University Campus Living Labs: Unpacking Multiple Dimensions of an Emerging Phenomenon

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Abstract

Universities and their changing role in society is a source of perennial debate. In this article, we examine the emergent phenomenon of *University Campus Living Labs (UCLL)*, the set of practices by which universities use their own buildings, streets or energy infrastructure as experimental settings in order to support applied teaching, research and co-creation with society. While most existing studies of UCLLs focus on them as sustainability instruments, we explore the UCLL phenomenon from an open-ended and fresh angle. Using living labs in five European universities as exemplary cases, we demonstrate the breadth and variability of this emerging phenomenon through five analytical dimensions to unpack the multiple forms and purposes that UCLLs can have. We furthermore consider aspects of inclusiveness and situatedness of living lab co-creation and testing and what the UCLL phenomena may come to mean for the continuously changing university, calling for future studies to substantiate these aspects.

Keywords: University Campus Living Lab, co-creation, sustainability, science communication, Quadruple Helix, public engagement

Introduction

The changing societal role of modern universities has been debated for decades (Martin, 2012; Trencher et al., 2014). Almost thirty years ago, Gibbons et al. (1994) pointed to the new production of 'Mode 2' knowledge, while Etzkowitz and Leydesdorff (1995) coined the 'Triple Helix' concept, with its increased collaboration between university, private industry and government, and Clark (1998) hailed the emergence of the entrepreneurial university. More recently, Trencher et al. (2014: 152) have argued that "the emergence of this entrepreneurial 'species' [is] not ... the last chapter in the ever-evolving modern university". Instead, a "broader and more ambitious function has emerged: that of a societal transformer and co-creator" (Trencher et al., 2014: 152), which entails a collaboration between universities and local government, industry and civil society to drive the physical and sustainable transformation of, for example, the region.

Within this broader area of interest in universities' evolving missions and contribution to society and sustainability, a literature is emerging that looks specifically at how universities are embracing the much hyped 'living laboratory' concept to promote sustainability in various ways (e.g., Evans et al., 2015; König, 2013). As Evans et al. (2015: 1) write, "[t]he living lab approach is increasingly popular with universities, who recognise that their campuses offer amenable real world locations in which to conduct applied research [and teaching]. [...] Living labs promise to bring researchers, students, external stakeholders [...], and university estates and facilities staff together to co-produce knowledge about new sustainability technologies and services in real world settings".

In brief, living labs can be defined as an "experimentation environment in which technology is given shape in real life contexts"[1] (Schuurman et al., 2013: 2). They foster collaborative work between various stakeholders to generate innovative solutions. Key to the living lab concept is processes of co-creation, the coming together of different actors in a joint activity that leads to a mutually beneficial outcome (Ramaswamy and Ozcan, 2014). Universities employ the idea of living labs for several related reasons, as will be

evident from the above: to co-create sustainable regional change, to enhance applied teaching and research about sustainability, to foster social learning and the co-production of sustainability science, or simply to make campus operations more energy-efficient (Trencher et al., 2014; Evans et al., 2015; König, 2013; Filho et al. 2017, 2020).

Universities either engage in urban living lab partnerships in their region or host them on their own campus. In this paper we explore the latter phenomenon, which we term University Campus Living Labs (UCLL), by studying five cases in which universities have turned their own campuses into living labs, that is, spaces where the university utilizes its own buildings, streets or energy infrastructure as real-life experimental settings. In doing so, we contribute a fresh perspective on universities and living labs. Despite rich insights from several interesting cases of living labs on university campuses (see e.g., Evans et al., 2015; König, 2013; Filho et al. 2017, 2020), we argue that a *shift in attention* to how they are explored is needed. While universities used to build designated laboratories to run experiments under controlled conditions, they are now using their campuses, staff and students as part of the experiment. Universities are no longer spaces that *contain* laboratories, but *are* themselves laboratories, entangled in co-creative relations. While the literature on universities employing the concept of living labs focuses its attention on various aspects of how these living labs can be the movers of sustainable development, we aim to go beyond this sustainability framing to illustrate a broader diversity of aims and modalities in this phenomenon, employing a Science and Technology Studies (e.g., Felt et al., 2017) lens that pays critical attention to knowledge politics, power and technoscience-society relations, and foregrounds an explorative approach. Thus, we are interested in understanding the *breadth* and *variability* of this phenomenon, motivated by the following research question: *Many forms of living labs have emerged on campuses in recent years, but what are the stated purposes of UCLLs, and what forms do they take?*

Our primary contribution is the examination of five analytic dimensions that discriminate the UCLL phenomenon's many shapes and

purposes. However, we are also interested in the broader shift towards co-creation within the university. Our analyses of living labs constituted within the socio-material milieu of a university campus therefore also motivates a discussion around co-creation in UCLL's and in living labs more broadly, as well as what the UCLL phenomenon may come to mean for the way universities develop – as something that has importance for "transformations in the inner organisation of the 21st century university system" (Tuunainen and Kantasalmi, 2017: 5). In doing so, we hope to inspire future papers to substantiate this agenda and discussion and continue the exploration of UCLL's as a multifaceted phenomenon.

We structure the article as follows: in the following section, we present and discuss the core concept of living labs, as well as their previous applications on university campuses. In the subsequent section, we outline our methodology and present our five cases, which have been chosen to represent variety in national contexts, university settings and initial arrangements. In our analysis, we identify five key dimensions along which our cases differ and use them to structure our analysis. We end the article with a concluding discussion.

Living labs on university campuses

As mentioned above, the idea that universities increasingly collaborate with external actors to facilitate technology transfers and co-produce knowledge to solve complex, transdisciplinary social challenges (Gibbons et al., 1994, Etzkowitz and Leydesdorff, 1995; Clark, 1998) has been richly described. Recently more attention has been placed on universities' role in not only contributing to, but enabling the sustainable transformation of a locality, as exemplified in Trencher et al.'s (2013, 2014) description of a fourth mission of 'co-creating for sustainability'. As such, this work extends a longstanding interest in understanding the "significant alteration [that] has taken place in science and university organization" (Tuunainen and Kantasalmi, 2017: 3).

As pointed out in the introduction, one of the co-creation tools that universities as well as industry and the public sector have embraced, and which has attracted academic attention (Leminen

and Westerlund, 2019), is the 'living laboratory'. The European Network of Living Labs (ENoLL) defines living labs as "real-life test and experimentation environments that foster co-creation and open innovation among the main actors of the Quadruple Helix Model, namely: Citizens, Government, Industry, Academia" (ENoLL, 2022). While there is some attention to how universities can use this instrument to e.g. facilitate technology transfer and boundary spanning (Van Geenhuizen, 2013, 2018), most often the focus is on the ability of living lab partnerships to promote urban or regional sustainable change (Bulkley et al. 2016; König and Evans, 2013; Evans and Karvonen 2014; Voytenko et al. 2016). Living labs are indeed generally becoming a political priority (Evans et al. 2015). Over the last ten years, living labs have emerged globally as a popular innovation instrument, to the extent that innovation scholars are labelling the ongoing phenomenon as 'the living lab movement' (Leminen and Westerlund, 2019: 250), while others capture the current trend in the notion of a 'Pilot Society' (Ryghaug and Skjølsvold, 2021).

In this paper, we focus particularly on living labs employed *on* university campuses, and we noted above how these living labs are almost exclusively explored in terms of sustainability – in their capacity to foster the co-production of sustainability science and offer applied and interdisciplinary teaching and research opportunities, and in their ability to aid green campus operations and foster social learning and change (Evans, 2015; Cole and Srivastava, 2013; König and Evans, 2013; Filho et al., 2017; 2020). According to Evans et al. (2015: 2), university living labs have the advantage that "consulting users and stakeholders allows complementary sets of projects to be strategically planned that offer holistic solutions to sustainability challenges". Moreover "by emphasizing the iterative process of experimenting and learning from year to year they provide a more coherent basis for action over time" (Evans et al., 2015: 2). This interest in living labs on university campuses as tools for sustainable change is also reflected in the increasing popularity of the 'International Sustainable Campus Network' (ISCN) and in the work of Verhoef and Bossert (2019), who published a practical guide to help universities

setting up living labs on campus. The uniqueness in a campus as a sustainability living lab, they point out, is the transdisciplinary approach, the ability to combine campus operations with the universities' primary functions of teaching and research, and the fact that universities are active at several scales of the experimentation and implementation of sustainability solutions. According to König and Evans (2013: 12), a university campus's living lab is a "site for social interaction and engagement resulting in knowledge production across organizational and disciplinary boundaries".

Although universities have increasingly embraced them, living labs have a history that extends well beyond their recent applications by universities and public governance institutions, and they have for many years also been used as tools for private actors to help commercialise their products (Voytenko et al., 2016). Living labs are thus applied in a multitude of ways and have been used to develop, for instance, health care, ICT products, smart cities (e.g., Hossain et al., 2019) and renewable energy transitions (Ryghaug and Skjølsvold, 2021; Nyborg and Røpke, 2013), as well as for driving sustainable urban transformation (Bulkeley et al., 2016). Their outcomes can be everything from concrete designs, products, prototypes and systems to scenarios, processes, concepts and ideas, and they draw upon a variety of methods such as behavioural data analysis, ethnographic research and focus groups (Hossain et al., 2019; Evans et al., 2015). In terms of user involvement, living labs can be either closed, i.e. involve pre-selected users (for instance a user panel), or they can be open to everyone who wants to participate (for instance a local community in a city) (Dell'Era and Landoni, 2014).

Recent STS scholarship highlights how living labs and test beds do not simply perform controlled experiments under presumably realistic conditions, but rather test entirely new socio-technical arrangements (Engels et al., 2019). Moreover, the experiments and tests reconfigure relations not only in the lab, but in wider society – in other words, real life experiments are often infrastructurally configured and seamless as they are no longer "spatially and temporally separate from the environment", but most importantly, they "operate on social relations" (Marres and Stark, 2020: 438). As living labs intervene across entire social orders, they may require changes to local laws and regulations and therefore share ideas with the notion of regulatory sandboxes (Engels et al., 2019: 2), or with what transition theory scholars call 'niches', i.e., protected spaces for experimentation (König and Evans, 2013) that can later be scaled up, e.g., to the entire city. Thus, the living lab concept brings with it several tensions and paradoxes: a core value proposition of living labs is their ability to conduct controlled experimentation (the 'lab' bit) while simultaneously allowing testing in real-world conditions (the 'living' bit). In such real-world environments, uncontrolled, 'messy co-creation' is often a more accurate description of activities in living lab sites (Engels et al., 2019: 8). Moreover, living labs and test beds play on the duality between being both protected and 'exceptional places' that are relieved of various constraints (legal, for example) to foster 'free' innovation and experimentation, yet they also claim 'representativeness', as they take place in real life (Laurent et al., 2021).

Taken together, the current literature on UCLLs have a distinct focus on them as tools for sustainability, whereas we claim they have a multitude of other aims, agendas and purposes that deserve more attention, and which come to light via a grounded and situated approach to studying UCLLs. In unfolding the UCLL phenomenon through five analytical dimensions of '*organizational anchoring*', '*industry collaboration*', '*sustainability & student involvement*', '*experimental ethos*', and '*visibility, self-identity & communication*', which emerged inductively during our analysis of the empirical material, we also aim to point out issues around co-creation in UCLL's that deserve more attention. Furthermore, we tentatively explore the potential importance of the UCLL phenomenon for the way universities develop, i.e., for changes in both scientific practices and the transformation of the university organization (Tuunainen and Kantasalmi, 2017: 6). These issues are currently understudied and should be further substantiated in future studies. In the following, we will shed light on these aspects of the UCLL phenomenon, but first we present our methods and data.

Methods and data

This article builds on an interpretive case study approach (e.g., Walsham, 2006) using material from five European universities that have integrated living lab activities into their campuses. The examples were selected out of a larger pool of living lab cases being studied in the Horizon2020-funded project SCALINGS (SCALINGS, n.d.). Our five cases were chosen to provide contrasts on the UCLL phenomenon in Europe, focusing on our research question of purpose and form to include as many understandings of the UCLL phenomenon as possible. They are affiliated with universities in Denmark (Technical University of Denmark, DTU), the Netherlands (Technical University of Eindhoven, TU/e), Poland (Wrocław University of Economics and Business, UEW), United Kingdom (University of the West of England, UWE Bristol) and Germany (HFT Stuttgart)—see Table 1, which provides basic information on each case study, with facts about the university, as well as the origin and special characteristics of each UCLL.

Originally, these cases were in a group of 36 cases produced for the entire SCALINGS project, following a shared protocol with the aim of understanding diverse forms of situated co-creation. The case studies were conducted in 2018–2019 and drew upon various materials such as semi-structured interviews with a wide range of stakeholders (researchers, students, operations staff and administrative personnel), as well as desk research and participatory observation in various events connected to the cases (see Table 3 in appendix). Since our aim is to investigate the UCLL phenomenon across a set of different cases, in order to unpack the many aims and forms UCLLs may have, we have focused on the comparisons between the cases, rather than describing each case in its own context, just as we have been forced to leave out a wealth of interesting detail. Furthermore, as the cases continue to develop since we ended our data collection, our case studies necessarily present instances of them as they were performing during the time we studied them.

Our analysis for this article took place in two separate phases. First, we identified a set of themes and asked the authors of the five cases to use these themes as a structure for describing the particularities of their case (that is, the origin of the living lab, the main idea, how the campus is mobilized for this, etc.; see Table 2). We developed the themes based on our study of the literature referred to above, which informed us about different core characteristics of living labs we could focus on to unpack their differences. The development of themes was also based on preliminary observations from our cases, which in an iterative process with the literature review also informed us about what aspects of living labs that were relevant to investigate in the context of this paper. Secondly, we conducted an interpretative analysis by comparing these themed descriptions across the five cases. This analysis process resembled an 'immersion/crystallization' (Borkan, 2022) process, characterised by a "process wherein researchers immerse themselves in the data they've collected" and a process of reflection "on the analysis experience and attempt[ing] to identify and articulate patterns or themes noticed during the immersion process." (Borkan, 2022: 787). The author group thus first spent time delving into the data by producing the case descriptions of their own cases and then reading the other case descriptions multiple times. This was followed by an analysis workshop, where emerging themes or dimensions of UCLL's were developed from these case descriptions and which were refined in multiple iterations in the group. The comparison thus resulted in *the identification of five analytical dimensions* that structure our empirical analysis in the next section.

Table 1. Basic information on each case study, i.e., facts about the university, origin and special characteristics of each UCLL.

	DTU	TU/e	UWE Bristol	HFT Stuttgart	UEW
History and characteristics of university	Founded in 1829 as a polytechnic and became a self-governing institution in 2001, with ownership of buildings and its own utility supply. Campus operations staff are very innovative.	Founded in 1956 by industry, government and academia. Has close ties to high-tech companies and e.g., Philips, which has its main seat in Eindhoven. Campus is integrated in the city.	Founded as a Technical College in 1595, but a public research university since 1992. UWE Bristol values collaboration with their community, industry and doing applied research.	Founded in 1832 as a winter school for craftsmen, now an inter-disciplinary modern University of Applied Sciences in e.g., architecture, civil engineering and physics.	Founded in 1950, with a focus on training in economics and management sciences. UEW's strategy emphasizes sustainable development and social and ethical responsibility.
UCLL origin	The 'DTU Smart Campus' project was initiated in 2015 by DTU's Office for Innovation & Sector Development (OIS) and Campus Service (CAS), mainly to support student innovation.	University policy to develop living labs in 2008. In 2009 the Intelligent Lighting Institute was established in the Atlas building. In 2019 the Atlas Living Lab was opened, one of 14 official research facilities.	The living lab was originally built in an ad-hoc manner in the mid-2010s by a senior researcher inside Bristol Robotics Lab to test assistive robots and monitoring systems together with older people.	The EnSign Living Lab was established in 2015 to enable a climate-neutral campus by 2030. It is one of 14 living labs funded by the State of Baden-Württemberg (€18 m).	In 2017 Green Team was established as a bottom-up grassroots initiative by researchers to support the sustainability agenda in Poland. Aim for an innovative "green campus."
UCLL characteristics	Entire campus infrastructure is test platform. Students, start-ups and staff can test concepts in real life, and set up prototypes, mock-ups or sensors in streets, in buildings or in the supply infrastructure, or they can be given access to consumption data from the supply system. Plans to test autonomous buses in the streets of Campus.	Lighting and indoor climate in Atlas building is intelligent. Students and staff can innovate measurement technology and enquire into the effect of lighting systems on issues such as winter depression or well-being. The latter is compared before and after the move to Atlas. Other buildings/streets on TU/e also test light + PV systems.	The Anchor Care Homes Assisted Living Studio resembles an apartment home. It has an open-plan living, dining and kitchen area, as well as a bathroom and a bedroom. It is instrumented with a network of wireless sensors linked to a smart home-controller hub, cameras and the university's internet connection.	The aim of Ensign was focused on developing a new sanitation refurbishment pathway for public estates and to scale it up to the city. It also aims to foster "science for sustainability" and interdisciplinarity. The LL allowed the testing of technologies developed in a master project: the ecoGIS app (improve environmental facility management).	UEW has committed itself to switch to green energy on campus by 2030. It has reduced energy consumption of heating/cooling and lighting through e.g. new windows and insulation, LED technologies, new thermostats and selective waste management. Also PV on roofs, aim for ground heat pumps and water-saving installations.

Table 2. Initial themes to be described for each case

Initial themes used to describe cases
1. *Genesis: What made the living lab(s) happen—what key actors and structures aligned to make it come into being?*
2. *What is the core idea, principle, goal or value creation of the living lab projects, and according to whom?*
3. *In what concrete ways is the university campus mobilized in order to reach these goals?*
- *What technologies and infrastructure are available for experimentation? (Fx data, energy, streets?).*
- *What do the living lab activities look like?*
- *What are the challenges experienced in going from idea to practice?*
4. *Is the living lab "open" or "closed"?*
- *Who is "the user"? How do these take part?*
- *What are the "boundaries" (e.g., is it a "room" on campus, a building, an open street, an innovation space etc.)?*
- *What makes the activities "living lab activities" and not e.g. test beds?*
5. *What does it mean for the shaping and form of these living lab activities that they are taking place on (this specific) university campus? Is the campus setting an advantage for co-creation and the living lab activities and if so, how?*
6. *Conversely, in what ways are the living lab(s) an advantage for the university in terms of a) its core activities (teaching, research, technology transfer) and b) its self-identity?*

Five dimensions of university campus living labs

Five analytical dimensions emerged inductively from our analysis of the case studies. These are dimensions that they particularly differ on, for instance, in respect of how the UCLL was initiated or how it caters to industry relations, thus illustrating the breadth and variability of the UCLL phenomenon.

The five dimensions are concerned with:
1. Initiative and organizational arrangement of the Living Labs (*Organizational Anchoring*)
2. Living Labs as a mediator for industry collaboration (*Industry Collaboration*)
3. Encouraging students to support the university's sustainability agenda (*Sustainability and Student Involvement*)
4. Integration of the Living Lab's experimental ethos into the university (*Experimental Ethos*)
5. Living Labs as providers of visibility and identity formation (*Visibility, Self-identity and Communication*).

Organisational Anchoring

Our first axis of analysis focuses on how the living labs have emerged, and how they are anchored in the university and are funded and "kept alive." Our cases demonstrate how the initiation and place of each living lab in the different university organisations varies significantly. Firstly, the cases differ in terms of who or where in the organisation the initiative came from. For instance, in the Polish case (UEW), the living lab activities were started as a bottom-up initiative in 2017 by 'the Green Team'—a group of academics devoted to sustainability and co-creation. Initially, the team had no separate budget or formal organisation, but spent time describing the movements' goals and tasks and recruiting supporters. In 2018, the University Rector signed the international "100% committed campaign" (The Climate Reality Project, 2021), which formalized the university's commitment to the sustainability agenda, and a separate budget of €10,000 was allocated for the Green Team. Subsequently, the teams' work brought EU funding for the renovation of campus buildings and the mobilization of, for example, the University Entrepreneurship Incubator InQube. In contrast to UEW, the University of Stuttgart's living lab, Ensign, was designed and driven top down, as it was initiated within a much larger regional framework: the State of Baden-Württemberg had invested €18 million in fostering real-world laboratories, of which half were associated with a university. A coterie of two to three professors were instrumental in developing EnSign, receiving support and

attention from top management, and fully-paid positions were allocated to support the project.

Secondly, the cases differ in how centralized or decentralized the UCLL activities are, both organisationally and geographically. Some universities have a centralised, coherent and strategic approach to the living lab which is anchored in a 'living lab team' and supported by the university's senior management, involving the entire campus area, or at least very public parts of it (e.g., Stuttgart, UEW). At UWE Bristol, on the other hand, the living lab initiative is more decentred and run by an independent researcher and department. They also vary in terms of their temporality. Sometimes the living labs have a permanent character, as seen in the cases of DTU and UWE Bristol, where the utility infrastructure (DTU) or a 'model apartment home' (UWE Bristol) is the permanent platform for multiple (sometimes minor) unconnected projects. In contrast, other UCLLs are temporary, as the Ensign project illustrates, where the transformation of campus is part of a project that received one-time funding.

In short, university campus living labs have very different beginnings and can be funded and anchored in their universities in multiple ways, varying from being driven by a volunteer bottom-up movement of researchers and financed through e.g., the EU to being born out of top-down state funding and framing.

Industry Collaboration

As indicated in Table 1, the universities' collaboration with industry (e.g., TU/e's history with Philips) and other external private partners (e.g., Anchor Care Home Charity's support of UWE Bristol) is a core driver for the development of some UCLLs. For Bristol Robotics Laboratory (BRL) researchers, the purpose of the lab is to bring together different forms of expertise to co-create pragmatic robotics solutions and reduce the time to market, and it is co-funded by the private Anchor Care Home Charity. Located in an old industry building on campus, the lab materializes long-term collaborations between the university and the private sector in and around Bristol. UK research councils and Horizon 2020 robotics projects have also contributed to the continued use and further investment in the built architecture of the lab. In

this sense, the living lab is a means by which to sustain collaborative relations over and throughout multiple projects. At UWE Bristol (and several other cases), the lab is also a means to convene networking and funding as they are in situ, durable manifestations of successful collaborations with external actors, and they give visibility to the research groups affiliated with them (Michalec et al., 2021).

The case of TU/e similarly demonstrates entwining with external private partners, in this case well-established industries in the southeast Netherlands. TU/e was established sixty years ago at the initiative of, among others Philips, a leading producer of lighting solutions. As one of the interviewees indicated, TU/e has a self-identity of being "no. 1" in Europe in terms of collaborating with the industry. Philips play a major role in Eindhoven, having driven the development of the university, as well as several public services such as shops, housing development and sports clubs. The majority of living lab activities at TU/e are about developing lighting technologies for improved human health—for instance, by focusing on developing lighting systems that reduce winter depression (seasonal affective disorder).

In comparison, living lab activities at DTU do not cater only to one specific industry, but have an entrepreneurial "start-up focus". The city of Lyngby does not have a history of being an industrial hub as Eindhoven does, and the start-up culture at DTU was emphasized by an interviewee in the Office for Innovation and Sector Development (OIS), who finds that students idealize "the entrepreneur as a rock star" (Interview). More than TU/e and UWE Bristol, the DTU Living Lab speaks to SMEs in the region and was developed as a means to cater for the student start-up environment at DTU.

Thus, to sum up, the living labs seem to be supporting technology transfers and mediating industry–university relations, but with a varying focus. Whereas TU/e and UWE Bristol have living labs that are oriented toward long-term industry and private-sector collaboration, the DTU living lab is oriented towards SMEs and student entrepreneurship.

Sustainability and Student Involvement

With the exception of UWE Bristol, our living lab cases also contain a focus on environmental sustainability. This means both supporting sustainability science by offering applied teaching and research opportunities, but also a policy of 'practicing what we preach', for instance, by lowering the energy consumption of their own university buildings. However, the cases differ in the role students play in the UCLLs: that is, whether living lab activities support *student innovation and entrepreneurship*, or whether the students are *social movement activists* who help universities to '*be* the sustainable change' by publicly demonstrating how sustainable change in all its socio-technical complexity can be done (see also Trencher et al., 2015).

For DTU, the main reason for making the energy and data infrastructure of the campus buildings available for experimentation was initially to support student innovation and offer students (and staff) the ability to test their concepts in real life by providing access to money (approximately €650) to purchase the equipment necessary for experimentation. This goal was combined with Campus Service's (CAS) focus on greening campus operations. The CAS manager, for instance, considered devising a competition for students—the student who created the biggest energy saving in their department would win a mountain bike or something similar. For UEW, student entrepreneurship also motivated some experimental activities, as when a student project used data from the integration of PV on campus roofs in computer simulation games. In this way, students have been cast as entrepreneurs.

However, the students also have a different role. In the case of UEW, the primary function of the living lab was not sustainable science or applied teaching opportunities, but to allow the university to *be* the motor of change. For cases such as UEW and Stuttgart, the students are seen as change agents and social movement activists whose involvement in the living lab activities of their university campus shape their attitudes towards having more responsibility. As the Vice Rector of UEW states, "our activities also involve creating the right attitudes among students, we shape youth,

future elites… Who, if not a university, should also promote these attitudes?" (Interview)

In summary, UCLLs typically serve two agendas in involving students: first, providing applied teaching opportunities to innovative, entrepreneurial students; and secondly, shaping the 'sustainability leaders of tomorrow' (Verhoef and Bossert 2019) and involving students in 'practicing what we preach' as social movement activists.

Experimental Ethos

A fourth dimension relates to the inherent tension between "controlled experimentation vs. messy co-creation" in living labs (Engels et al., 2019: 8). Among the UCLL cases there is a difference between living labs that conduct experimentation in a "closed, controlled, laboratory" that sits apart from the rest of the university and living labs that are integrated with the entire university organization. This tension manifests itself in a triple comparison of UWE Bristol, TU/e and DTU. In UWE Bristol, the living lab is a confined (simulated) apartment situated within the Bristol Robotics Lab. Although the living lab is open to visitors, by default people on campus (staff, students, external collaborators) are *not* part of the lab: They perform their daily activities in support of the university's functions, unaffected by the presence of the living lab. The lab is detached from the general life and function of the institution. It serves particular and delineated purposes like other labs in the university and could have been placed elsewhere than on campus and in the university organization.

In comparison, the corresponding lab's placement *on* and *in* DTU is a central part of the design of the 'DTU Smart Campus' living lab, where its primary goal is to feed into the teaching mission, start-up culture and tech-transfer activities. The DTU Smart Campus project was developed in synergy with an ambitious renovation plan for DTU's campus, the aim being an architecture that nurtures the meeting of minds and co-creation and which ensured that DTU would be able to 'use its own supply infrastructure to an even greater extent for experimental teaching and research'"(Transforming DTU, 2021).

The DTU living lab could potentially become deeply integrated within the university organiza-

tion and require a more fundamental change to university practices, relations and identity, so that the entire university becomes the living lab. Such a living lab is perhaps as much an "organisational experiment" (Kleinman et al., 2018: 553) as it is a technical facility. It demands that the entire university organisation is open to novel ways of doing teaching, learning, managing operations, administrating and so on. For those universities that use their own land, buildings, streets, wires and tubes for experimentation, the physical university can also be seen as an integrated practice, rather than simply a container for research, education and innovation activities.

At TU/e, on the other hand, the living labs are formally registered as one of the fourteen laboratories on campus, and the expectations are that they resemble more traditional, controlled laboratories. TU/e has a strong focus on the method of building a living lab, emphasising seeking consent and ethical issues related to the actors involved (staff, students), such as their possibilities to opt out and their having control over the collection of data. Thus, in contrast to the Assisted Care Home Studio at UWE Bristol and the living labs at TU/e, which are both controlled—either in terms of seclusion (UWE Bristol) or methodological rigour (TU/e)—the living lab at DTU is less controlled and in a sense ubiquitous; the entire energy infrastructure, buildings and streets are always open as an experimental setting. It is not gated like the UWE Bristol living lab, and everyone in the university organisation, as well as external collaborators, are invited to utilise the infrastructure as a test bed. Moreover, staff, students and guests are constant sources of data, without necessarily knowing they are being involved in tests or that the data they produce is being used. These data could consist of, for instance, consumption data from the use of electricity, water, heating, lighting, or other digital data giving information on movement patterns, either of pedestrians or users of autonomous buses.

In summary, living labs can range from resembling more traditional, closed and controlled laboratories that have no influence on the 'normal' practices, missions and identity of the university, or they can be more widely integrated into the university, requiring more fundamental partici-

pation and a willingness to change on the part of staff and visitors.

Visibility, Self-Identity and Communication

The final dimension concerns how UCLLs make research and innovation processes visible and engage the public in the inner workings of the university. It teases out the cases' differences in terms of the porosity of the boundary between the university and society, between 'inside' and 'outside'. The living labs' activities on campus potentially open up the universities to society and raise their public profiles, as well as supporting an identity as pioneering, future-oriented, innovative and co-creative universities. Their openness makes UCLLs tools for communicating scientific processes and engaging people in science, but also for branding the university as (socially) sustainable and responsible (Horst et al., 2017).

Notably, the self-image, identity and visibility universities can gain from living lab activities seem to be key factors for creating them. For UEW, for instance, the activities of the Green Team are used by senior management to create an image of a university that is open to the non-academic environment and one which values social responsibility. The HTF Stuttgart Ensign project's interviewees mention how the living lab fosters a sense of collective identity and how members of the lab were reportedly seen as the 'cool ones' on campus, those who carried the torch for a 'pioneering institution' and 'innovative university' and who are equipped with 'soft skills' and the ability to engage in co-creative activities. In the same vein, the UWE Bristol Lab values co-creating with users and self-identifies as a transdisciplinary, 'multi-professor' lab, showing the public how roboticists at BRL are concerned with social issues such as health and well-being. Equally, TU/e researchers emphasize the visibility that the living labs give the research groups that are affiliated to them. Finally, DTU's Smart Campus stresses that the living lab's activities conducted in the campus's public areas display the university's research and experimentation to a wider audience.

The university campus living labs thus seem to be connected to ideas about *identity*, *visibility*, *branding, openness, public engagement* and *responsibility*. Moreover, whereas most science

communication is about communicating a scientific *result* (to brand universities), living labs are also about communicating the ongoing research *process* to society. As a result, they invite 'outsiders' to witness, and potentially shape, the messy process of knowledge production, rather than seeing only the successful, polished results.

However, the society–university boundary has different degrees of porosity across each case. As already mentioned, the UWE Bristol Lab is visible to all visitors to the Bristol Robotics Laboratory and is often the first stop on tours given to guests at BRL, itself a major destination for high-profile campus visits. However, the lab lies in a closed-off building on campus, access to it is restricted, and all visits have to be coordinated, while visitors are not allowed to take photographs, among other things due to IPR concerns. The lab carefully curates a specific image of what goes on there.

The DTU Smart Campus living lab also stresses demonstrating its research. As stated in an internal memo from CAS and OIS to the top management in 2018, "Smart Campus can become another 'lighthouse project' where DTU's campus… is included as one large test facility. The big vision may be that when you walk around campus you meet robots, see flying drones, and in general meet DTU's research in 'real life'". However, contrary to the UWE Bristol case, the DTU living lab is 'always open', and the performances relating to it are unedited, uncontrolled and uncodified. Visitors can come anytime and watch experiments that are succeeding as well as failing—such as when students are in the process of testing a rocket or smart rubbish sensors in the street. The DTU living lab lets in the outside world to take part in the research process, whereas in the UWE Bristol lab the communication resembles more classical branding exercises. The invitation is, strictly speaking, less open, and the boundary less porous.

To recapitulate, the UCLLs are important branding tools for universities and for opening up to society, but with different degrees of porosity. This difference can be illustrated by Erving Goffman's (1959) concept of front-stage behaviour, which is controlled according to how you want others to perceive you, and back-stage behaviour, where you let your guard down (Goffman, 1959: 70). In this perspective, the BRL Lab has a frontstage form of openness, while DTU's vision might let the visitor see more of the backstage.

The multiple modalities and dimensions of the UCLL phenomenon

Our paper has unpacked five dimensions on which our UCLL cases differ markedly: *Organisational Anchoring*, *Industry Collaboration*, *Sustainability and Student Involvement*, *Experimental Ethos* and *Visibility, Self-identity and Communication*. In unpacking the UCLL phenomenon by describing the many purposes, logics and forms that living labs can have on university campuses, we depart from the majority of studies that focus on UCLLs as instruments for the green transition; instead we study them in their own terms and as a phenomenon that has other implications, perhaps even for how the universities themselves develop. Some of our findings are aligned with those of other recent studies on living labs on university campuses, which have, for instance, noted how UCLLs are an opportunity to educate and mobilize students as "potential future sustainability leaders" (Verhoef and Bossert 2019: 11) or how UCLLs have additional benefits beyond providing applied research and teaching opportunities, such as "additional funding, real-life data, results display and exposure" (Verhoef and Bossert, 2019: 43; Evans et al., 2015). Moreover, the empirically rich accounts of how living lab activities are entangled in very different university organizations, strategies and practices lend support to arguments that emphasise how universities around the world are far from homogenous institutions (Horst and Irwin, 2018).

However, our analysis is also unique. We have contributed rich empirical accounts of the multiple modalities of UCLLs, underlining the wide range of ways this phenomenon can be played out, and ways in which the UCLL phenomenon is interesting beyond its role in promoting sustainability. The five dimensions show that UCLLs mobilise other agendas in various ways. For instance: to change the world, to facilitate user-oriented innovation and technology transfer, to

improve higher education and student innovation, to conduct human health and robotics research, to heighten the universities' public visibility and funding opportunities, and so on. In this way, for instance, we engage with and unpack Evans' et al.'s (2015: 4) observation that living lab projects have wider implications and should not only be seen as "disjointed sustainability initiative[s] but … part of a wider drive towards applied learning and employability skills". As we demonstrate, the UCLLs can indeed have an educational (or technology transfer, branding, science communication etc.) logic that precedes, or is entangled with, their function as 'sustainability initiatives'. Thus our analysis shows how UCLLs are co-constituted and co-shaped by several agendas simultaneously. In DTU, for instance, the 'student innovation agenda' was the most dominant starting point for the living lab, but it could not be disentangled from the agenda of 'the greening of campus operations'. In UEW, the sustainability agenda was broader than 'a green campus' and more focused on 'changing the world' through bottom-up activism. This agenda was merged with an institutional desire to showcase to the 'outside' that the university was open to collaboration with the non-academic actors and valued social as well as environmental responsibility. In TU/e, the living labs were clearly tied to industry relations, but also shaped by a strong institutionalised commitment to methodological rigour and ethics, among other things. In HTF Stuttgart, the ambitions for a sanitation refurbishment pathway were not clearly dissociable from ambitions to be a future-oriented, pioneering institution that catered for 'soft co-creative skills'. As for the BRL Bristol's roboticists, they were not only concerned to bring technology closer to market, but also saw their living lab as equally an opportunity to acquire funding and as an expression of concerns with social issues such as health and well-being.

Our analysis of the dimensions of 'visibility, self-identity and communication' and 'experimental ethos' perhaps most clearly exemplify what we add to existing literature on UCLLs. First, concerning the dimension of 'visibility and communication', which focuses on university-society boundaries, we suspect that the role of UCLLs as science communication and branding

tools, and as anchors for project proposals and funding, may play a more important role for universities than the 'university living lab' literature has so far discussed, with its dominant attention to sustainability. While e.g. Trencher et al (2014: 154) emphasise that living labs are one of several 'research & social engagement paradigms' that are employed by universities in the co-creation for sustainability mission, alongside, for example, 'technology transfer', 'transdisciplinarity', 'cooperative extension systems', etc., our analysis show that their role for universities extends beyond the co-creation for sustainability framework.

We also believe that our analysis on how UCLLs 'open up' to society and collaborate with external actors contributes an epistemic politics that extends Evans' et al.'s (2015: 5) remark on "the ability of the living lab framework to [merely] facilitate engagement with non-academic stakeholders". Insights from STS are invaluable in revealing these politics: UCLLs, as well as living labs in general, encompass a wide range of knowledges and epistemic cultures (Knorr Cetina, 1999) – e.g. both engineering and 'softer skills'. Moreover, these are sites at which different forms of knowledge and expertise has different legitimacy (Collins and Evans, 2007; Callon et al., 2009), sites at which some 'lay-knowledges' may be considered inferior to expert knowledge (Wynne, 1992), notably expert knowledge that is dominated by 'matters of fact' (Latour, 2004). For UCLLs that engage with non-academic actors and encompass both natural and social sciences, reflecting on the a priori skewed power relation between these different knowledge cultures, often revealed through which methods are selected and who does the selecting, is important to remember.

A common feature of the UCLLs we assessed is the diversity of modes but also ideas, interests and driving imaginaries not only between each of the sites, but within each living lab. As we wrote above, the UCLL's were co-constituted by several agendas simultaneously. Yet a curious aspect of this diversity is that difference often goes unacknowledged. Take sustainability, itself a usefully ambiguous imaginary that can, for instance, at once compel competing visions of progress, from eco-modernist technological innovation to communitarian re-imaginations of public services

(Beck et al., 2021). Experiments at UCLLs that have sought to transition the status quo towards these visions have often been marked by contention and even outright conflict over which and whose version of sustainability should win out (Torrens et al., 2019; Yuana et al., 2020). The danger here then is that despite widespread commitments to openness, UCLLs that ignore difference risk back-grounding the politics and power relations of knowledge production and ultimately foreclosing mechanisms that might allow certain participants negotiate or actively shape competing agendas through translation for instance (Callon, 1986) or democratic processes of steering the direction of innovation (Stirling, 2009).

Secondly, our discussion of the UCLL dimension of 'experimental ethos' provides new perspectives with our focus on how 'ubiquitous' living labs may become integrated into the university campus and –organisation, requiring a more substantial willingness to change on the part of staff and visitors compared to more traditional, closed and controlled laboratories. The university's physical campus as a living lab may become an 'integrated practice', rather than being just a container for research, education and innovation activities. How are established power relations between various epistemic cultures and university hierarchies reconfigured in these processes? Issues may also pertain to, for instance, if some of the living lab data is collected by a private company. This was for instance the case for the UCLL at DTU and it created tensions, because it mattered for the type of projects that could be done. Without compar-ison, imagining a situation where the interests of e.g. private companies are literally built into the physical campus infrastructure and UCLL, it would be relevant to consider what that may mean for the development of research and teaching.

Hence, these points lead us to two aspects of the UCLL phenomenon that we find very inter-esting, and which we provide tentative observa-tions on, before we conclude our paper, hoping that they can inspire future research. These relate to, first, co-creation dynamics on university campuses and, second, what role UCLL's may play for the ongoing evolution of university practices and organisation and relations with wider society.

Unpacking situated living lab co-creation on university campuses

Co-creation is very often mentioned as one of the main *activities* of living labs alongside, e.g., 'test-ing' and 'validation' (Hossain et al., 2019). Yet, sev-eral things about co-creation in living labs remain taken for granted and understudied in much living lab literature (see e.g., Hossain et al., 2019). Here, we specifically discuss aspects of inclusiveness and situatedness of living lab co-creation, which provides some points for reflection about knowl-edge politics and co-creation in general, but also about specific aspects of UCLL co-creation that is worth enquiring further into, in our view.

As we wrote in the introduction, co-crea-tion is an umbrella term that generally denotes the coming together of different actors in a joint activity that leads to a mutually beneficial outcome. Van Geenhuizen (2018: 1283) empha-sises co-creation as the learning process in living labs, which "ideally, encompasses joint problem-definition and problem-solving using improvi-sation and experimentation – this in designing, implementation and testing of solutions in an iterative way". What the co-creation outcome can be in a living lab is extremely diverse, given the wide variety of ways living labs are employed, ranging from being tools for industry to co-create with the users to being governance instruments for cities. In the context of univer-sities, we also locate very different modes and outcomes of co-creation. While the co-production of knowledge in terms of sustainability science and interdisciplinarity was a central aim for the Stuttgart UCLL case (and e.g., Evans et al., 2015), the examples in the present article also include the co-design (Sanders and Stappers, 2008) of material stuff, and broader social visions and their real-life demonstration. For instance, we can see co-creation reflected in the "participative methods and user-centered design" in the UWE Bristol case, where assistive robot technologies are developed together with the elderly, or as the co-creation of a demo society in the case of UEW.

In line with our discussion in the last section about the importance of reflecting on knowledge politics, power relations and inclusiveness, we think it is crucial to consider collaboration dynamics in living labs in terms of who is involved,

how, in what actor role and with what agency. This has been explored by e.g., Hakkarainen and Hyysalo (2013, 2016), Hyysalo and Hakkarainen (2014), Leminen (2013) and Nyström et al. (2014), but deserves more research focus and STS attention, in our opinion.

In most of our UCLL cases, the students are involved in living labs, but in very different roles. The literature on campus living labs for sustainability often mentions students as powerful change agents. However, the ethical review board at TU/e is attentive to potential issues such as the university hierarchy and power relations between students (who may be eager to get their degrees) and their teachers (who may want quick results), which could make it difficult for vulnerable students to opt out of a living lab setting, and TU/e also actively seeks consent from students and other actors involved in living lab co-creation. Conversely, at DTU, although some students knowingly engage in the living lab and are acknowledged as competent innovators, most students (and staff) are automatically and unknowingly involved in the boundless living lab, for instance, by producing consumption data (see also Marres and Stark, 2020). Therefore, although we previously suggested that the TU/e case resembled a controlled lab and that DTU allowed messy co-creation, it may be the other way around: mutually beneficial co-creation implies that actors know they are participating, are able to "speak back" (Engels et al. 2019: 8) and can negotiate their own role and interests in the design process (Elkjær et al., 2021). Otherwise, they are enrolled as passive objects following a more standard testing or laboratory-like paradigm, which is the case for DTU when, for example, energy consumption data from campus is used. Thus, although TU/e has a more controlled lab approach, TU/e is also more reflexive about methods and the stakes involved for all actors and thus more conscious that co-creation is happening.

Situatedness of co-creation

Finally, studying living lab co-creation at UCLL's provide a good opportunity to discuss *situatedness* of co-creation, and how co-creation processes are contingent upon 'place' and the socio-material space they develop in. Indeed, STS emphasise that

knowledge production and innovation is always situated in specific cultural, organizational, socio-political and regulatory settings (Haraway, 1988; Jasanoff, 2005). Although the literature on university living labs is concerned with 'locally situated knowledge' and 'place-based needs' (König and Evans, 2013; Trencher et al., 2014), little attention is paid to whether the living lab is placed on campus or in the city, and what that means for co-creation processes and outcomes. However, we could ask, for instance, whether the university campus space supports freer, more innovative or responsible living lab experimentation and co-creation compared to other, e.g., urban, spaces[3]. In this context – although all UCLL configurations lead to unique modes of co-creation – the institutional capacity and history of universities is relevant to highlight as factors that may shape UCLL's in certain ways compared to other urban labs. An exploration of the role of the university as a supposedly 'interest free' living lab space, for instance, would be interesting to do. What has previously been discussed in the literature is whether UCLLs are a particularly 'neutral' anchor for responsible innovation. König and Evans (2013: 1) argue that, because of "their considerable resources and durability, universities have a pivotal role to play in addressing sustainable development." Similarly, Verhoef and Bossert (2019: 11) emphasise that universities are "trustworthy institutions" that can create long-term strategies, as they are not "connected to election periods or annual sales." In comparison to this, our cases might underline that universities are indeed bound by interests that shape those of the living labs', as our cases show (Anchor Care Home Charity, Philips, etc.). Nonetheless, although our empirical material does not merit an extended discussion of universities as a 'neutral anchor', it does point to socio-material aspects of the 'exceptional' university campus space that may shape UCLLs, making them differ from other types of living labs in distinct ways.

In arguing that university campuses are 'special' compared to other urban living lab spaces, we could also draw on Laurent et al. (2021). They point to how islands have become popular living lab sites as they are places of both exception and representativeness and these characteristics may also apply to university campuses. Although it is debatable whether university campuses can

be considered 'islands' in the surrounding city, one could argue that a university is a 'place of exception' in many senses. They are sometimes, for instance, referred to as a 'mini city in the city', and they do share traits with other regulatory sandboxes; they often have ownership over their own infrastructure and buildings, and are thus in a sense able to 'lift restrictions' and enable unique and organizationally facilitated co-creation between operations staff, students, researchers, the municipality and industry. What the universities' institutionally captured collaboration and self-ownership of the experimentation platform means for innovative processes would be interesting to enquire further into, as our cases tentatively suggests that these features makes UCLLs very flexible living labs that are conducive to early concept development[4]. Our cases also suggest that it is easier to recruit test people in UCLL's (staff and students and allegedly 'pro' technology), and that it is an advantage for researchers to have the test site close by and "on their doorstep" (Evans, 2015: 3).

Integration of UCLLs in university practices

These perspectives brings us to questions relating to how living labs at campus are co-developing with the societal role and day-to-day practices of universities. Living labs on university campuses can be interpreted as new ways of continuing university–industry–society relations and 'hybrid experiments' (Kleinman et al., 2018) and as instruments in the emerging mission of 'co-creation for sustainability' (Trencher et al., 2014). As others have observed, UCLLs synthesise universities' core business of research, teaching and social responsibility and provide frameworks for the co-production of knowledge (Evans et al., 2015: 6). Our cases suggest that living labs are an easy way for industries to collaborate with universities via small-scale projects: companies have easier access to students, and living labs give students access to real-life problems to solve, such as lowering energy use in buildings. The UCLLs are boundary objects (Star, 2010) that organise and mediate new relations between companies, students, researchers, operations staff, neighbours, municipality or city officials and university management. In our view, however, what seems particularly interest-

ing about these new UCLLs is that they have the potential to reconfigure these relations—and the university's identity, role and practices—on a more substantial level, because of their potentially substantial integration into the 'everyday life' of the university. The socio-material integration in the setting of the university campus is key to this: the university as an organisation not only facilitates co-creation in the region, but might *itself* become the experiment.

Our discussion of the experimental ethos and visibility dimensions bear witness to this, suggesting that having ubiquitous or pervasive living labs on campus may require more fundamental changes to the myriad of day-to-day practices carried out at a university, configure new roles and relations between staff and students, and open-up its hitherto closed areas of backstage experimentation, thus revealing processes and unpolished results. As opposed to other organisational features of mediation (science shops, tech-transfer offices, public science communication events or industry-oriented projects), these UCLLs are perhaps more deeply entangled with the everyday socio-material practices performed at universities. As noted in König and Evans (2013), deeply integrating operational and academic sustainability requires an institutional culture change. Thus, UCLLs potentially reconfigure the university from the inside, materially and through knowledge production, and these new relations may foster and enable new identities, narratives and public images of the university as something that is sustainable, participatory and co-creative. However, as noted before, important question concern whose interests are translated in living labs and, for instance, what kind of knowledge and objects are the outcome of new actor configurations in UCLLs, and what it means for teaching practices. UCLLs that do not acknowledge the politics and power constituted by methodology and privileged access risk merely conforming to incumbent interests rather than genuinely transforming transdisciplinary relations and practices of universities, science, industry and society that might yield more sustainable as well as more equitable and just ways of doing and being in the world (Smith and Raven, 2012).

The UCLLs also beg a discussion of their role as science communication tools, beyond their role in mediating innovative relations and co-creation, as we also pointed out earlier. An important feature of living labs is their role as instruments to showcase and *demonstrate* to a public audience certain desirable socio-technical futures and research agendas (Engels et al., 2019; Ryghaug and Skjølsvold, 2021). In this sense, UCLLs also seem to reflect some of the responsibility and openness heritage from the science shops that arose in the 1970s and 1980s to allow the public free access to scientific knowledge as a response to concerns that research had become elitist and that researchers in their ivory tower (Shapin, 2012) had lost touch with social problems (Dickson, 1984; Irwin, 1995). Thus, the UCLLs are perhaps replacing the crumbling ivory tower figure with the public image of the university as a sandbox in which everyone is invited to play.

Conclusions

To conclude, in this exploratory study, we have described the UCLL phenomenon through five analytical dimensions, unpacking the breadth and variability in the UCLL phenomenon, and showing the multiple purposes UCLLs have beyond being drivers of sustainability. Instead, UCLL's promote student innovation and cater for industry relations, science communication and public visibility, among many other things. We have furthermore considered how these dimensions illuminate the many forms of co-creation that the UCLL space caters to, and we have identified several aspects around living lab co-creation as well as UCLL co-creation in particular, that merit further attention. Moreover, we have started an exploration of the UCLLs' entanglement with their host universities, although it remains an open empirical question as to whether UCLLs will substantially change universities.

This study nuances our understanding of the UCLL as an empirical phenomenon, but also contributes to broader STS debates about co-creation (e.g., Pfotenhauer et al., 2021; Müller et al., 2021), public engagement with science and science communication (e.g., Horst et al., 2017), as

well as knowledge politics, transdisciplinarity and the relationship between science, university and society (e.g. Gibbons et al., 1994; Nowotny et al., 2001; Tuunainen and Kantasalmi, 2017). Our study also taps into important issues concerning the notion of test beds and living labs, such as those raised by Engels et al. regarding the co-production of social and technical orders, democratic accountability and regulatory control, and "the responsible use of test beds as vehicles for innovation" (Engels et al., 2019: 2). Marres and Stark similarly draw our attention to the current test bed hype, calling for a new sociology of testing and arguing that "something more radical is happening … than simply attempts to move tests from the laboratory into social settings" (Marres and Stark, 2020: 423), in that engineering "tests the very fabric of the social" (Marres and Stark, 2020: 425), and conflate engineering tests and social experimentation. In this paper, we have touched upon such issues in our discussion of the ubiquitous DTU Smart Campus living lab, which potentially changes a myriad of day-to-day practices at the university and becomes just as much an organisational experiment as a technical facility. What is more, such pervasive living lab settings where "anything can be a test situation" (Marres and Stark, 2020: 434) leave little space to 'opt out of the experiment', posing important questions as to who participates and how, as well as who is able to initiate such tests (Marres and Stark, 2020: 434). What remains underexplored in STS studies of living labs and test beds, however, is what this radical – and sometimes infrastructurally configured and seamless (Marres and Stark, 2020) – mode of testing means if it is situated in a university campus, thus 'operating on', governing and modifying the social environment *here* and not the environment in other urban spaces. This paper takes the first steps toward addressing what happens when new, ubiquitous testing environments move into the very heart of universities – a crucial site for research and innovation in society – and what such reconfigured socio-material relationships mean for how universities and knowledge practices develop and for the co-production between the 'exceptional' university campus space and living lab configurations.

Indeed, ubiquitous test environments involving unknowing experimental subjects are not the only types of living labs on universities, and we have seen that several of the cases – and much of the living lab literature (Hossain et al., 2019) – focus on co-creation and on active participation. We have called for more STS attention to what co-creation could and should mean in the specific setting of UCLL's, and who participates and in what ways. What is important to note in this connection is that co-creation only fosters socially inclusive and responsible innovation if explicit efforts are made to include all relevant stakeholders in the process, be they university students, partners or otherwise (Müller et al., 2021) and on terms that are appropriate and equitable. Moreover, co-creation in UCLLs is not a substitute for democracy - if co-creation is to achieve its more radical participatory goals, it requires institutional and structural support (Smallman and O'Donovan, 2023). Pragmatically, this means that socially inclusive co-creation at UCLLs must be supported by institutional levers with which the power and politics of knowledge production within these spaces can be acknowledged and addressed. As we wrote earlier, a critical eye towards whose knowledge and interests are translated in UCLL's is thus needed. Indeed, as Turnhout et al. argue, knowledge co-production settings comes with unequal power relations, with 'elite actors' having more time, skills and resources available to "shape these processes to serve their interests" (Turnhout et al., 2020: 16). It remains to be seen whether universities or their industry partners are willing to cede decision making power and governance in ways that are enduring and reach beyond the spatially, temporally and institutionally boundaries of UCLLs. But without this, it is not clear how structural features of the wider world such as social inequality may be altered or reproduced.

As we have acknowledged earlier, some of our observations need further substantiation. What our unique comparative methodology gains in terms of breadth of understanding of the UCLL phenomenon, it lacks in terms of the depth of understanding of some of the dynamics we describe. We hope that future work can continue the exploration of what UCLLs are, what they mean for universities and society, and the threats they pose as well as the promises they hold for responsible research and innovation.

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Notes

1 Engels, Wentland and Pfotenhauer (2019) find that terms such as 'real-world laboratories,' 'test beds' and 'living labs' are often used interchangeably, both in literature and by actors engaged in such activities. Although a difference between the concepts of e.g. 'test beds' and 'living labs' can sometimes be located in the increased focus on 'co-creation with users' in living labs compared to e.g. test beds, as Schuurman et al. (2013) also note, the boundaries between living labs and other similar innovation approaches such as prototyping, field trials, test beds, societal pilots and market pilots is not clear cut and often fuzzy in practice. In this article we use the term 'living lab' for consistency.

2 However, since the Ensign project ended it has served as a platform for follow-up flagship projects to continue Living Lab activities on campus (e.g. iCity, M4Lab).

3 For an elaboration on the concept of spaces of innovation, see e.g. Clausen and Gunn (2015), Dorland et al. (2019).

4 This discussion is inspired by the webinar "Three perspectives on Living Labs and climate targets for 2030," at which the DTU Smart Campus case was discussed together with other Danish Living Lab cases, held May 20, 2020.

Appendix 1.

Table 3. Case study empirical material

DTU (DK)	11 interviews (campus service, OIS, researchers, LKT science city), participant observation, desk research
TU/e (NL)	9 interviews (campus service, teacher, researchers, data management, ethical review board), desk research
UEW (PL)	9 interviews (student, researcher, staff union, campus renovation, etc.), 2 workshops with stakeholders
UWE Bristol (UK)	11 interviews, extended site visits and participant observation and desk research
HFT Stuttgart (DE)	19 interviews (researchers, managers)