, I. (2020). Living Lab handbook for urban living labs developing nature-based solutions. Project handbook, Urban Nature Labs (UNaLab) project, European Union's H2020 programme. Available online at https://unalab.eu/system/files/2027-07/living-lab-handbook2020-07-09.pdf.

Holmes, A. G. D. (2020). Researcher positionality—A consideration of its influence and place in qualitative research—A new researcher guide. *Shanlax International Journal of Education*, *8*(4), 1–10.

IPCC. (2022). Summary for Policymakers. Climate Change 2022: Impacts, Adaptation, and Vulnerability. Contribution of Working Group II to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change.

Lee, S., Paavola, J., & Dessai, S. (2022). Towards a deeper understanding of barriers to national climate change adaptation policy: A systematic review. *Climate Risk Management*, *35*, 100414.

Leichenko, R., McDermott, M., & Bezborodko, E. (2018). Barriers, limits and limitations to resilience. In *Towards coastal resilience and sustainability* (pp. 33–56). Routledge.

Lupp, G., Huang, J. J., Zingraff-Hamed, A., Oen, A., del Sepia, N., Martinelli, A., Wulff Knutsen, T., Lucchesi, M., Olsen, M., Fjøsne, T. F., Balaguer, E. M., Arauzo, I., Solheim, A., Kalsnes, B., & Pauleit, S. (2021). Stakeholder perceptions of nature-based solutions and their collaborative co-design and implementation processes in rural mountain areas—A case study from PHUSICOS. *Frontiers in Environmental Science*, *9*, 678446.

Lupp, G., Zingraff-Hamed, A., Huang, J. J., Oen, A., & Pauleit, S. (2020). Living labs—A concept for co-designing nature-based solutions. *Sustainability*, *2021*(13), 188.

Mahmoud, I. H., Morello, E., Vona, C., Benciolini, M., Sejdullahu, I., Trentin, M., & Pascual, K. H. (2021). Setting the social monitoring framework for nature-based solutions impact: Methodological approach and pre-greening measurements in the case study from clever cities milan. *Sustainability*, *13*(17), 9672.

Malmberg, K., Vaittinen, I., Evans, P., Schuurman, D., Ståhlbröst, A., & Vervoort, K. (2017). *Living lab methodology handbook*. Zenodo. https://doi.org/10.5281/zenodo.1146321

Mastelic, J. (2019). *Stakeholders' engagement in the co-design of energy conservation interventions*. Doctoral thesis. Université de Lausanne.

McCormick, K., & Hartmann, C. (2017). The emerging landscape of urban living labs: Characteristics, practices and examples. Lund University. Available online at https://portal.research.lu.se/en/publications/the-emerging-landscape-of-urban-living-lab-characteristics-pract.

Mendizabal, M., Heidrich, O., Feliu, E., García-Blanco, G., & Mendizabal, A. (2018). Stimulating urban transition and transformation to achieve sustainable and resilient cities. *Renewable and Sustainable Energy Reviews*, *94*, 410–418.

Mitić-Radulović, A., & Lalović, K. (2021). Multi-level perspective on sustainability transition towards nature-based solutions and co-creation in urban planning of Belgrade, Serbia. *Sustainability*, *13*(14), 7576.

Mohajan, H. K. (2018). Qualitative research methodology in social sciences and related subjects. *Journal of Economic Development, Environment and People*, *7*(1), 23–48.

Nesti, G. (2018). Co-production for innovation: The urban living lab experience. *Policy and Society*, *37*(3), 310–325.

Newton, P., & Frantzeskaki, N. (2021). Creating a national urban research and development platform for advancing urban experimentation. *Sustainability*, *13*(2), 530.

Resilient Cities Network. (2021). Urban resilience. Available online at https://resilientcitiesnetwork.org/urban-resilience/

Rijke, J., Geerling, L., Quan, N. H., & Trung, N. H. (2021). Removing challenges for building resilience with support of the circular economy. In *Climate Resilient Urban Areas* (pp. 109–127). Palgrave Macmillan.

Schuurman, D., De Marez, L., & Ballon, P. (2015). Living Labs: a systematic literature review. *Open Living Lab Days 2015, Proceedings*. Presented at the Open Living Lab Days 2015.

SCORE. (2022). Coastal City Living Labs (CCLLs). Available online at https://score-eu-project.eu/coastal-city-living-labs/

SCORE. (2023). Project concept. Available online at https://score-eu-project.eu/project-concept/

Sharp, D., & Salter, R. (2017). Direct impacts of an urban Living Lab from the participants' perspective: Livewell Yarra. *Sustainability*, *9*(10), 1699.

Ståhlbröst, A., Bergvall-Kåreborn, B., & Ihlström-Eriksson, C. (2015). Stakeholders in smart city Living Lab processes. In Americas conference on information systems: 13/08/2015–15/08/2015. Americas Conference on Information Systems.

Ståhlbröst, A., Habibipour, A., Chronéer, D., Vaittinen, I., Zalokar, S., & Mafe, C. (2018). UNaLab ULL framework. Available online at https://unalab.eu/en/documents/d21-unalab-ull-framework.

Steen, K., & van Bueren, E. (2017). The defining characteristics of urban Living Labs. *Technology Innovation Management Review*, *7*(7), 21–33.

Stibe, S., Pilla, F., Silvana Sabatino, D., Barbano, F., Pulvirenti, B., Brunetti, F., Mägdefrau, N., Staufenbiel, J., Rai, A. C., Kumar, P., Adnan, M., & Drebs, A. (2017). Implementation plans for the iSCAPE Living Labs. D2.2. Project deliverable, Improving the Smart Control of Air Pollution in Europe (iSCAPE) project, European Community's H2020 Programme. Available online at https://www.iscapeproject.eu/wp-content/uploads/2017/06/iSCAPE_D2.2_Living-Lab-implementation-plans_-v05_FINAL.pdf.

Thompson, J. (2022). A guide to abductive thematic analysis. *The Qualitative Report*, *27*(5), 1410–1421. https://doi.org/10.46743/2160-3715/2022.5340

Torabi, E., Dedekorkut-Howes, A., & Howes, M. (2018). Adapting or maladapting: Building resilience to climate-related disasters in coastal cities. *Cities*, *72*, 295–309.

Valente, S., & Veloso-Gomes, F. (2020). Coastal climate adaptation in port-cities: Adaptation deficits, barriers, and challenges ahead. *Journal of Environmental Planning and Management*, *63*(3), 389–414.

Van Buuren, A., Vreugdenhil, H., Van Popering-Verkerk, J., Ellen, G., Van Leeuwen, C., & Breman, B. (2018). The pilot paradox: Exploring tensions between internal and external success factors in Dutch climate adaptation projects. In B. Turnheim, P. Kivimaa, & F. Berkhout (Eds.), *Innovating climate governance: Moving beyond experiments* (pp. 145–165). Cambridge University Press. https://doi.org/10.1017/9781108277679.011

van Thiel, S. (2014). *Research methods in public administration and public management: an introduction*. Routledge.

Vollstedt, B., Koerth, J., Tsakiris, M., Nieskens, N., & Vafeidis, A. T. (2021). Co-production of climate services: A story map for future coastal flooding for the city of Flensburg. *Climate Services*, *22*, 100225.

von Wirth, T., Fuenfschilling, L., Frantzeskaki, N., & Coenen, L. (2019). Impacts of urban Living Labs on sustainability transitions: Mechanisms and strategies for systemic change through experimentation. *European Planning Studies*, *27*(2), 229–257.

Voytenko, Y., McCormick, K., Evans, J., & Schliwa, G. (2016). Urban living labs for sustainability and low carbon cities in Europe: Towards a research agenda. *Journal of Cleaner Production*, *123*, 45–54.

Westerlund, M., & Leminen, S. (2011). Managing the challenges of becoming an open innovation company: Experiences from Living Labs. *Technology Innovation Management Review*, *1*(1), 19–25.

How to cite this article: Quadros Aniche, L., Edelenbos, J., Gianoli, A., Caruso, R., DeLosRíos-White, M. I., Pyl Wissink-Nercua, C., Undabeitia, A., Enseñado, E. M., & Gharbia, S. (2024). Contextualizing and generalizing drivers and barriers of urban livings labs for climate resilience. *Environmental Policy and Governance*, 1–34. https://doi.org/10.1002/eet.2097

APPENDIX A: BARRIERS AND DRIVERS FROM THE LITERATURE

Tables A1 (barriers) and A2 (drivers) below illustrate the gap in the literature of a systematic overview. The middle column displays a non-exhaustive list of examples and sub-categories from the literature. In the right column, the categories are listed as originally presented in the references. For the purpose of this study, overall categories are proposed in the left column, linking and combining overlapping (sub-) categories from the literature for a more systematic analysis: social and cultural; institutional and political; and technical aspects.

TABLE A1 Barriers based on a literature review: proposed overall categories based on examples of barriers in relation to climate resilience.

Proposed category	(Examples and sub-categories of) barriers from the literature	Category and source from the literature
Social and cultural barriers	Limited stakeholder participation and linkages among different actors	Leadership and strategy[1] Technical[2] Collaboration[5]
	Lack of education and awareness, including which and how information is communicated, to whom and by whom	Socio-cultural[2] Education and awareness[4]
	Behavioral issues	Co-responsibility, increased public-private interface, social participation[4]
	Decreasing exposure of individuals to nature	Political and cultural[3]
	Short-term thinking	Political and cultural[3]
	Stakeholders might receive ineffective training and support in case of shocks, resulting in service disruptions	Health and well-being[1]
	Lack of communication among neighboring communities	Collaboration[5]
Institutional and political barriers	Conflicting agendas and values	Institutional[2]
	Issues with the prioritization of resources	Institutional[2]
	Policy inertia and resistance to change	Policy, regulatory and financial[3] Co-responsibility, increased public-private interface, social participation[4]
	Ineffectiveness in the implementation of policies and plans	Leadership and strategy[1]
	Lack of political will from the authorities	Political and cultural[3]
	Lack of long-term commitment from leaders and authorities	Authority and political leadership[4]
	Fragmented and siloed governance, with uncoordinated action among multi-level government agencies and between public and private actors	Co-responsibility, increased public-private interface, social participation[4] Collaboration[5]
	Low involvement of high-level government agents and reduced empowerment of municipalities	Informed, inclusive and adaptive multi-level governance[4] Collaboration[5]
	Reduced sharing of best practices	Institutional[2]
	Lack of funding	Financial[2]
	Perversive incentives and inflexible and inappropriate regulations	Economy and society[1] Policy, regulatory and financial[3]
Technical barriers	Lack of an overall agreed operationalization on resilience to incorporate it into climate adaptation plans	Conceptual[5]
	Absence of an integrated cross-cutting approach	Leadership and strategy[1] Technical[2] System[5]
	Climate change adds another layer of complexity to the conventional planning: uncertainty, complex, and nonlinear structure	Collaboration[5] Uncertainty[5]
	Lack of long-term and autonomous climate adaptation policies	Institutional[2]
	Limited capacity to support integrated planning and policymaking	Leadership and strategy[1]
	Issues in accountability, legality, and procedures in the regulatory framework	Institutional[2] Regulatory framework[4]
	Issues with methodologies, staff, and expertise	Technical[2] Integrated and adaptive planning and management[4]

TABLE A1 (Continued)

Proposed category	(Examples and sub-categories of) barriers from the literature	Category and source from the literature
		Uncertainty[5]
	Lack of proper monitoring	Technical[2] Integrated and adaptive planning and management[4]
	Lack of data availability and accessibility	Infrastructure and environment[1] Technical[2] Education and awareness[4]
	Lack of technology availability as a social tool	Living Lab approach to innovation[4]
	Low capacity to respond to extreme events	Infrastructure and environment[1]
	Improper planning process	Economy and society[1] System[5]
	Challenges when increasing coping capacity for the short-term and synergies among adaptation and mitigation measures	Coping capacity[5]
	Lack of flexible and quickly adaptable plans, as well as a systemic and operationable perspective	Adaptive capacity[5]

Note: Based on [1]Rijke et al. (2021); [2]Aktürk & Dastgerdi (2021); [3]Leichenko et al. (2018); [4]Mendizabal et al. (2018); [5]Fu & Li (2022).

TABLE A2 Drivers based on a literature review: proposed overall categories based on examples of drivers in relation to climate resilience.

Category	(Examples and sub-categories of) drivers from the literature	Category and source from the literature
Social and cultural drivers	Learning from disasters and the past	Learning from disasters and narrative research[4] Adaptive capacity[5]
	Good and effective communication	Education and awareness[4] Collaboration[5]
	Stakeholder participation and collaboration	Social participation[2,4] Collaboration[5]
	Boosting adaptive capacity with long-term transformative actions	Adaptive capacity[5]
Institutional and political drivers	"Co-responsibility, increased public-private interface"	"Co-responsibility, increased public-private interface"[4]
	"Authority and political leadership for disruptive innovations and change"	"Authority and political leadership for disruptive innovations and change"[4]
	"Informed, inclusive and adaptive multi-level governance"	"Informed, inclusive and adaptive multi-level governance"[4]
	"Improve horizontal and vertical coordination to build adaptive capacity through collaboration"	"Improve horizontal and vertical coordination to build adaptive capacity through collaboration"[5]
	Effective collaboration among local actors, considering their interests, objectives, and awareness levels, into the regulatory framework	Regulatory framework[2] Collaboration[5]
	Diversification of economic activities	Economic measures[3]
	"Living Lab approach to innovation"	"Living Lab approach to innovation"[4]
	Integrated, multi-scale, cross-cutting, adaptive planning	"Integrated and adaptive planning and management"[4] System[5] Uncertainty[5]
	Flexible and robust strategies, that embrace uncertainty	Uncertainty[5]
	Knowledge, resources, and expertise beyond the capacity of a single institution and jurisdiction	Collaboration[5]
	Assessing new knowledge, anticipating different scenarios, and learning from the past	Adaptive capacity[5]
	Provide evidence and prioritize actions	System[5]

(Continues)

TABLE A2 (Continued)

Category	(Examples and sub-categories of) drivers from the literature	Category and source from the literature
	Integrate climate change adaptation and mitigation	"Integrated and adaptive planning and management" [4] Coping capacity[5]
	"Regulatory framework, including codes, accountability, pricing, taxation, penalties and incentives"	"Regulatory framework, including codes, accountability, pricing, taxation, penalties and incentives"[2,4]
	Education and awareness: availability, accessibility, and ability to use data	Education and awareness: availability, accessibility, and ability to use data[4]
	Systemic perspective that interwinds social, ecological, and technological networks	System[5]
	Restoration and retrofitting of infrastructure and ecosystems	Engineering measures[3]
	Appropriate land-use planning, building codes, insurance schemes, and diversification of economic activities for coastal cities	Land-use and policy measures[3]

Note: Based on [1]Rijke et al. (2021); [2]Aktürk & Dastgerdi (2021); [3]Leichenko et al. (2018); [4]Mendizabal et al. (2018); [5]Fu & Li (2022).

APPENDIX B: CASE STUDIES

TABLE B1 Case studies: Coastal City Living Labs (CCLLs) within the SCORE project: vision, strategic goals, climate hazards, and sectoral impacts (author).

CCLL	Vision	Strategic goals	Climate hazards	Sectoral impacts
Oeiras, Portugal	Co-create an inclusive climate action community through active stakeholders' engagement and foster citizen awareness for the climate resilience of Oeiras territory	1. To increase awareness of the climatic risks and impacts among different departments and levels in the city management, stakeholders, and the public, integrating, and aligning their knowledge and actions toward a common vision. 2. To create an open network that builds trusting relationships, promotes the dialog among the different stakeholders involved in climate actions in the territory, and establishes effective communication	Coastal flooding Land flooding Coastal erosion Coastal storm surge	Risk to tourism Loss of cultural heritage Damage to commercial buildings Damage to residential buildings Damage to energy networks Damage to civil infrastructure
Benidorm, Spain	An international reference model city developing innovative and cost-efficient climate adaptation solutions based on reliable and accessible climate-related data, integrating all stakeholders to create a long-term plan toward environmentally sustainable, resilient coastal communities	1. Strengthening the CCLL's capacity to identify, automatically collect, standardize and analyze data to guide decisions and to take proactive and coordinated actions on climate-related issues. 2. Building meaningful partnerships by fully engaging all stakeholders through knowledge and information sharing toward identification of the problems and risks as well as addressing the impacts of climate change to coastal communities in Benidorm. 3. Create opportunities to showcase successful climate-smart technologies aligned with Benidorm's socio-economic context focused on sustainable nature-based solutions which bring added value to its coastal areas	Coastal flooding Land flooding Coastal erosion Coastal storm surge	Risk to tourism Loss of cultural heritage Damage to commercial buildings Damage to residential buildings Damage to energy networks Damage to civil infrastructure
Massa, Italy	An inclusive open lab meaningfully co-designing feasible science-based innovative climate adaptation solutions that leads to collaborative synergies between all stakeholders toward achieving social, economic and environmental resilience of coastal communities in Apuo-Versilia	1. Build and strengthen the ability to identify, collect, produce, and monitor past and current (climate) data to co-design science-based adaptation solutions and actions. 2. Raising awareness of site-specific climate change and anthropogenic impacts in Apuo-Versilia among all citizens through active participatory processes and innovative communication systems. 3. Building a long-term self-sustaining open lab through partnerships with relevant and committed stakeholders	Coastal flooding Land flooding Coastal erosion Coastal storm surge	Risk to tourism Loss of cultural heritage Damage to commercial buildings Damage to residential buildings Damage to energy networks Damage to civil infrastructure
Oarsoaldea, Basque Country, Spain	Become a reference in ecosystem-based solutions and coastal adaptation in the Basque Country,	1. To have the CCLL as an orchestrator 2. To activate citizens' support and to encourage participation	Coastal flooding Land flooding Coastal erosion Coastal storm surge	Risk to tourism Loss of cultural heritage Damage to commercial buildings

(Continues)

TABLE B1 (Continued)

CCLL	Vision	Strategic goals	Climate hazards	Sectoral impacts
	through enhanced engagement of key stakeholders and citizens participation	3. To have transparency, improved plans, multidisciplinary work, open-minded attitude, and collaboration, to ensure the CCLL sustainability		Damage to residential buildings Damage to energy networks Damage to civil infrastructure
Piran, Slovenia	Become a pioneer in Slovenia in co-creating innovative solutions by empowering the citizens and stakeholders to collaborate in the context of climate change prevention, adaptation and mitigation	1. To empower everyday citizens to collaborate with researchers, businesses, and local authorities to develop climate change prevention, adaptation and mitigation strategies and actions by: • Raising awareness (communication campaigns and knowledge transfer and capacity-building) from the bottom-up local level to the national level—and across Slovenia • Involving different stakeholders and integrating their expertise (co-creation) from the beginning till planning and executing concrete actions • Improving and expanding the early warning system • Partnering with nature toward sustainability	Coastal flooding Land flooding Coastal erosion	Risk to tourism Loss of cultural heritage Damage to commercial buildings Damage to residential buildings Damage to energy networks Damage to civil infrastructure
Samsun, Turkey	A self-sustaining Coastal City Living Lab implementing a roadmap of cooperation among all stakeholders to plan, design and scale up nature-based solutions toward social, economic, and environmental resilience of the communities living on the Kizilirmak Basin	1. To build a self-sustaining management board by establishing partnerships with committed stakeholders to get financial and technical support from internal and external resources 2. To strengthen the knowledge and technical capacity on nature-based solutions by improving the CCLL capacity to produce, collect, and share climate-related data 3. To raise awareness on climate change risks and hazards in the Kizilirmak Basin area and to share learning experiences on successful climate adaptation solutions	Coastal flooding Land flooding Coastal erosion	Risk to tourism Loss of cultural heritage Damage to commercial buildings Damage to residential buildings Damage to energy networks Damage to civil infrastructure
Sligo, Ireland	An enduring and self-sustaining citizen science coastal cooperative integrated in the North-West to co-create inclusive and innovative approaches toward ecologically sustainable climate solutions and resilience of coastal communities in Ireland	1. Enable coastal communities to use technologies to help with monitoring and finding ecosystem-based solutions 2. Increase ability to identify and analyze climate change effects, risk, mitigation and impacts to coastal areas in Sligo and extending this ability to other places 3. Building meaningful dynamic partnership with citizens, scientist, government, and private sector focused on shared climate change solutions in coastal communities in harmony with nature	Coastal flooding Land flooding Coastal erosion	Risk to tourism Loss of cultural heritage Damage to commercial buildings
Vilanova I la Geltrù, Spain	The Vilanova i la Geltrù/ Province of Barcelona CCLL as a reference and	1. Achieve institutional recognition of the CCLL by setting up a strong and stable structure of committed	Coastal flooding Land flooding Coastal erosion	Risk to tourism Loss of cultural heritage

TABLE B1 (Continued)

CCLL	Vision	Strategic goals	Climate hazards	Sectoral impacts
	research-technological engine, co-creating data-based, innovative, and collaborative solutions toward integrated coastal management and climate change adaptation, scaled up to Catalunya and the Mediterranean area	stakeholders, co-creating data-based innovative solutions for climate change adaptation 2. Enhance research, technical and financial capacity of the CCLL to propose, promote, validate, and monitor EBA solutions 3. Develop a clear communication strategy by engaging all stakeholders to share and showcase climate-related data and promote integrated coastal management solutions 4. Build the CCLL capacity to be able to scale up and replicate the LL methodology in Catalunya and in the Mediterranean area	Coastal storm surge	Damage to commercial buildings Damage to residential buildings Damage to energy networks Damage to civil infrastructure
Dublin, Ireland	Co-create data-driven policies using innovative EBAs and smart technologies to empower communities in building Dublin's coastal climate resilience	1. Increase awareness on the climate-related risks, opportunities and synergies with other EU/LL projects, as well as the effectiveness and co-benefits of EBAs integrated with smart technologies, among citizens, municipality staff, and other stakeholders 2. Engage citizens with the SCORE smart technologies, such as sensors and spatial digital twin systems for early warning, to co-develop data driven policies 3. Improve the technical expertise among the CCLL team and stakeholders in EBAs and smart technologies to increase Dublin's climate coastal resilience	Coastal flooding Land flooding	Risk to tourism Loss of cultural heritage Damage to commercial buildings

APPENDIX C: CO-OCCURRENCE OF BARRIERS AND DRIVERS AMONG CCLLs

TABLE C1 Co-occurrence of barriers among CCLLs (author)[a].

	OE	BE	MA	OA	PI	SA	SL	VI	DU
OE	-	16	7	8	10	11	17	14	7
BE	-	-	15	7	12	13	14	18	9
MA	-	-	-	7	10	12	12	10	8
OA	-	-	-	-	10	6	10	9	4
PI	-	-	-	-	-	7	16	11	11
SA	-	-	-	-	-	-	10	14	6
SL	-	-	-	-	-	-	-	14	8
VI	-	-	-	-	-	-	-	-	9
DU	-	-	-	-	-	-	-	-	-

[a]The tables were automatically colored from the lowest to the highest number of co-occurrences, ranging respectively from red to green.

TABLE C2 Co-occurrence of drivers among CCLLs (author)[a].

	OE	BE	MA	OA	PI	SA	SL	VI	DU
OE	-	23	14	9	20	24	12	23	17
BE	-	-	12	10	20	24	13	20	14
MA	-	-	-	9	10	18	13	13	13
OA	-	-	-	-	9	13	10	11	8
PI	-	-	-	-	-	19	12	17	14
SA	-	-	-	-	-	-	17	24	14
SL	-	-	-	-	-	-	-	19	10
VI	-	-	-	-	-	-	-	-	13
DU	-	-	-	-	-	-	-	-	-

[a]The tables were automatically colored from the lowest to the highest number of co-occurrences, ranging respectively from red to green.

TABLE C3 Number of unique barriers and drivers per CCLL (author).

	Barriers	Drivers
OE	10	16
BE	13	10
MA	17	5
OA	13	8
PI	9	7
SA	12	9
SL	16	10
VI	24	10
DU	10	15
Total	124	90

APPENDIX D: DETAILED BARRIERS AND DRIVERS

D.1 | SOCIAL AND CULTURAL BARRIERS

TABLE D1 Social and cultural barriers (author).

Category	Social and cultural barriers	
Sub-category	Stakeholder engagement and awareness	
Barriers		
	Similarities	Particularities
Common vision	Lack of a common vision among the different stakeholders, who hold diverse (and sometimes conflicting) interests and priorities (MA, DU, OA, SL, VI)	The divergent views can result in more time to take decisions, as there is no consensus (VI)
	Multiple visions from different departments in the local authority (DU, VI)	Different visions from external parties (MA), academia (VI), private sector (VI) or even within the CCLL stakeholders (OE)
	Mis-integration among the national, regional, and local government levels (OE, DU)	Unclarity on the criteria for success (SA)
Stakeholder engagement	Difficult to keep stakeholders engaged (OE, PI, SL, VI) and committed (OE, PI, OA, MA) in the long-term	Difficult to keep stakeholders enthusiastic (MA)
	People need the right incentives or rewards to be involved (OE, SA, VI)	Issues in identifying the stakeholders (SA)
	Some citizens might feel powerless as individuals, have unclear expectations, and not feel represented (SL, MA)	Some groups of actors might be more difficult to engage, but are important within the LL approach (VI)
	Citizen "fatigue" with many ongoing projects (DU, PI)	Limited time availability and conflicting schedules, lack of focus in the discussions (MA)
		Hierarchical organizational culture (MA)
		Fluctuation of visitors (amount and profile) (BE)
		Diverse technological experience (SA)
Lack of awareness	Lack of awareness among some actors (OE, BE, SA, SL)	Misperceptions (DU)
	Lack of trust (MA, OA, SL)	Lack of dissemination of best practices (DU)
	Carelessness toward dealing with climate impacts and its urgency (MA, PI, VI, SL)	Uncertainty in projections (MA)
	Lack of knowledge (DU, VI)	Unclarity of jargons and concepts (SA)

TABLE D1 (Continued)

Category	Social and cultural barriers	
Sub-category	Stakeholder engagement and awareness	
Barriers		
	Similarities	**Particularities**
	Lack of proof of benefits (SL, OE)	Political resistance to certain types of solutions (BE) and collaborations (SA)
	Overall resistance to new ideas (PI, SL)	Temporary visitors as tourists might lack understanding on the issue and contribute to negative climate-related impacts (BE)
	Resistance to change the lifestyle or business-as-usual (SL, MA, BE)	
	Population is not interested in topics related to climate change (PI, VI), especially among citizens who do not feel directly affected (OA, PI)	
	High demands and expectations from citizens (OE, MA)	
Sub-category	Communication and dissemination	
Barriers		
Similarities	**Particularities**	
No common space for synergies among stakeholders (OA, VI)	Stakeholders sometimes are not all identified (PI)	
Not all stakeholders are included in communication efforts (OE, SA)	Stakeholders are not able to work together (SA)	
Lack of adequate language and design (DU, SL, PI)	Issues in communication strategies in terms of channels (SL)	
Use of jargons and terminologies that are difficult to grasp by actors (SA, OE)	Lack of clarity in communications (SL)	
Timing between reaching maturity and communicating results (OE, PI)	Problems with dissemination of best practices and knowledge retention (DU)	
Lack of information about the solution's benefits (OE, BE)	Lack of feeding project results into policymaking (DU)	
	Lack of visibility of immediate results (PI)	
	Limited learning from previous results (SL)	
	Limited financial resources to conduct dissemination activities (SL)	
	Resistance to work with foreign experts and organizations (PI)	

D.2 | INSTITUTIONAL AND POLITICAL BARRIERS

TABLE D2 Institutional and political barriers (author).

Category	Institutional and political barriers	
Sub-category	Institutional	
Barriers		
	Similarities	**Particularities**
Silos	Local authorities work in silos and lack communication among departments (DU, MA)	Resources available at local authorities are spread (MA)
	Difficulties in coordinating with the different level government entities, which have diverse competences and processes (BE, OA, OE, PI, VI, SL)	Jurisdictional barriers (OA)
	Lack of collaboration among different stakeholders was mentioned (PI, MA, SL)	Difficult to align policy-strategic and operational levels, especially among different authority entities (OA)
		Culture of silos complicates the implementation of large European projects, that require a multidisciplinary approach (VI)
		Difficult to access to different resources due to silos (DU)
		Lack of collaboration among public and private actors (VI)
Bureaucracy	Bureaucracy (OE, BE, MA, OA, PI, SA, SL, VI)	Bureaucracy affects how innovative ideas are implemented (BE)
	Excessive and slow bureaucratic procedures (BE, MA, OA, PI, SL)	Bureaucracy limits stakeholder interaction and co-design activities (MA)
	Bureaucracy affects how data is accessed, shared, and published (OE, SA, VI)	Existence of many laws and regulations can be an issue, especially as it crosses diverse competencies (BE)
		Difficult to align many different authorities and navigate their procedures (OA)
		Internal bureaucracy, among CCLL members (MA)
Unclear governance structure and roles within the CCLL (VI, SA, MA)		Lack of CCLL empowerment to implement solutions (SL)
Sub-category	**Resources**	
Barriers		
	Similarities	**Particularities**
Financial	Limited financial resources in general (OE, BE, MA, OA, PI, SA, SL, VI, DU)	Limited or uncertain funding for communication (VI), stakeholder participation (OA), implementing solutions as sensors (MA), maintenance (VI), and scaling up (VI)
	Limited or uncertain funding for research (OA, VI), implementing solutions (SL, VI), as to nature-based solutions (BE, PI)-, and monitoring (SA, VI)	Lack of a dedicated budget to tackle climate matters (SL)
	Available funding might not be sufficient for conducting trainings and capacity-building activities (PI, SL)	Difficulties in accessing EU funds for climate action (OE)
	Issues with public funds (BE, PI, VI)	Other issues as lack of public service facilities (PI), social welfare health (SL), and illegal urbanization of the coast (VI)
	"Competition" among many issues and projects to be prioritized (OE, SA, VI, SL)	Lack of political will at different government levels and jurisdictional issues may affect funding distribution (OA)
Human	Limited human resources in general (OE, BE, MA, PI, SA, SL, VI, DU)	Time limitation can affect how actors communicate, collaborate with each other (PI), and participate in projects (MA)
	Time availability in general (BE, DU, OE, PI, SL)	High workload at local authorities, which can lead to work delegation and limiting knowledge retention (DU)
	Time availability within the CCLL team (BE, MA, SA, VI)	Lack of staff can impact trainings with citizens for civil protection purposes (PI)

TABLE D2 (Continued)

Sub-category	Resources	
Barriers		
	Similarities	**Particularities**
	Working on too many projects simultaneously (DU, OE, PI, SL, VI)	Changes in staff can make the project process more difficult (VI)
	Understaffing is an issue in some local authorities (DU, PI, SL)	The overall resources are perceived as limited in relation to the vastness of the problems faced by the CCLL (MA)
The lack of both financial (BE, MA) and human resources allocation (OE, SL) after the project ends, endangering the CCLL sustainability in the long-run (BE, MA, OE) and the willingness of stakeholders to commit (OE, OA)		
Sub-category	**Political and external factors**	
Barriers		
	Similarities	**Particularities**
Political	Political resistance (BE, DU)	Lack of political will (OA)
	Lack of political support (DU, PI)	Lack of political engagement (VI)
	Lack of political commitment (PI, OA)	Conflict between long-term (climate) issues, the need for short-term actions, accountability, and the political timeline of mandates and budgets (OE)
	Uncertainty regarding political changes after elections (BE, MA, VI)	Conflicts from diverse political competencies across different localities (VI)
		Establishment of goals at one level and action at another (OE)
External socio-economic	Increasing inflation and domestic expenses (OE, SL)	Diminishing population (PI)
	Ukrainian war, resulting increased prices (BE, VI, OE) and economic recession (BE, OE, SA, SL), and changes in the everyday life (PI, VI)	Ongoing Covid-19 pandemic causes a health emergency (MA) and a reduction in revenues from tourism (BE)
		Aging population (SL)
		External issues create uncertainties that might affect the CCLL expected results (VI), such as sudden budget cuts (OE) and stakeholders' priorities (VI)
Urban infrastructure	Lack of equipment such as sensors (BE, MA)	Lack of a coastal meteorological station (BE)
	Restricted access to land to implement climate solutions are barriers too (DU, VI)	Limited energy, internet, electricity, water, and transportation infrastructure (SA)
		Lack of a clear definition of the physical setting (DU)

D.3 | TECHNICAL BARRIERS

TABLE D3 Technical barriers (author).

Category	Technical barriers
Sub-category	**Knowledge and experience**
Barriers	
Similarities	**Particularities**
Lack of climate change expertise (OE, VI, BE)	Scale of the issues might be difficult to grasp (OE)
Lack of experience with LL setting up, management and governance, and business model (BE, OA, PI, SA, SL)	Limited knowledge on communication (VI)
	Limited knowledge on methods for stakeholder engagement (BE)
	Lack of experience with climate-related financial risks (DU)
	Lack of clarity on what constitutes a risk and how to manage it (SA)
Sub-category	**Technical and internal capacity**
Barriers	
Similarities	**Particularities**
Limited knowledge and experience with digital twin (SL, VI, OA)	Limited technical capacity (VI)
Limited knowledge and experience with citizen science (BE, SL, VI, OA)	Limited experience with engineering, sensors, modeling (BE)
Limited knowledge and experience with overall smart technologies (PI, OA)	Lack of knowledge on tools to measure impact or calculate environmental footprint (BE)
Lack of experience on socio-economic assessments (DU, OA)	Lack experience in setting up operational plans (OA)
Limited knowledge and experience with ecosystem-based approaches and nature-based solutions (OA, SA, SL)	Internal bureaucracy (MA)
Lack of knowledge on how to move from theory to practice concerning the implementation of a LL (OE, DU)	Reduced CCLL size (OA)
Lack of an internal collaborative culture (BE, MA)	Internal miscommunication (SL)
	New team (no ongoing collaborative activities or platform) (OA)
	Lack of local people on the team (SL)
Sub-category	**Data**
Barriers	
Similarities	**Particularities**
Issues with data availability and accessibility (OE, BE, MA, OA, PI, SA, SL, VI, DU)	Limited collaboration between stakeholders which possess data (PI)
Data being scattered among different organizations and lack of a common database (BE, DU, MA, PI, SA)	Low coherence between existing studies makes it difficult to integrate data (MA)
No compatible platform or homogeneous data (BE, DU, MA, SA, VI)	Data spreading complicates the identification of data sources (MA)
Data spreading restricts access to data (BE, DU)	Restricted access to certain data from some private institutions (VI)
Lack of open-access datasets (SA, MA)	Restricted access to certain data from some knowledge institutions (SA)
Restricted access to certain data from some public institutions (MA, BE, DU, PI, SA)	Constraints related to data copyright rights that require prior authorization to be published (OE)
Bureaucratic and long procedures to access data (SA, MA, SL)	Unclarity on the role of nonexpert stakeholders, as citizens, with respect to data accessibility (MA)
Lack of real-time data on climate change effects (BE, SL)	Lack of specific data related to climate issues (SA)
Insufficient monitoring data (BE, VI)	Lack of sensors and meteorological station (BE)
Lack of digital data (SA, BE, VI)	Lack of free tools and simple calculation methods (VI)
Lack of data at the appropriate local scale (VI, BE, SA)	Not enough data about the benefits of the proposed solutions (OE)

TABLE D3 (Continued)

Sub-category	Long-term view and uncertainty
Barriers	
Similarities	**Particularities**
Overall uncertainty and difficulty to manage a long-term view can impact the CCLLs sustainability in the future (OA, SA)	Some stakeholders are looking for a quick win (MA)
Difficulty of thinking and planning on the long-term (MA, SA)	The necessity of the actions might not be perceived by some actors (VI)
It is more difficult to engage and commit stakeholders due to the uncertainty around climate matters (BE, OA, OE, VI)	Actors may not be willing to change (SL)
Urgent need for short-term actions (OE, OA)	Lack of capacity building concerning climate change at local administrations (OE)
Actors might not be interested (SL, OE, BE)	Limited ability to implement long-term actions (BE)
Limited resources for long-term actions (BE, OE, VI)	Large scale of climate issues (MA)
Limited understanding of the timescale of climate events (SL, VI)	Difficulty to grasp and prove the effectiveness of innovative ideas that might not have immediate results (VI)
	Climate impacts are unpredictable (SA)
	Climate impacts are going faster than predictions (VI)
	Not all problems have been quantified (SL)

D.4 | SOCIAL AND CULTURAL DRIVERS

TABLE D4 Social and cultural drivers (author).

Category	**Social and cultural drivers**
Sub-category	**Stakeholders**
Drivers	
Similarities	**Particularities**
Great community awareness of climate challenges (BE, MA, OE, PI, SA, VI)	Specific groups which are more sensitive in the context, such as the youth (MA, SL), academics (SL), multi-national companies (OE), fishermen and farmers (SA), culture sector (SA), research and development institutions (OE), or highly educated citizens (OE)
Stakeholders committed to solving environmental issues (BE, PI, SA, SL, VI)	Ambitious and experienced group of stakeholders (OA)
Stakeholders interested in the CCLL ambitions (MA, VI, OE, SA)	Partnerships with educational organizations (DU)
Rising and prioritized awareness (OA, SL)	Partnerships with international organizations (BE)
Stakeholders willing to work together (OE, PI, SA, SL, VI, MA)	Experience with citizen science (DU)
Proactive stakeholders (OE, SL)	Concrete problems, as disruption of public services (DU), data availability (DU), and economic impact (MA)
Good contacts and being part of relevant networks (BE, PI, SA, VI, OE)	Existence of other Living Labs and projects makes people more familiar with the approach and interested in it (DU)
Partnerships with private organizations (BE, DU, OE, SA, VI, PI)	Diverse forms of incentives to support CCLL activities per type of stakeholder (SL)
Partnerships with public organizations (BE, DU, OE, VI, PI)	Certification for activities as an incentive for commitment (OE)
Partnerships with research organizations (BE, DU, OE, SL, VI, PI)	
Various active community groups (BE, DU, PI, SL)	
Various active technical groups (DU, VI)	
Culture of citizen participation (OA, DU, BE, OE, SA)	
Environmental education programs in schools and with citizens (DU, MA, OE, PI, SA)	
Concrete evidence of the problems (PI, VI)	
Being explicitly open to all people and ensure stakeholders are met as equals, regardless of their background or hierarchical position (MA, PI)	
Good behaviors, as being good listeners and respectful to all, as well as transparent in information sharing (MA, PI)	
Sub-category	**Communication and dissemination**
Drivers	
Similarities	**Particularities**
Promoting communication and raising awareness of climate issues (OE, BE, MA, PI, SA, SL, VI, DU)	Encouraging dissemination among different groups of stakeholders and establish proper communication channels (OE)
Strong media and public relations can be an advantage to promote climate communication to all sectors of society (BE, PI, SA)	Continuing the debate on risks and awards associated with climate change to keep it a priority (SL)
Existence of tools and initiatives related to environmental awareness that can be linked with CCLL goals (DU, OE, PI)	Raising awareness among everyday citizens, involving respect for all regardless of background or level of knowledge, good listening, transparency, and adequate language (PI)
	Raising awareness can increase public commitment to the project (OE)
	Establishing a platform or physical place for people to meet (PI)
	Providing leadership and setting an example among actors (SL)

TABLE D4 (Continued)

Sub-category	Communication and dissemination
Drivers	
Similarities	**Particularities**
	Trainings and capacity building on the topic, such as on how to read climate data (DU)
	A large number of tourists could be a potential resource to spread information (BE)
	Reinforcing communication between different public agencies and their presence brings opportunities for funding and visibility (SA)
	Private actors should be involved and communicated in a way that they can understand climate change risks (SA)
	Private sector adopting more climate friendly practices and promoting good behavior (SL)
	Disseminating the evidence of environmental problems (MA)
	Disseminating existing innovative, respectful, efficient, and economically viable solutions produce synergies among partners (VI)
	Piloting projects on the topic of climate change, increasing accountability and credibility of the CCLL and expanding networks (VI)

D.5 | TECHNICAL DRIVERS

TABLE D5 Technical drivers (author).

Category	Technical drivers
Sub-category	Knowledge and experience
Drivers	
Similarities	**Particularities**
Capacities with technologies, models, and tools (BE, DU, OE, SA, MA, OA, PI)	Knowledge and experience with parameters (SL)
Knowledge and experience with data management and analysis (MA, BE)	Knowledge and experience with citizen science and sensors (DU)
Good ICT (Information and Communications Technology) infrastructure (BE, SA)	Existence of technical communities (DU)
Sensor networks (MA, DU)	Technical collaborations among municipalities and universities (VI)
Monitoring systems (SA, MA, OA)	Experience with European Commission projects (DU)
Good use of technology in society (OE, SL)	Knowledge on marine science and coastal management (OA)
Knowledge and experience with the LL approach (DU, VI)	Knowledge on climate-related impacts (OA)
Extensive knowledge related to climate issues and projects (MA, OA, SA, SL)	Knowledge on water literacy (PI)
Knowledge on risk and vulnerability assessments (DU, OE)	Knowledge on environment and climate change (VI)
Knowledge on ecosystem-based approaches (SL, OA, VI)	Knowledge on climate adaptation (VI)
Working in a diverse team (PI, SL, VI)	Sharing the same vision, even if from different perspectives (VI)
Working in a multidisciplinary team (BE, OA, OE, PI)	Experience with proposal writing (SA)
Possessing research skills (DU, MA, OA, PI, SA)	Experience with managing resources (SL)
Good teamwork, organization, and internal communication (BE, DU, MA, SA, SL, VI)	Having powerful and knowledgeable institutions in the team brings endorsement and is attractive to new actors to join (OE)
Being a committed team (SL, SA, VI)	Relevant digital platforms (DU)
Territorial intelligence (OE, MA, SL)	Synergies and knowledge exchange can result in scaling up of interventions (VI)
Experience with fundraising (VI, SA)	
Collaborations among different stakeholders provide opportunities for knowledge exchange and sharing information and data on climate-related issues (SL, VI, SA, PI, OA, BE, OE)	
Collaborations among universities (SA, VI)	
Collaborations within private sector (VI, OE)	
Collaborations among public departments (VI, DU, OE, SA)	
Collaborations among local organizations (VI, OE)	
Potential synergies with different existing and new projects dealing with similar topics, such as LLs, ecosystem-based approaches, and coastal climate issues (DU, MA, OA, VI)	
Willingness to share and learn with each other among CCLLs (BE, OA, PI, SA, SL, VI)	
Willingness to share and learn beyond the CCLLs network (OA, MA, SL, VI)	
Synergies and knowledge exchange can result in replication of solutions (MA, VI, SL)	

Sub-category	Climate-related policies, programs, and actions
Drivers	
Similarities	**Particularities**
Existence of climate studies (OE, BE, OA, PI, SA, SL, VI, DU)	Initiatives that provide relevant data reports, action plans related to adaptation and resilience (OA)
Existing relevant climate projects, plans, programs, and activities (BE, DU, OE)	Initiatives that provide knowledge on risks, impacts, and vulnerability assessments (OE, SA)
CCLLs can be linked and involved in existing climate projects, plans, programs, and activities (DU, OA)	Studies and frameworks available at the European level (OE)
Studies and frameworks available at the local level (OE, OA, SA, SL, VI)	Existing plans bring opportunities for more innovative climate solutions (PI)
Studies and frameworks available at the regional level (BE, OA, PI, SA, VI)	Previously implemented ecosystem-based solutions available for monitoring (VI)
Studies and frameworks available at the national level (OE, PI)	Research institutions engaged with educational programs (OE).
Presence of research institutions in the territories, engaged with sustainability and climate change (OE, SA)	Existing studies and data can provide a baseline for the analysis (DU)
Increasing prioritization of climate action (SL, VI)	Data being (mostly) standardized is helpful for supporting the decision-making process (SA)
Opportunity to focus on smart strategies for the long-term while bringing climate action to the short-term discussion (BE, OE)	Adequate data and information might give weight to administrations in the decision-making, as well as in a greater involvement of all parties to achieve the CCLL objectives (BE)
Data availability (BE, DU, MA, OE, SA, SL, VI)	
Data accessibility, especially open-access data (BE, OE, SA, VI)	
Good territorial knowledge of the geographical area (BE, OE)	
Existing studies and data can provide concrete proof of the problems (DU, MA, SL, SA)	
Working in close collaboration with institutions and stakeholders is valuable in getting information and data (BE, OE, VI)	
Sub-category	**Innovation and practice**
Drivers	
Similarities	**Particularities**
Innovative plans require a cross-cutting approach (BE, DU, MA, OE, PI, SA)	Openness to new ideas and willingness to experiment, either from innovative municipalities (OE), national plans (PI), external stakeholders (MA), young people (BE), highly educated and wealthy citizens (OE), or the CCLL teams themselves (OA)
Innovative plans require a multi-disciplinary team (BE, OE, PI)	Openness to trialing potential solutions with clear Key Performance Indicators is a behavior to be encouraged (DU)
Innovative plans require a cross sectoral support (DU, MA)	The LL approach is an open space for innovation (MA)
Bridging knowledge actors with the public sector and communities, increasing this interaction to bring collaboration into practice (MA, OE)	LL as an opportunity to introduce innovative solutions (PI)
Having clear and recent examples, as well as a leadership attitude from actors (DU, SL)	LL has a good scale for piloting (VI)
	Working with the right and limited time (SL)
	Collaborations among different departments in the local authorities (DU)
	Collaborations among universities (SA)
	Collaborations among multiple municipalities and public agencies (SA)
	Quadruple helix model of Living Labs as a form to promote cross collaboration (PI)
	Working closely with stakeholders (BE)
	Proper channels of communication and a proactive environment can foster proper collaboration (OE)

(Continues)

TABLE D5 (Continued)

Sub-category	Innovation and practice
Drivers	
Similarities	**Particularities**
	Political will is crucial in taking the initiative to invite stakeholders to join project activities and making climate issues a priority, to lead to concrete innovative actions implementation (OE)

D.6 | INSTITUTIONAL AND POLITICAL DRIVERS

TABLE D6 Institutional and political drivers (author).

Category	Institutional and political drivers
Sub-category	**Resources**
Drivers	
Similarities	**Particularities**
Funding from the project itself (BE, SA, SL)	Opportunities when involving private and industry partners (DU)
Availability of funds in general (SL, VI)	
Financial resources for climate issues at the local level (municipality or County Council) (DU, OE, PI)	
Financial resources for climate issues at the national level (MA, OE, SA)	
Financial resources for climate issues at the European level (BE, MA, OA, OE, SA, VI)	
Experience in funding raising (MA, BE, SA, VI)	
Opportunities when developing networks (OE, SA)	
Sub-category	**Political and external forces**
Drivers	
Similarities	**Particularities**
Climate issues as a priority (OE, VI)	Green approach by the local party (DU)
Good alignment between the local authorities' political vision for urban development, the climate agenda, and the CCLL objectives (OE, VI)	Political will to make the city a smart destination (BE)
Opportunity to improve cities' image while increasing the climate adaptation, increasing tourism activities (BE, MA, SL)	Political will to innovate and experiment (OE)
Boosting tourism (BE) and heritage (SA), can improve municipal finances to invest in climate actions (BE, SA)	Trust in the local authorities (OE)
	The LL integrative Approach can be "easy to sell" to politicians, who are now attracted to participatory approaches (OA)
	Changes in governments pose opportunities (OA)
	Sensibility of the politics to support the CCLL (BE)
	Climate adaptation can bring opportunities for increasing mental health (SL), becoming a smart destination and a green city (BE), and gaining the reputation of being a frontrunner (SL).
	The private sector incorporating climate action in the value chain (OE)

APPENDIX E: CODING PROCESS

Based on a manual preliminary analysis of the empirical results in the reports, the researchers created a first categorization of barriers and drivers, as "every single point of significance should be included as a code during the first round of coding (Thompson, 2022, p. 1413). For each category, a code was created in ATLAS.ti. All reports were coded to allow a systematic analysis through organizing, grouping, and comparing the ideas from the different cases. During detailed data analysis, some of the preliminary codes were merged, and some others were included, as "the second round of coding is more selective as it consolidates codes that could be included under a single heading and

TABLE E1 Overview of the codes and occurrences per document/CCLL (author).

	BE	DU	MA	OA	OE	PI	SA	SL	VI	Totals
Institutional and political barriers	24	12	22	14	27	20	19	27	28	193
4_B_institutional_political-bureaucracy	6	0	4	2	2	1	2	1	2	20
4_B_institutional_political-CCLL recognition	0	0	0	1	0	0	0	1	0	2
4_B_institutional_political-external-other urban issues	3	0	1	0	6	4	1	6	5	26
4_B_institutional_political-financial resources	6	2	6	5	6	5	5	10	8	53
4_B_institutional_political-governance-management	4	3	5	7	9	3	3	3	6	43
4_B_institutional_political-human resources	2	4	3	0	3	5	2	9	5	33
4_B_institutional_political-physical infrastructure-impacts	2	2	2	0	1	4	6	2	1	20
4_B_institutional_political-political	3	2	3	2	5	2	0	0	4	21
Institutional and political drivers	12	4	4	4	12	2	10	6	7	61
5_D_institutional_political-funding	4	3	3	2	5	2	8	3	4	34
5_D_institutional_political-image-tourism	7	0	1	0	0	0	3	3	0	14
5_D_institutional_political-political	3	1	0	2	6	0	1	0	3	16
5_D_institutional_political-value chain	0	0	0	0	1	0	0	0	0	1
Social and cultural barriers	14	13	21	11	25	13	16	25	26	164
4_B_social_cultural-communication-dissemination	1	6	0	1	7	5	7	6	2	35
4_B_social_cultural-long-term-uncertainty	4	0	5	4	9	0	3	3	6	34
4_B_social_cultural-stakeholders acceptance-awareness	6	3	8	2	6	4	5	11	5	50
4_B_social_cultural-stakeholders engagement	4	3	6	4	4	4	4	6	12	47
4_B_social_cultural-stakeholders vision	1	2	5	1	4	0	1	2	4	20
Social and cultural drivers	14	17	15	6	25	21	22	24	26	170
5_D_social_cultural-communication-dissemination	4	2	1	0	5	6	4	4	3	29
5_D_social_cultural-cross-cutting	3	3	1	0	3	3	4	0	0	17
5_D_social_cultural-openess to all people	0	0	1	0	0	3	0	0	0	4
5_D_social_cultural-stakeholder engagement	5	9	2	1	9	10	11	11	17	75
5_D_social_cultural-stakeholders acceptance-awareness	6	5	11	6	16	8	8	18	12	90
Technical barriers	15	5	11	12	6	6	17	9	17	98
4_B_technical-CCLL knowledge-experience-teamwork	7	3	2	11	4	3	5	7	4	46
4_B_tecnhincal-data	8	2	9	1	2	3	12	2	13	52
Technical drivers	23	27	21	18	26	15	33	26	42	231
5_D_technical	2	4	4	0	2	0	4	2	2	20
5_D_technical-CC policies-plans-programs	2	2	0	3	8	2	5	3	7	32
5_D_technical-data	8	3	4	1	4	0	11	3	3	37
5_D_technical-knowledge exchange-synergies	2	7	6	6	3	4	9	6	16	59
5_D_technical-long-term	1	0	0	0	1	0	0	0	0	2
5_D_technical-practice	0	1	1	0	4	0	0	1	0	7
5_D_technical-prototype-new ideas	1	1	2	1	5	2	0	2	1	15
5_D_tecnhical-CCLL knowledge-experience-teamwork	9	13	6	8	7	8	10	10	16	87
Totals	216	164	196	136	268	168	251	252	307	1958

codes can be removed that are deemed insignificant or not repeated" (ibid). By looking at the relationships among codes and their collective capacity to portray the story, themes were developed and contrasted with existing literature. "Following an abductive research approach, the clustering and explanation of themes should be guided, but not determined by existing theoretical understanding" (ibid, p. 1415). Table E1 presents an overview of the themes, codes, and occurrences per document (CCLL).