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The Innovation Power of Living Labs to Enable Sustainability Transitions: Challenges and Opportunities of On-Campus Initiatives

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ABSTRACT

Living labs are becoming increasingly popular as suitable arrangements for cocreation and innovation by bringing multiple stakeholders together to work on (solving) complex societal challenges. University campuses are ideal places for living labs, and many universities use such arrangements for various experiments in relation to sustainable future initiatives. Despite the popularity of the living lab concept, much remains unclear about their ways of operation and their potential to innovate. This study aims to show some of the current challenges of on-campus living labs involved with experiments concerning the energy transition. A total of six different living labs were examined based on semistructured interviews with different stakeholders ranging from researchers to operational staff members. Our results show several internal and external challenges, such as the living lab set-up and multiple operational challenges concerning administration, coordination and governance. More external challenges include the overall embeddedness of living labs within the more traditional organizational structure of the university and the tensions between academic and operational processes. Despite these challenges, we conclude that a university campus is still a fruitful place for living labs to cocreate and innovate. By creating awareness and understanding of the challenges living labs face, future initiatives may be facilitated better so that campus living labs are able to unlock their potential to innovate and contribute to societal challenges sooner rather than later.

1 | Introduction

As institutions for knowledge creation, transfer and innovation, universities play a vital role in enabling a more sustainable future (Cortese 2003; Lozano et al. 2013). With their strong links to governments, citizen groups, industries, investors, businesses and the younger generation, universities are ideal places to experiment and influence society by creating awareness in trying to become, for example, climate neutral (Purcell, Henriksen, and Spengler 2019). Besides research and education, the third mission of universities is to share their knowledge with a wider audience. However, according to Göransson, Chaminade, and Bayuo (2022), this is often translated into technical products rather than social innovation activities. Trencher et al. (2014) argue that universities need to engage in a new mission aimed at 'co-creation for sustainability'. To this end, universities need to engage in open, collaborative structures of various actors (Trencher et al. 2014; Ventura, Quero, and Díaz-Méndez 2020). To do so, new approaches to transdisciplinary knowledge (co)creation need to be incorporated into the current university activities (König 2015).

Klooker and Hölzle (2024) focus on the creation and evolution of collaborative innovation spaces. They argue that both the

creation process and the evaluation approach are vital for collaboration spaces as they evolve and change continuously over time. Collaborative innovation happens in an 'in-between space' where actors can break free from organizational culture and experiment together. That illustrates the role of space and boundary objects in facilitating effective collaborative innovation, leveraging the affordances of convergence, generativity, socialization and collaborative learning within innovation spaces (Caccamo 2020; Ystrom and Agogué 2020). This perspective is also relevant for living labs, where the influence of the physical space on the living lab, its organization, governance and participants plays a significant role (Della Santa, Tagliazucchi, and Marchi 2022). Perez Mengual, Danzinger, and Roth (2024) offer a taxonomy to facilitate the intentional design of innovation spaces, such as living labs, extending beyond physical layout to include value propositions for all stakeholders. This taxonomy aims to ensure that innovation spaces are purposeful and sustainable, emphasizing the need for clear design intentions from the outset. It covers the design of space, processes, actors, value propositions and creation within the innovation space, guiding designers and participants towards clarity on key value propositions and related design implications, thereby enhancing operational effectiveness.

Not even 10 years ago, living labs were still considered a rather new methodology with limited attention (Dell'Era and Landoni 2014). Since then, the number of living labs has increased dramatically, which has sparked research and led to a diverse and scattered body of knowledge (Greve et al. 2020; Hossain, Leminen, and Westerlund 2019; Leminen and Westerlund 2019). Living labs are cocreation settings where different stakeholders experiment, develop, test, validate, innovate and learn together in real-world environments. Among a number of arrangements for cocreation and innovation, living labs are regarded as the most promising structure of partnership development along the university–industry–government nexus (Burbridge and Morrison 2021).

University campuses are often regarded as favourable locations for living labs to foster open innovation by bringing a diverse group of stakeholders together for research, showcasing and learning (Leal Filho et al. 2019; Martek et al. 2022). On a campus, living labs are close to extensive research facilities and may benefit from a culture of innovation and access to state-of-the-art knowledge. As many universities own large (campus) premises, the campuses may provide a long-term space for experiments and innovations when strategically coordinated with the campus development plans (Leal Filho et al. 2019).

On-campus living labs are particularly well suited for accelerating the sustainability transition as these labs can potentially affect the university's operations, including anchoring sustainability in its functioning (Vargas, Mac-Lean, and Huge 2019). Campus living labs may also have ample opportunities to impact the local environment beyond the campus (Martek et al. 2022; Purcell, Henriksen, and Spengler 2019) by contributing to the United Nations 2030 Agenda for Sustainable Development with the 17 Sustainable Development Goals. For example, living labs can play a role in the energy transition towards low-carbon cities (Voytenko et al. 2016).

In that, university campuses may be considered intermediary spaces with a city-like character. Comprising controlled lab environments (microscale) and being part of the city (macroscale), university campuses are suitable testbeds for bigger societal transitions (Martek et al. 2022; Purcell, Henriksen, and Spengler 2019). The campus (including all its resources, infrastructure and facilities) then becomes an innovation, teaching and learning arena, improving the campus and university operations by translating sustainability concepts into tangible outcomes (Save, Terim Cavka, and Froese 2021). Westerlund, Leminen, and Rajahonka (2018) show that living lab research includes a number of different topics, such as design, cities, innovation, ecosystems and universities. Universities, in particular, are often heavily involved with living labs and seen as a local force in driving societal impacts (Compagnucci et al. 2021).

Although the campus may seem like an ideal place for living labs with great potential as innovators, educational environments and cocreation facilitators, there is still a lack of evidence about their impact, effectiveness and potential to innovate (Ballon, van Hoed, and Schuurman 2018; Paskaleva and Cooper 2021; Schuurman, De Marez, and Ballon 2015). Equally, knowledge about success factors and enablers for cocreation in living labs is scarce (Greve et al. 2016). Particularly, research into the embeddedness of higher education in living labs is limited, at an early stage, and calls for more research on the organization and governance within this context (Tercanli and Jongbloed 2022; van den Heuvel et al. 2021).

A targeted investigation is necessary as off- and on-campus living labs face different challenges (van den Heuvel et al. 2021). For instance, stakeholders and their roles might differ significantly; on-campus living labs mostly involve stakeholders internal to the university, which might influence their role in living labs. For example, governmental stakeholders' roles might shift from a more regulatory one (off-campus) to one more akin to a client's when it is filled by campus operations (on-campus). This internal filling of stakeholder roles might lead to potential role conflicts, as the same parties setting and enforcing campus rules may need to bend or break them in a living lab context. Furthermore, researchers may assume dual roles when initiating and coordinating on-campus living labs, balancing these with their research responsibilities.

Despite each campus's specific context, the overall organizational structures of universities are structured similarly. Also, less complex ownership structures, easier access to infrastructure and a natural experimentation mindset on campus make campuses particular compared to other urban settings. Hence, campus living labs may use 'their own' university premises for experimentation while applying 'in-house' knowledge. The characteristic organizational structures of universities, internal stakeholders and the specificities of the campus environment highlight the need for specific attention to on-campus living labs.

Our research responds to the calls for a specific investigation of living labs in a higher education context as we aim to uncover the challenges of on-campus living labs. Previous work on campus innovation (including living labs) concentrated on corporate decision-makers and the role of managers (Du Preez et al. 2022;

Rymarzak et al. 2023), but recent work on living labs suggests including different stakeholders in future studies (Hossain, Leminen, and Westerlund 2019; Tercanli and Jongbloed 2022). Therefore, we will focus specifically on the intraorganizational perspectives of corporate university staff and researchers involved in on-campus living labs, as these are underresearched. Set in the realm of living labs and their impact on sustainability transitions, we will focus on the challenges participants encounter in living labs working towards innovation for the energy transition.

In this explorative study, we aim to get more insights from the intraorganizational university perspective to establish why campus living labs are not more prevalent and whether campus living labs may live up to their potential to innovate. The intraorganizational perspective allows us to pinpoint challenges arising in a specific campus context without introducing additional (external) complexities. Subsequently, conditions hindering the facilitation and innovation processes of living labs on campus might surface more clearly. Our findings contribute to the literature on living labs, especially in campus contexts, by providing comprehensive oversight and structure to encountered challenges. These challenges might enable universities to create beneficial conditions within their sphere of influence so that campus living labs are empowered to play an accelerating role in the energy transition while campuses enforce their role as innovation environments.

2 | Literature Background: Living Labs as a Driver for Sustainable Innovation

Experiments play a vital role in sustainability transitions (Fuenfschilling et al. 2019; von Wirth et al. 2019), and different types of experiments aim to add to sustainability visions (Sengers, Wieczorek, and Raven 2019). In this realm, living labs seem to be a favourable and popular context for sustainability experimentation (Torrens et al. 2019).

Unlike the more typical scientific laboratories that experiment under controlled conditions, living labs operate in real-world settings (Evans and Karvonen 2014) and in transdisciplinary ways, transgressing institutional boundaries and the science–society divide. This is done through the integration of practice and experience-based knowledge (Alvargonzález 2011; Klein 2010).

However, living labs are treated as much more than real-world sustainability experiments, as many definitions, interpretations and types of labs exist (Greve et al. 2021; McCrory et al. 2020). Several scholars have endeavoured to elucidate different natures and characteristics of labs by exploring different lab concepts. In their reviews, McCrory et al. (2020) and Schäpke et al. (2018) present an overview of different sustainability-oriented lab concepts, distinguishing for example, real-world labs, transformation labs, urban living labs and living labs. Chronéer, Ståhlbröst, and Habibipour (2019) identify the key components of urban living labs while comparing them to traditional living labs. We will dive deeper into the latter two concepts in the following sections.

Different research avenues see living labs as (1) a system, an ecosystem or a network; (2) a combined approach; (3) a context or an environment; (4) a method, methodology or approach; (5) a tool for the enhancement and implementation of public and user involvement; (6) a development project for products, services and systems; (7) a business activity or operational mode; and (8) an innovation management tool (Leminen and Westerlund 2016). In general, the different notions make the concept confusing, and this inspired a number of scholars to provide descriptions of living labs' associated core characteristics, including stakeholders, user roles, participation, openness, context, coordination, aims, duration, scale, innovation outcomes, challenges, sustainability, activities and business models and networks (Følstad 2008; Hossain, Leminen, and Westerlund 2019; Steen and van Bueren 2017; Stuckrath and Rosales Carreón 2021; Veeckman et al. 2013).

Westerlund and Leminen (2011, 20) define living labs as 'co-creation ecosystems for human-centric research and innovation. (...) [T]hey are physical regions or virtual realities where stakeholders form public-private-people partnerships (4Ps) of firms, public agencies, universities, institutes, and users all collaborating for creation, prototyping, validating, and testing of new technologies, services, products, and systems in real-life contexts'. Two recent literature reviews synthesized that living labs are set in demarked real-world spaces (physical or virtual) that aim to solve societal challenges in transdisciplinary ways in cocreation with different stakeholders in public–private–people partnerships settings (Greve et al. 2021; Hossain, Leminen, and Westerlund 2019). The European Network of Living Labs (ENoLL) presents cocreation, a multimethod approach, real-life setting, orchestration, multistakeholder participation and active user involvement as the common characteristics of living labs (ENoLL. 2023).

To qualify living labs, we align with the literature by deriving four key characteristics from both Westerlund and Leminen's definition and the ENoLL framework. Given the sustainability focus of this paper, we have explicitly included 'sustainable objectives' as an additional characteristic: (1) real-world environment, (2) transdisciplinary approach, (3) cocreation, (4) public–private–people partnership and (5) sustainable objective. Thus, living labs need to (1) be set in a physical setting where real-life events occur (in our case the campus), as opposed to simulated or theoretical contexts; (2) integrate academic and nonacademic knowledge and methods from multiple disciplines to address complex problems beyond the scope of any single discipline; (3) collaboratively generate value, solutions or outcomes by (4) involving government, businesses and users to address societal challenges or pursue shared goals; and (5) have a sustainable objective, contributing to sustainability or the sustainability transition.

On-campus living labs can be seen in the realm of urban living labs (König and Evans 2013). Urban living labs use cities as learning environments for innovations and aim to increase urban sustainability across different topics, like climate change, energy transition, transportation and food systems (Bulkeley et al. 2016; Nevens et al. 2013; Rodrigues and Franco 2018; Steen and van Bueren 2017; Voytenko et al. 2016). As campuses contain a city-like character in the means of facilities, various users, food outlets, infrastructure, housing and up-and-downstream consumption and emissions, on-campus living labs compare to urban living labs. Also, in many of the described key components

of urban living labs, campus living labs are similar to urban living labs. For example, campus living labs like urban living labs have a strong governance and political component as they need to be supported by decision-makers—in the case of urban living labs from cities and politicians, in the case of campus living labs the university executive board. Further, they both have a physical representation, engage the previously mentioned stakeholders and experiment and innovate for sustainable solutions and transformation (Chronéer, Ståhlbröst, and Habibipour 2019).

A close relationship with city governments and university campuses, often being part of cities, reinforces that perception. As such, campuses can be seen as in-between spaces, vital for innovation. For instance, Schliwa and McCormick (2016) place the campus between a district and the city on a geographical scale, emphasizing its in-between character from an urban perspective. Consequently, campus living labs can be considered suitable innovation, testing and learning fields, which can positively affect universities and wider societal and urban sustainability transitions on multiple levels (Martek et al. 2022; Purcell, Henriksen, and Spengler 2019). Crucial properties of campuses for living labs focused on sustainability transitions include access and intervention possibilities into urban challenges on a smaller scale. For instance, to achieve climate neutrality, universities need to reduce their carbon emissions, particularly along their supply chain, from buildings and (re)construction, and energy production (e.g., emissions from natural gas for heating) (Herth and Blok 2023). These issues, which require transdisciplinary approaches, are also urban challenges addressed in living labs. On-campus, these challenges can be tackled exceptionally well due to the city-like character of campuses, reduced ownership complexities, easier access and intervention possibilities in infrastructure and experimentation-prone users such as students.

However, universities are described as having rather inflexible structures with limited opportunities for change (Rymarzak et al. 2023). This also pertains to the implementation of living labs and innovation projects. Du Preez et al.'s (2022) study showed that most innovation projects (including living labs) on 13 Dutch campuses were relatively mature, comprising Technology Readiness Levels 6 and up. This indicates a lack of fundamental experimental real-world labs, aligning with the above-described rigid organizational structures. Despite the growing interest in living labs, their principles, such as transdisciplinary, citizen involvement and multistakeholder collaboration, seem difficult to integrate into the current structure of higher education institutions (Tercanli and Jongbloed 2022). Campus living labs might thus need to break implicit and explicit rules to create a more open and collaborative network structure (Du Preez et al. 2022; Ventura, Quero, and Díaz-Méndez 2020).

Living lab approaches inherently involve relinquishing complete control, dealing with unpredictable outcomes and embracing failure (and the learning it brings). These issues are particularly relevant given the limited knowledge about the emergence of campus living labs. Many living labs often emerge and disappear quickly (Perez Mengual, Danzinger, and Roth 2024; Ballon, van Hoed, and Schuurman 2018), and campus living labs typically arise ad hoc and in unstructured ways (Martek et al. 2022). Moreover, few studies address the success and failure factors of living labs (e.g., Bergmann et al. 2021; Greve et al. 2016), and even fewer do so in campus contexts (e.g., Callaghan and Herselman 2015), where the findings tend to remain case dependent, making tailored facilitation of campus living labs challenging. As such, they are relatively unique within the usual university governance structures. Our study on campus living lab challenges might, therefore, not only uncover roadblocks in the innovation process but also contribute to providing tentative indications of why they might fail.

3 | Method

In this exploratory study, we targeted several campus living labs with the overall theme of the energy transition within the campus environment of the Delft University of Technology (TU Delft) to investigate from intraorganizational multiple-stakeholder perspectives. We applied a qualitative approach and collected our data through semistructured interviews to unravel the challenges stakeholders face in their daily operations (Creswell 2014). A long list of campus innovations was compiled from a list of the university corporate office and cases published by Du Preez et al. (2022). After removing duplicates, an initial set of 17 cases was selected. We evaluated if these cases comply with the previously described characteristics of living labs, namely, (1) real-world environment, (2) transdisciplinary approach, (3) cocreation, (4) public–private–people partnership and (5) sustainable objective, and excluded those that did not. Additionally, we consulted operation staff to make sure we did not miss any initiatives that might not be included in our long list. This resulted in a final sample of six cases (see descriptions in the following).

We conducted 15 semistructured interviews with campus living lab participants between March 2021 and April 2022 (see Appendix B). At least two respondents per case were interviewed—one from the university's operations side (including involved project developers and managers, mainly from the university corporate office of Campus Real Estate & Facility Management [CREFM]) and one from the research side (including professors and researchers). Additionally, we interviewed two representatives on the university's living lab vision, independent of a specific case. Here again, one university operation representative and one research representative were included.

As interviews were conducted during the Covid-19 period, they were mainly held online via video calls, while two took place physically on campus. The interviews lasted between 35 and 60 min; all were audio-recorded (with the interviewees' consent), and comprehensive interview notes were taken. Interviews adopted an exploratory approach to allow interviewees ample room for reflections, including (1) a descriptive part of the project, clarifying its goal, roles and timeline; (2) questions about the choice for a living lab set-up and its structure; (3) the added value of the living lab being on campus and for the campus; (4) the consequences of the living lab for the university; and (5) challenges and lessons learned (see Appendix C for the interview guideline).

The interviews were transcribed and verified for accuracy. Transcripts were then analysed qualitatively by open coding using Atlas.ti 22, which aligns with the explorative character

of this study (Saldaña 2015). A second coding round was done to detect emergent patterns and create preliminary themes and categories. During both coding processes, analytic memos were written and later analysed. The themes found in the dataset provide an in-depth view of the campus living labs' challenges described by participating operational and research staff (presented in Section 5). We addressed the validity of our analysis by checking and discussing themes and their interpretations internally and reliability by sharing and back-checking themes and emerging results with some interviewees for recognition and feedback (Golafshani 2015). Finally, we cross-checked our findings with the existing literature in Section 6.

4 | Case Descriptions

At the end of 2021, TU Delft counted 27,270 students and 6347 employees (TU Delft 2022a). The university campus is located in the Netherlands metropolitan region of Rotterdam and The Hague and is connected to the city of Delft. It extends over 161 ha and is one of the biggest campuses worldwide (TU Delft 2022c). In its current strategic framework, TU Delft aims to become a climate-neutral and circular campus by 2030. Additionally, the university wants to use its innovation power for a more sustainable future and its campus as a living lab (TU Delft 2018, 2019). The recent sustainability vision and ambition report contains a specific subchapter on that topic. It states that 'using the campus as one large laboratory is expected to speed up the experimentation, evaluation, and implementation of new solutions that contribute to the sustainable development goals' (van den Dobbelsteen and van Gameren 2021, 52). The Executive Board decided in November 2022 to invest 100 million euro in executing the sustainability plan to increase the campus sustainability. A significant part of the budget (20 million euros) is reserved for facilitating future innovations and living labs (to be developed) (TU Delft 2022b).

Table 1 presents the cases in the study sample, indicating their development phases—preparation, running or completion—at the time of the interviews. Note that the cases vary in scope with some being single living lab initiatives and others umbrella types encompassing (future) living lab initiatives.[1] The latter are marked with an asterisk in the following table.

5 | Results

We structured our results as follows. First, we present the perceived opportunities of on-campus living labs under study (Section 5.1). Next, we provide an overview of challenges faced by campus living labs, categorized as internal (Section 5.2) and external (Section 5.3), both pertaining to a living lab's point of view. Here, 'external' refers to on-campus challenges, consistent with this study's focus on campus environments. Figure 1 illustrates the interrelation of challenges, with internal challenges situated within the initiatives of campus living labs, while external challenges pertain to the broader campus and organizational context within universities. It is worth noting that campus living labs and the campus itself are embedded within a wider context, as depicted in the figure and established previously.

At this stage, the ideal-type living labs described in the literature do not appear to be fully realized on the campus, as our cases deviate from this ideal by not fully aligning with all dimensions. Previous studies confirm that many living labs deviate from that ideal type in practice (Greve et al. 2021; Steen and van Bueren 2017). Nevertheless, we argue that our cases qualify as campus living labs as all these initiatives are aimed at cocreation and innovation in a real-world setting (see Appendix A), targeting societal challenges from the outset. As particularly the user integration dimension seems to be the bottleneck to being ideal-type living labs for the investigated cases, we will discuss this dimension in more detail in the remainder of this article.

5.1 | Opportunities for Living Labs and Benefits for the Campus

The university campus was considered favourable in all cases under study—a space where theory meets practice. Opportunities for the living labs to be on campus and for the campus to host living labs were mentioned, like bridging industry and academia, an experimentation mindset and many networks and stakeholders being present naturally.

The closeness to academia, state-of-the-art knowledge and prestige of working with a renowned university were seen as attractive for third-party stakeholders to engage on campus. As was the university's lack of commercial interest, which leaves room for innovations.

Campus living labs promise practical experiences for researchers and students, immediate relevance of the research and outcomes by tackling societal questions. Researchers valued the possibility of using the premises 'in front of their door' instead of searching for other suitable places and getting access to buildings, infrastructure systems and data that would otherwise be inaccessible:

> It provides access that you normally don't have (...) And it offers tremendous value for researchers because they can get other kinds of data that are usually free of proprietary or other legal constraints [on campus].
>
> (1:5)

Further, campus living labs were believed to draw extra funding, which is becoming increasingly important for the university's finances. They were also mentioned to contribute to the campus sustainability goals, showcasing what the university is working on, what can be done on a bigger scale and which challenges might be encountered, which might increase the organization's credibility regarding its sustainability ambitions and accelerate the university's sustainability transition.

> (...) the advantage could be that if things work out, they can get extra funding, perhaps to improve the buildings, and in various ways they might achieve these carbon footprint objectives more easily or in a better way, with the help of researchers.
>
> (1:27)

TABLE 1 | Description of study cases on the TU Delft campus (alphabetical order).

Case	Description
Brains4Buildings[a]	Brains4Buildings aims to reduce energy consumption, flexibly respond to energy supply, demand and user behaviour and increase user comfort in buildings by developing methods using big data derived from the Internet of Things devices, smart meters and management systems. The consortium includes 39 partners and plans for 7 living labs. One of them is located at TU Delft; it is themed around smart buildings, installing sensors and AI in buildings. Development phase: The living lab at TU Delft is in preparation.
Development of new campus area[a]	TU Delft is developing a new campus area in the southern part of its campus. New buildings and location development are planned, and the first construction projects have started. The complete development of the area is planned for the coming decades. However, the preparation and development phases must already include infrastructure and room for living labs and innovations. Therefore, sustainable innovations and living labs will be profoundly integrated from the beginning, especially in the energy system. Development phase: In preparation
E-bike charging station	The solar e-bike charging station on campus was developed in collaboration with students from two faculties, researchers and the campus and real estate corporate office. It contains PV cells that deliver direct current to charge e-bikes parked directly at the innovatively designed structure. Students are continuously involved in research and monitoring around the solar e-bike charging station. Development phase: Operational research and monitoring are running.
Geothermal well	The drilling of a geothermal well on campus started in December 2022. The geothermal well will provide sustainable heat to the campus and neighbouring city districts. The shareholder and stakeholder set-up includes TU Delft, researchers and energy companies, all striving to develop an innovative business case. The well will provide heat and a worldwide hotspot as a real-life and running research location on geothermal energy and the energy transition, the heat network and the business case development. Development phase: Running
Innovative façade	A small number of innovative façade panels were initially tested on one faculty building, then scaled up to an entire façade side on another. The indoor climate behind the façade is measured and monitored. Although a circular business model was developed, it was ultimately not implemented. The stakeholders included, for example, TU Delft's Campus and Real Estate corporate office, researchers, banks and companies. The façade is installed, and data monitoring by researchers is ongoing. Development phase: Operational research and monitoring are running.
Parking garage Rotterdamseweg	The parking garage is newly built on campus. It includes roof PV panels and a wooden façade with plants and bird nests to combine electricity generation and biodiversity. PV panels will be installed on the façade, for which TU Delft researchers calculated the yields and the best positioning. Additionally, smart e-charging stations will be installed, together with battery storage and a local minigrid. Development phase: In preparation

[a]Cases vary in scope, with some being umbrella types encompassing (future) living lab initiatives.

Various interviewees stated that campus living labs have the potential to improve campus quality and attract and bind external partners, top researchers and students, which might translate into a competitive advantage.

Sparking enthusiasm through visibility and radiance, communication and public relations opportunities were other benefits mentioned, along with educating the public. The latter includes getting the public in contact with innovations, fostering acceptance, translating research to practice and showcasing the university's research activities with tangible results. Also, according to a participant, campus living labs distribute costs and can be seen as an investment with a return on research and infrastructure. Likewise, a strong motivation of most respondents was to use existing assets and 'practice what you preach'. Nevertheless, the living lab concept was also used in a typical buzzword sense, as one respondent explained: 'we use the word living lab because it's deep, and it gets funding' (24:6).

5.2 | Living Labs Face Internal and External Challenges on Campus

5.2.1 | Internal Challenges of Living Labs on Campus

Internal challenges are those perceived as internal from a living lab's point of view and are categorized as organizational, collaboration and acceptance challenges.

5.2.1.1 | **Organizational Challenges.** Organizational challenges include the coordination of the different stakeholders,

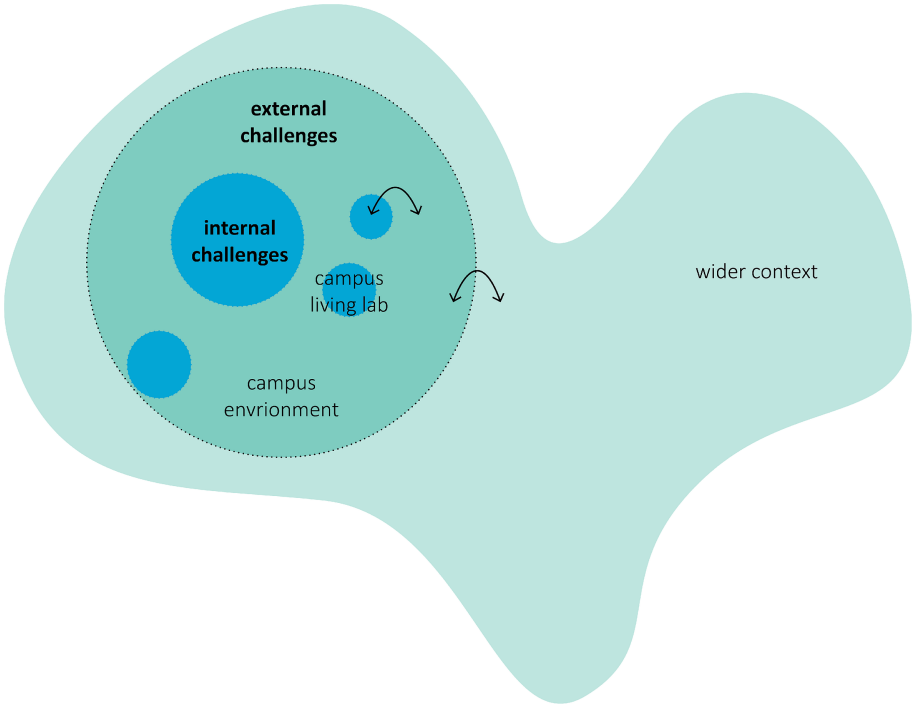

FIGURE 1 | Interrelation of internal and external challenges within the wider context. [Colour figure can be viewed at wileyonlinelibrary.com]

roles, motivations, goals, decision-making processes, a common definition or understanding living labs, questions of ownership and responsibility, funding and financing, monitoring, scaling, impact and continuity. The interviews showed a lack of understanding of what living labs are about. 'Not everyone understands the iterative nature of a living lab setup. It's confusing and repetitive at the same time' (24:21). Even respondents within the same initiative had different understandings:

> There was a lot of confusion, I must say, different types of understanding of what we're doing until today. Which was a big challenge.
>
> (16:12)

To overcome that issue, the respondents explicitly mentioned that they would spend more time and effort in the initiation phase to clarify each stakeholder's motivations and goals.

> I think we really had the idea that we understood everyone's motivations, and it was very clear that we didn't. And there were things people really cared about that we didn't understand from all different sides. And those motivations, I think, should have much more attention. (...) I think just having those preconceptions, those concerns, those motivations, very clearly detailed, and not superficially, really spend time on digging into what these mean as well, would be really helpful.
>
> (14:51)

None of the cases strategically monitored the overall (innovation) process. Because engaged individuals initiated the living labs, monitoring was not a primary concern, yet a tracking and monitoring system would later seem beneficial.

> (...) well, at the beginning of the process, we didn't know how big of a process it was, which I think was part of the issue; we thought it could be relatively simple. (...) So we didn't start the process with such an idea that it would take quite a long time and that we should really monitor the process in detail.
>
> (14:45)

Besides, no visions and wider goals were defined other than directly related to the project realization. Nevertheless, all cases were believed to have a direct scaling potential on or outside the university campus. On campus particularly, even the continuity of living labs, like the further development or stacking of projects beyond the current concrete project realization, does not seem to be the norm.

Funding and financing are seen as central challenges. Campus living labs were assumed to require more resources (time, people and money) than traditional projects and have to deal with complex stakeholder settings. Because they operate in the real-world environment, they often require a viable business case to get off-ground. However, for a viable business case, one party's commitment is often needed to carry the 'initiation risk'. Without anybody taking that risk, there is no viable business case; without a viable business case, nobody wants to take the risk: the well-known chicken-and-egg problem.

5.2.1.2 | Collaboration Challenges. Collaboration challenges include learning and knowledge sharing, complex decision-making, resources, flexibility and alignment and new

working methods. Respondents reported no cross-campus living lab knowledge flow about, for example, common organizational challenges, which leads to repeatedly finding individual solutions.

Decision-making requires 'consent of all parties, and you need to be very open about what you're doing' (16:13), making collaboration and cocreation with multiple-stakeholder complex. It also involves addressing decisions about resource allocation and contributions in untraditional or previously unknown ways and questions of ownership and responsibility. These new ways further concern the need to align various stakeholders' distinct cultures, rhythms, motivations, goals and plans while being open and flexible. This required time investment and was perceived as a slow process with 'literally hundreds of meetings' (16:23).

Besides, we observed a lack of user integration in our cases. We categorize this as another internal challenge, as the integration of users is central to the concept of living labs.

5.2.1.3 | Acceptance Challenges. Challenges related to acceptance concern past experiences and new ways of working, trust and making room for mistakes and uncertainty. According to the respondents, campus living labs ask stakeholders to open systems and infrastructure. Several researchers mentioned the challenge of overcoming past experiences regarding attempts to initiate campus projects that resulted in having bad experiences and negative emotions, like frustration and indifference. This hinders trying again—even though circumstances might have changed. It also shows a mutual need to respect each other's roles in the university environment.

> If you come up with a good idea and you don't respect the needs of Campus Real Estate [CRE]—their most important job is to facilitate the operation of the campus in the smoothest way that we can think of. If you don't respect that and just say, hey, I have a great idea, let's go for it. Yeah ... On the other hand, CRE needs to be aware that they are on the smartest campus that we can think of. So let's bring in our expertise to stimulate campus as living lab.
>
> (23:52)

5.2.2 | External Challenges for Living Labs on Campus

External challenges, from the perspective of the living lab, are categorized into university organization, resources, coordination, campus and bridging operation and academia. Note that 'external' still refers to on-campus challenges, given this paper's focus on a campus context.

5.2.2.1 | University Organization. The university organization is a traditionally hierarchical and rigid structure. Because different university entities have different roles, goals and aims, the decision-making process was perceived as complex and layered. No campus living lab frameworks or processes were in place, so decision entities lacked guidelines and mandates. Clear instructions from the university's top-level leadership are required to provide a mandate and flexibility in project management processes to integrate living labs:

> So if the facilities managers [project managers for campus development] are told that the university expects them to involve the academic community, then they have a clear instruction and a mandate to follow, which otherwise could also be done without the involvement of the research community.
>
> (1:29)

Campus living labs were unfitting in the existing organizational structures as they do not align with the university's standard project management practices and processes. They differ from traditional projects and require new decision-making, integration and collaboration processes. This also concerns legal questions, flexible processes and room for mistakes. Without guidance in these new ways of thinking and working, it would be 'maybe easier not to do it' (2:26), especially because the current structures, (selection) criteria (e.g., in tenders), roles and processes do not allow for experimentation, flexibility and uncertainty. As campus living labs are not defined tasks for operations, there is also little room in project planning for them.

> Because if [the planning] remains tightly within its assignment, then there is actually little room for a living lab there.
>
> (20:44)

As long as they are not embedded in processes and evaluation criteria, the potential to strategically use campus living labs as innovation tools is not realized.

5.2.2.2 | Resources. Questions of resource allocation and funding are internal as well as external challenges. Externally, it concerns the resource allocation and funding in the university organization. This is tightly linked to the support and assigned importance (and thus granted resources) of the university's top-level management. Resources include space, human resources, financial resources, dedicated processes and coordinators. A scientist mentioned:

> I think it causes quite some time to be invested both from CRE, from the researchers, etc. So we could do some of this research by working with others on other projects, and we would spend much less time on the organization. So we have to decide where to invest. And I think that the university as a whole is not yet aware maybe of what those costs are, because it's sort of hidden in additional work.
>
> (14:69)

If campus living labs are not embedded organizationally, they keep being considered a voluntary extra task or side project, depending on individuals and ad hoc emergence. 'Now it is ad

hoc based on individuals who may or may not want it' (20:81). Even though interviewees unanimously called for a campus innovation/living lab coordinator or manager, they repel another centralized entity.

> I don't think it should be centralized. But there is a support system that's missing in terms of knowledge sharing, and then monitoring and evaluation and an overview of projects. (...) And I don't believe the answer is centralizing. (...) I think it would be restrictive. You would put a bottleneck in something that's already really quite lively.
>
> (24:92, 99, 103)

5.2.2.3 | Coordination. All respondents noted that their projects were not strategically coordinated, but bottom-up initiated and depended on individuals' enthusiasm, willpower, negotiation skills, capacity and stamina.

According to the interviewees, campus-wide coordination could support financing possibilities, link stakeholders, connect people, provide transparent decision-making structures, support internal and external communication, facilitate project processes and create a platform for knowledge sharing and cross-fertilization.

> I think you would need a website with guidance on how to set up a living lab; what are the ingredients? What are the pros and cons? Why would you do this? And then take you through a step-by-step on how to get a living lab set up. What do you do, what can you expect for an outcome, and then how to run that on campus? But that should be managed by a living lab office or coordinator or someone who understands academics, project management, commercialization of projects, innovation, ecosystems, startups, getting funding. (...) According to me, someone needs to be assigned the job of setting that up.
>
> (24:53, 54)

An internal shared understanding of what campus living labs are, was considered essential to provide a baseline and to better align and coordinate scientists and operations. Interviewees also mentioned challenges regarding monitoring and the continuity of campus innovation projects (stacking projects, where one leads to the next). Knowledge-sharing networks were not in place to establish collaborations, facilitate continuity, foster cross-case learning and exchange organizational practices. Knowledge was considered to flow rather outside than be implemented within the university.

> How is it possible that we don't see what we are working on and spin-offs from TU Delft that have brilliant ideas? They sell their expertise to places all over the Netherlands, but there's nothing of their expertise to be found on campus. That's strange.
>
> (23:61)

5.2.2.4 | Campus. Being the campus owner, the corporate office CRE has a high decision power regarding campus living labs. For example, the allocated location for one of the cases was rather unfunctional. Permission for the campus living labs and their potential location are needed, which depends on CRE and the aesthetics committee, and the alignment with CRE's campus strategy. The university is believed to introduce more risks to its operation by allowing innovative initiatives on campus, while the campus' reliable operation must be ensured. Integrating living labs was seen as difficult due to the rigid complex environment and a relatively closed community with its own rules and culture. This might work as an obstacle, as a respondent puts it:

> A campus also has its own rules. Its own culture, its own elasticity or a lack thereof, its own priorities. So that can also be a hindrance.
>
> (18:37)

5.2.2.5 | Bridging Two University-Internal Worlds—Operations and Science. We came across various challenges related to the university's internal different roles and ways of working—operations and academics, who are both inherently involved in campus living labs.

University operations and academics are perceived from both sides as highly separate and are repeatedly called 'two parallel worlds' (20:39). This translates into different perceptions of what campus living labs are and mutual expectations about roles and responsibilities. Operation staff handle living labs as standard projects they facilitate, whereas researchers see them as knowledge implementation, creation and research places. Scientists are highly motivated to apply their knowledge and expertise in their backyard; however, they do not want to manage or take ownership of the campus living labs.

These dynamics are further complicated when operational entities fulfill different roles simultaneously. Specifically, CRE can have two distinct roles within campus living labs: On the one hand, as a stage gate for facilitating innovations on campus (external for campus living labs). On the other hand, as a stakeholder, participating in the living lab, such as in the user role (internal for campus living labs). In some cases, CRE may simultaneously fulfill both roles. These overlapping roles contribute to ambiguity in defining responsibilities at strategic, tactical, and operational levels.

The interview results showed that as long as campus living labs are not formally embedded in operation processes and evaluation schemes (e.g., integration in selection criteria, tenders, key performance indicators and reward systems), their execution is an extra task and an additional risk for operations. Living labs are contrary to what operation staff is expected to do, namely securing the functioning of the campus with minimal risk and delivering high-quality projects on time and within budget. Their focus is thus realizing a specific project assignment, as expressed by an operation staff respondent:

> I just got that assignment to make sure those parking spaces are there. (...) Yes, and when [mentions name] came to me like, we also have to do this [integrate a

> living lab], I thought to myself that it would just cost an extra year. I wasn't very happy with it at first. (...) Our real estate development very much needed to continue, and [I had] to make sure that the living lab story wouldn't affect the planning of my project.
>
> (19:30, 37, 41)

Alignment issues of operation and scientists is another issue. It concerns the often-diverging project and research plannings and campus development timelines. Operation's campus projects often have strict lead times with little leeway for experimentation, higher risks, uncertainty and unexpected outcomes. In contrast, research planning needs to allow time for, for example, hiring new researchers when funding is granted and the mentioned unexpected outcomes. Whereas academic break times are excessively used for operation projects, academics often only then have the chance to take a break from education and teaching, which complicates alignment.

6 | Discussion

6.1 | Moving Campus Living Labs Forward—Discussion of the Results

Although we found many of the expected opportunities of being on campus, fewer living labs were initiated on our campus than expected. This emphasizes the importance of getting insights into the challenges for campus living labs in the distinct university environment. Campus living lab participants mentioned indeed numerous challenges they encountered in their daily operations. First, a number of participants experienced the complexity of their projects as hindering the innovation capabilities of their labs. Second, living lab participants acknowledge the tensions between the traditional university structure and the open-ended nature of their labs. This leads to a perception of operating in two parallel worlds (operation and science), which challenges the potential to innovate as it seems hard to integrate these two ways of thinking and hinders collaboration. Third, campus living labs struggle with their internal organization structure as there are no clear guidelines on organizing their lab, and many encounter the incremental search for a suitable structure as hindering their progress.

The university campus holds invaluable assets for innovations, providing safe experimenting conditions in a real-world environment and hosting great intellect. Yet, in our case, campus living labs are not used as strategic tools for innovations and the university's sustainability transition (nor were our cases included in education and curricula, for that matter). This aligns with Lough's (2022) statement that HEIs are not living up to their potential in creating social value by advocating for and scaling their innovations. Our results show that top-down and bottom-up initiatives are needed to tap into that potential.

Currently, it seems that the campus living labs are facilitated by university staff that treats living labs as standard (demonstration) projects with Technology Readiness Levels 7–9. As such, decisions are made on an ad hoc basis without any proper understanding of the specific nature of living labs compared to standard projects (Du Preez et al. 2022). Thus, campus living labs are handled based on a traditional project logic, and this 'projectification' of experimentation where a project-logic forms the base (Torrens and Wirth 2021) is not a favourable breeding ground for living labs. Their approach is more explorative and open to unintended outcomes and innovations, including more room to manoeuvre and failure. This makes the intent with which living labs are set up inherently different than projects.

Also, research shows that living labs need long-term funding to keep them alive and to sustain the innovation activities and their scale-up. However, they are usually financed on a project basis, which does not fit with the number of unforeseen outcomes such labs encounter (Hossain, Leminen, and Westerlund 2019). Thus, transparent decision-making criteria must be created to avoid these unmotivated ad hoc decisions and prevent financing only experiments that fit into the established project logic. The buzzword issue of labelling projects 'living labs' for funding or publicity shifts the focus from solving core challenges to simply being or becoming a living lab. This is facilitated by a lack of common understanding of what a campus living lab constitutes, which is problematic internally and externally, as implications might diverge substantially (Save, Terim Cavka, and Froese 2021).

For instance, we noticed that our cases differed in scope, as some represent single living lab initiatives, while others are rather umbrellas for various living lab initiatives. The latter is the case for the Brains4Buildings and the development of a new campus area. These two layers correspond to what Schuurman (2015) calls the living lab organization and living lab project. These different perspectives emphasize the need to create clarity and a common understanding within the university. Additionally, if other potential issues are unclear to stakeholders, for example, uncertainty, unpredicted outcomes, failing and learning during the process, this could cause problems due to different expectations. Thus, intensified communication and specific motivation, expectation and goal management for all stakeholders are necessary (Leal Filho et al. 2022).

Considering the traditional organizational set-up of universities, front-end user integration is not a traditional practice. Our findings revealed that user integration had the weakest compliance among the five identified characteristics (refer to Appendix A).

Similarly, Steen and van Bueren (2017) found that user integration for cocreation was lacking in many urban living labs as well. Yet, not integrating users from the front end can be understood as a missed opportunity and belittling their role in the innovation process. As such, this somewhat violates the user-centeredness of living labs but this seems not uncommon in university contexts where the role of users is often not yet clear. This is in contrast to urban living labs, where citizens play a clear and vital role as users. On campus, the users are often part of the multiactor university's operation and administration and are much less clearly identified. In this respect, the potential multiactor role of the university makes it vital to clarify the different roles within a campus living lab.

The organizational and process hurdles hinder innovations as living lab members report spending energy sorting out administrative issues continuously, also addressed by Callaghan and Herselman (2015). As suggested by Martek et al. (2022), setting up a university-wide support network for living labs may indeed help to facilitate their administration and coordination activities. The question remains where this facilitation point should be located in the organization and what responsibilities should be mandated (Tercanli and Jongbloed 2022). Some of our respondents opposed yet another centralized university body and argued that the facilitation process needs cocreation, flexibility and experimentation itself to deviate from the traditional project approach, which does not fit with the innovative nature of living labs. Also, innovation coordination and integration should become part of the overall university operations. Consequently, this requires changes in existing structures, for example, project timelines and requirements, to allow for flexibility and cocreation (Evans et al. 2015). As the impact of the existing campus innovations still seems incremental, better organizational facilitation and integration could free up capacities to innovate and may lead to an increased impact of living labs.

The identified challenges call for transparent organizational structures, decision-making and integration of campus living labs into current operational processes and reward structures (Save, Terim Cavka, and Froese 2021). To that end, an internal reframing of living labs is needed. Instead of seeing such labs as a risk factor, they need to be understood as opportunities to contribute to the (campus and societal) sustainability transition, which also includes the integration of society in the role of users. This aligns with universities' (third) mission and may contribute to overcoming disciplinary and operational silos in and around the university environment. Under these conditions, campus living labs could then function as intraorganizational and extraorganizational boundary spanners to drive innovations (van Geenhuizen 2016). Consequently, traditional roles in the university organization and the science–society divide must change to enable cocreation, co-ownership and more flexibility in standard processes to simplify alignment and prevent possible lockins (Rymarzak et al. 2023).

Although we studied the challenges of living labs from the perspective of one university campus, our findings may apply to living labs at other university campuses as these contexts of the university organizational settings are comparable. Despite some local specificities, we believe campus living labs may encounter the challenges we have detailed through our study. The awareness of these potential challenges might pave the way for adequate preparation and better operations of campus living labs and may avoid getting stranded before reaching their goals.

6.2 | Limitations and Future Research

Limitations of this study include the single focus on one university campus, which limits its generalizability. Nevertheless, as mentioned previously, we assume our findings applicable to other comparable university campus settings. In line, we encourage comparing campus settings and their implications for on-campus living labs. Next, our work presents results derived from data gathered in a relatively short period, representing the current situation at that point in time. However, living labs are dynamic and organic in their development. This is why longitudinal studies would be valuable for tracking their progress over time. Finally, we focused this work on the intraorganizational university stakeholder perspective, omitting third parties and potential users and students. The diversity of cases and their different phasing make it difficult to include all stakeholders. Again, longitudinal studies could also create more room to integrate their views. The same applies to the different types and organizational layers of living labs. Including them could help in further specifying the challenges.

Although our scope was narrow, our findings may still apply to other settings. However, making general statements would exceed the scope of this study, which is why we highlight several avenues for future research. Including other higher education institutions to compare different types of campuses (e.g., city and rural) and their location-specific challenges would be valuable in understanding if and how other environments are better equipped to facilitate living labs. Similarly, comparing organizational facilitation and embeddedness could help create optimal environments for living labs. Additionally, we are calling for studies that investigate how far our findings might be applicable to other contexts beyond the campus. It would also be valuable to assess whether users and third parties recognize our findings and to identify any additional challenges in that process.

We see the need for more empirical research on the success factors of campus living labs, as simply overcoming the here mentioned challenges might not automatically ensure their success. Because we saw campus living labs facing the same challenges and continuously reinventing the 'living lab wheel', we encourage future research to develop phase-related oversights of tools and structures to support living labs' coordination, governance and learning processes. Furthermore, new approaches would be desirable to ease the way from a campus with fragmented, ad hoc, single-case living labs to an integrated 'campus as a living lab' perspective. As these processes themselves will need and entail cocreation, unexpected outcomes, failure and learning, tracking and sharing them would be of value. For innovation and living labs, an open culture of mistakes is vital. However, very few failed living lab cases are published in the literature, which does not align with that proclaimed culture. It also means losing shared, valuable learning opportunities for living labs, their hosting organizations and stakeholders.

7 | Conclusion

Although university campuses seem ideal locations for cocreation and innovation through living labs, many universities fail to use these arrangements to their full potential. This is especially pertinent for various experiments related to sustainable future initiatives. Our study shows a number of internal and external challenges that hinder living labs in their progress towards the energy transition on campus. Such internal challenges include the need for a clear living lab set-up and front-end user integration, well-coordinated administration and effective governance to facilitate stakeholder

collaboration. External challenges relate to the difficulty of embedding living labs into the traditional organizational structure of the university and possible tensions between academic and operational processes. Despite these challenges, university campuses still remain fruitful locations for living labs to cocreate and innovate as long as future initiatives are fittingly facilitated by the university administration and the internal organization of living labs is further developed. This will enable living labs to unlock their potential and contribute to complex societal challenges, such as the acceleration of the energy transition sooner rather than later.

Data Availability Statement

The supporting material for this study includes interview transcripts. Those documents may reveal the identity of participants. For this reason, the transcripts are not openly shared. The data will be preserved per the consent document until 31 December 2024, after which they will be deleted. The document can be made available to other researchers for verification purposes after the appropriate GDPR-related agreements have been put in place.

Endnotes

[1] Another layer to consider is the entire campus as a living lab, as stated in TU Delft's sustainability report. However, we excluded this layer from our study because it was not yet operationally developed at the time of data collection.

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Appendix A

Evaluation of Study Cases Regarding Their Living Lab Characteristics

Case	Real-world environment	Cocreation	Transdisciplinary approach	Public–private–people partnership	Sustainable objective	Remarks
Brains4Buildings	•••	•••	••	•	•••	User involvement is not yet defined or specifically integrated.
Development of new campus area	•••	••	••	••	•••	Specific living labs have to be developed and integrated into area development and construction plans.
E-bike charging station	•••	•••	•••	•	•••	User behaviour is monitored; however, they were not actively involved from the beginning.
Geothermal well	•••	•••	•	••	•••	Even though campus operation (heat network) can be seen as the user actively participating, the neighbouring residential districts, which are planned to be provided with heat as well, were not included. The research will be done on the geothermal well (disciplinary), whereas we see the living lab approach in the business case.
Innovative façade	•••	•••	•••	••	•••	The circular business model was designed and set up as a living lab but, in the end, did not come into practice. The innovative façade itself is considered a testbed.
Parking garage	•••	••	•••	•	•••	User involvement is not yet defined or specifically integrated.

Note: ••• High score. •• Medium score (still in line with expectations). • Low score.

Appendix B

Interview Data

Interviewee	Case	Date
Energy transition role	C	08.02.2021
Sustainability role	F	22.03.2021
Project coordination role	A	27.05.2021
Academic role	F	28.05.2021
Asset management role	B	31.05.2021
Academic role	B	31.05.2021
Asset management role	D	01.06.2021
Real estate development role	F	01.06.2021
Academic role	A	08.06.2021
Academic and advisory role	C	02.12.2021
Academic role	D	21.03.2022
Academic role	E	22.03.2022
Academic and advisory role	G	23.03.2022
Project coordination role	E	24.03.2022
Innovation management role	G	12.04.2022

Appendix C

Interview Guideline

- Could you tell me what the living lab is about and what goal it pursues?
- What is a living lab for you?
- Why did you choose a living lab set-up?
- What are the opportunities and challenges of facilitating living labs on campus?
- What are the opportunities and challenges of the campus environment for living labs?
- How do you monitor your living lab?
- What impacts/consequences does your living lab have for the university organization?
- What were the biggest enablers and barriers in the process?
- If you had the chance to start over, what would you do differently this time?
- Is there anything left you would like to share or say?