Leendert Verhoef and Michael Bossert

The University Campus as a Living Lab for Sustainability

A Practitioner's Guide and Handbook

**The University Campus
as a Living Lab
for Sustainability**
A Practitioner's Guide
and Handbook

Authors
Leendert Verhoef
Michael Bossert

**The University Campus
as a Living Lab
for Sustainability**
A Practitioner's Guide
and Handbook

Authors
Leendert Verhoef
Michael Bossert

TUDelft
Green Office

Hochschule
für Technik
Stuttgart
University of Applied Sciences

ISCN
International Sustainable Campus Network

Index

Preface

Universities are enhancing their contribution to a sustainable world by developing sustainable campuses and by stimulating implementation of scientific findings, among other things. However, for university managerial, strategic or support staff responsible for this transformation, there is no appropriate, available material on how to do this. Instead, an abundance of material is available on why it is important and there are several reports in scientific journals on the expertise behind that. This puts great pressure on those staff members, who have scarce time and money and need to reliably generate results but have to learn on the job or gather information through peers in oral or case study form.

The goal of this handbook is to help practitioners increase the speed of putting sustainability science and education into practice by maximizing the possibilities of campuses and to speed up sustainability in campuses by maximizing researcher and student input. The book builds on hands-on experience and analyzing operational practice in Living Labs on campuses and in the literature. It attempts to give guidelines as to:

- *__why we need to__ speed up innovation and sustainability implementation and why universities should lead the way and are positioned superbly for this role*
- *__what sustainability is__ (in a nutshell) and what Living Labs are*
- *__where to combine__ sustainability, Living Labs and university campuses into the approach of 'Campus as Living Lab'*
- *__how to start and run__ a Living Lab and run a process and stakeholder approach*
- *__when the vision__ of global sustainable campuses will come true.*

The booklet takes a pragmatic approach; therefore, we have limited references to those necessary and given a mix of theoretical and scientific papers, workshop reports, websites and more experience-based books to guide interested readers and practitioners. While writing the booklet, we have assumed that your university already has some sustainability program in place.

This booklet is the first version. The authors are fully aware of the wealth of experiences generated in universities around the world. Therefore, all remarks, comments and suggestions will be gathered through our website __www.campusaslivinglab.org__ and will be discussed and used by practitioners and co-writers.

As experience grows, we envision this handbook becoming part of the standard material for university sustainability coordinators around the world, staying up-to-date through their input and acknowledging the value of that co-creation process.

We hope that it helps university sustainability offices as well as all stakeholders involved in sustainability education, innovation and implementation.

The authors,
Leendert Verhoef and Michael Bossert

The Vision

Urgent challenges

With increasing population and growing economies, pressure on the Earth as a 'life supporting system' is increasing. The latest UN population projections[1] estimate that, by 2050, global population will increase to about 9 billion and about 11 billion by the year 2100. Keeping this in mind, if the world remains on a business as usual path, there will be widespread issues like food scarcity, lack of water and basic amenities – to name a few. These issues are clearly stipulated through the seventeen United Nations Sustainable Development Goals (UN SDGs)[2]. In conjunction with the commitment by the 21st UN Conference of Parties in the Paris Declaration[3], climate change limitation through CO_2 emission reduction has been declared vital for our human future. With fast-growing emissions, it calls for radical changes and new views and approaches.

The global challenges are very complex and may require rethinking and reorganizing our entire economic and resource management system. This is the arena of global thinking, international treaties and a strong realization that this is very urgent, as 2050 is around the corner if thinking in terms of these vast infrastructural changes. For instance: ending fossil fuel use or researching CO_2 storage solutions. It requires rethinking natural resource management systems, distribution systems, sector coupling, grocery production and city systems.

For many actors, such scales and terms are not practical. Each and every one faces challenges in their own environment and different scales: regional, urban, buildings and products. This may seem easier. But the large number of actors and disciplines which are involved in overcoming and facing legal, financial and other hurdles complicate challenges on this lower level as well. A serial ('slow') way of change will just not be fast enough. More and more stakeholders want to 'act here and now' to demonstrate solutions for those complex problems.

The seventeen United Nations Sustainable Development Goals, adopted in 2015. Goals are, amongst others, zero poverty, no hunger, good health and wellbeing, affordable and clean energy, climate action and industry, innovation and infrastructure. Each goal has specific targets to be achieved by 2030.
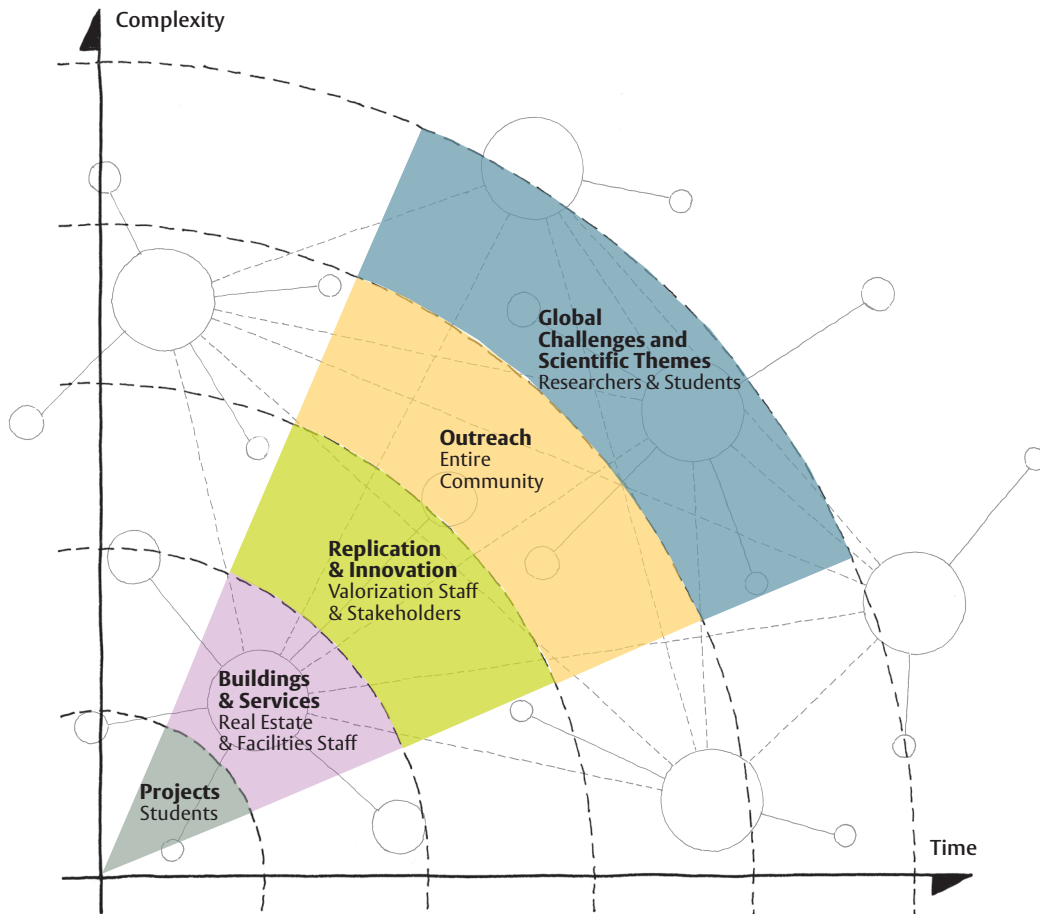
Universities are active on five scales of implementation: 1. small projects done by students, 2. medium scale of buildings by operations staff, 3. innovation and valorization with stakeholders, 4. outreach to the region by all and 5. global societal challenges by researchers. All implementation scales are to be addressed with UN SDGs in mind.
Each scale is complex for those stakeholders involved and is urgent in its own time scale.

Why universities should lead

The urgency of the UN global sustainability challenges to secure a clean, healthy, safe and prosperous world for everyone and the necessity to improve material, water, land and energy efficiency by several factors is clear. The complexity of these challenges calls for transdisciplinary, integral, innovative, systematic and user-centered approaches to enable a global sustainability transformation. The urgency calls for action on all scales: from fundamental science, student projects, field testing to full-scale rollout.

Higher education institutions and universities, in particular, have always kept adapting themselves to the basic needs of societies, in order to improve human living conditions. In fact, the long-term goal of university communities is not only the advancement of science just for science's sake. Rather, "advancing science, serving society"[4] is the ultimate goal. Universities seek to improve all aspects of life, which necessarily entails attention to the principal needs of societies (*Holdren, 2008*).

Universities as knowledge hubs and as part of complex city systems can work on various levels simultaneously:

- set an example together with their stakeholders in local and regional government (*Trencher and Bai, 2016; Leal Filho and Brändli, 2016 ; Verhoef et al., 2017*),

- mobilize transdisciplinary solutions, connect to industry (*Mowery, 2007; Watson-Capps and Cech, 2014*) and

- deliver students as potential future sustainable leaders to the world (*Daneri et al., 2015*).

Furthermore, universities have the unique chance to create long-term strategies and plans, as they are not connected to election periods or annual sales. Moreover, they are globally considered as trustworthy institutions, which proof knowledge by academic research.

Students as leaders of the future

Around the world and throughout history, students have been an important force for change in ethics, global inequality and in politics, among other things. In sustainability and the university's role in society, similar grassroots movement and student engagement has emerged also. In Western Europe, this has led, among other things, to the Green Office movement[5], where students challenge and demand their university to pay attention to sustainability in curricula and in practice. This continues in projects and thesis work in developing countries on water management, solar energy or agriculture. These pioneering students benefit from an investigative and innovative environment during their years of formal education. The less directly interested can benefit from embedding into a sustainable campus during their years of education as well.

The students should be taught to be proactive to sustainability challenges. When entering the professional world in a traditional corporate career, they can be under pressure to reduce idealism during their career. Traditionally, with increasing influence, reduced idealism and more realism is experienced. The graduates and leaders of the future should be empowered to remain ambitious and even increase their efforts and awareness with increasing influence.

Of course, many graduates choose to take their own path and start or join small societally conscious startups, with idealism to make the world a better place. The pathways to sustained global societal conscious leadership of current and future generations are many and hopeful.
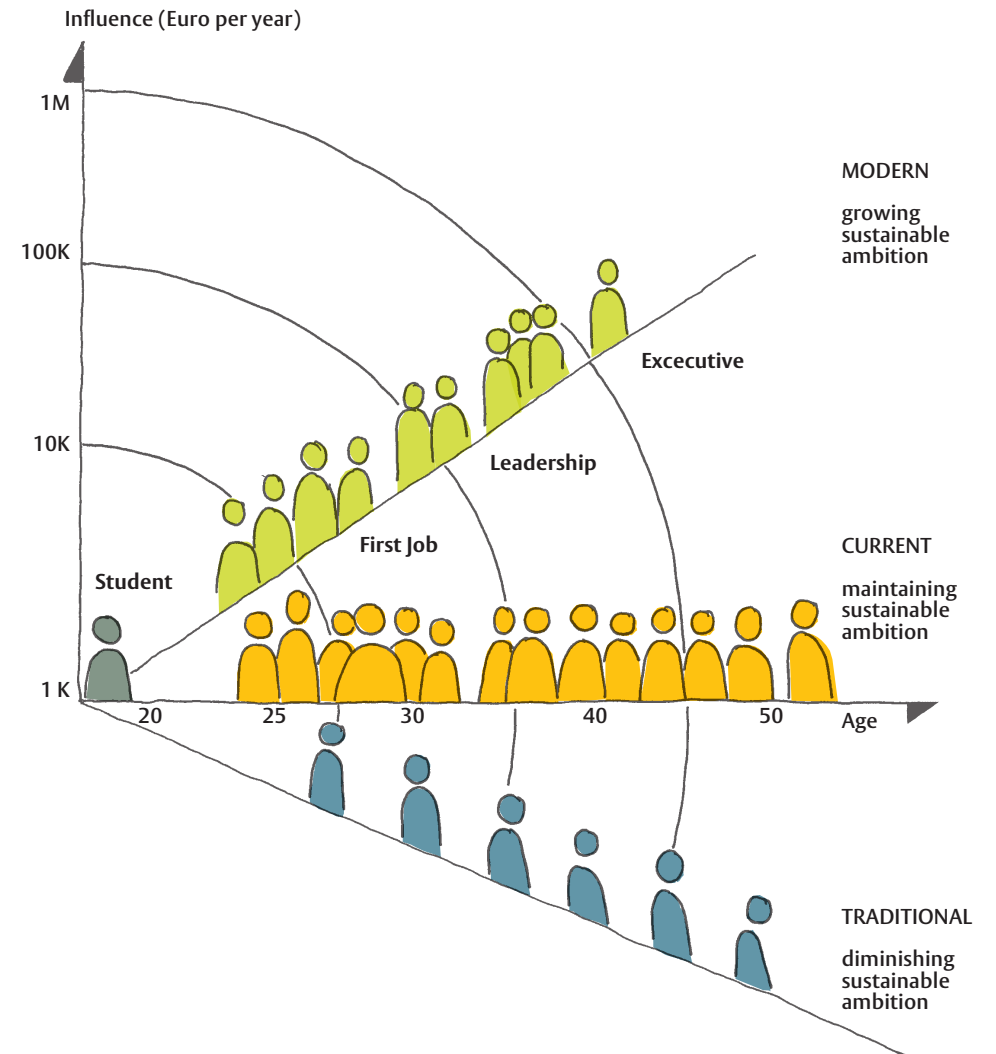
In traditional career paths from student, to first job, to managerial and executive position the societal influence increases but idealism decreases. In modern careers graduates will maintain or increase sustainability ambition with increasing influence.

Universities as trustworthy and neutral wayfarers

As universities are the leaders in, among other things, inter- and transdisciplinary research, quantum computing, data modelling, machine learning, 3D printing, they can potentially play a leadership role in this new era of a necessary global transformation as a trustworthy and neutral entity in a globalized and divided world. Hence, it could be interpreted that university communities now have a central and urgent part to play and a great capacity to tackle such challenges by, for example:

- conducting rigorous inter- and transdisciplinary scientific research that informs about past, current and projected future conditions;

- educating a new generation of students year after year; delivering knowledge, competences and values through teaching;

- innovating and testing solutions and intervention principles of sustainable development, also on campus and its surrounding as a downscaled complex city system, in the form of Living Labs.

Taking deep sustainability approaches in university communities and their unique environment will have enormous short and long-term global impacts on sustainability in the decades to come. In reflection of this, universities are entering a new era in which the functions of 'co-creation for sustainability' could be interpreted as the seeds of a newly emerging mission for them (*Beynaghi et al., 2014; Trencher et al., 2014*).

Checkpoint: The Vision

☐ The world is facing a number of urgent, grand challenges, described in the UN Sustainable Development Goals

☐ Universities should take a leading role in solving these, because of their know how and research capabilities

☐ On top of that, students are the leaders of the future

☐ In a turbulent world, the universities can be trustworthy wayfarers

Our Campuses

Unique and similar

Each university is unique in various ways, but all of them have the same basic system. According to Cortese (*Cortese, 2003*) this system has four dimensions. These four dimensions must also be assessed and reported on in an ongoing process, which introduces a fifth dimension:

1. Education
2. Research
3. Campus operations
4. Community outreach
5. Assessment and reporting.

Naturally, these dimensions are interdependent. Therefore, changes — especially those which have in view a transformation process addressing the complex field of sustainability — need to be set up using transdisciplinary methodology.

Campus operation

The function of a campus is to provide space for the primary processes (research and education) in the form of buildings with laboratories, teaching spaces, study spaces and office and meeting spaces. Further facilities are food- and ICT services and nature/outdoor/recreational facilities.

Not all campus operations have the same contexts. One large distinction between university operations is whether the real estate is owned (such as in the Netherlands) or not (such as the public universities in Germany). Another big distinction is if the university has technical studies or not. A final one is whether sustainability education is mandatory (such as in Sweden) or not according to the national regulations. Technical universities require laboratories, with their own peculiarities. However, they also generate knowledge in hardware management.

Campuses worldwide

Universities are often small communities, almost cities, with their own offices, housing, restaurants and other facilities. They are often connected to the city, region and government and are internationally connected by international projects, research communities and students. The students are 'inhabitants', but also they are eager, high-potential young people, studying and preparing for leadership positions in their work and country.

Universities themselves are significantly contributing to the global environmental footprint. In 2011 there were around 180 million students in Institutes of Higher Education(*Goddard, 2012*). Worldwide, there are some 18,500 universities and in 2015 213 million students[6]. This will grow to 262 million students by 2025 (*Goddard, 2012*). The World Bank estimates 13 million teachers in tertiary education. With an estimate of 9 million support staff, the total population of all HEI's is more than 230 million, or 3.2% of the world population (which was 7.3 billion in 2015).

Ecological footprint of universities worldwide

Global GHG emissions were 49.3 Gton in 2016 (*Olivier et al, 2017*). Taking two university statistics in 2015: TU Delft (a technical university, total population of 25,600 in 2015 and CO_2 exhaust of 112 kton - direct, indirect and embodied) emitted 4.4 tons/person/year. University of Utrecht (a non-technical university) emitted 1.7 tons/person/year. These two average at 3 ton/person/year. Using this as representative, all universities globally amount to 0.7 Gton of CO_2 annually, around 1.4 % of the global CO_2 emissions (*Verhoef, 2018*). Eliminating those emissions will be a major contribution to the global warming problem. Some initial estimates of the built environment share of campuses (500 km²) and land use (1,500 km²) reinforce the environmental impact of our universities.

213 million Students
22 million Staff
3.1% of world
population

500 km² Buildings

0.7 Gton CO$_2$ Emission
1.4% of global Emissions

1.500 km² Land Use
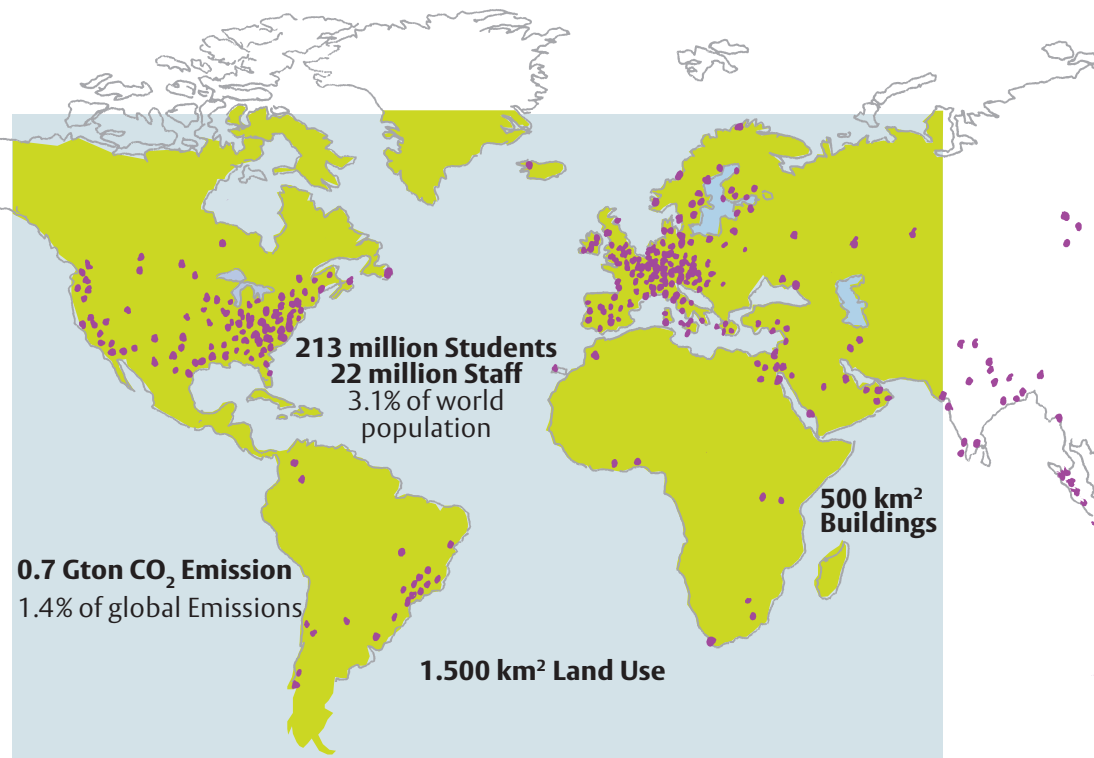
All universities combined represent a significant part of the world population and have a substantial environmental footprint. They can contribute to global sustainability by making their own operations climate neutral and circular.

Recently, it was argued that the emergence of student involvement makes the case for process innovation when implementing circularity: For many university operations departments, changing to sustainability and/or circularity principles is (very) new and requires (big) changes. This adoption process goes in three steps: awakening, acceptance and leadership and can take 10 years or more. Most universities tackle energy use and supply, the waste system or the food systems. These can still be done by existing management models and metrics. CO$_2$ neutrality and circular systems require more: a rigorous re-shaping of the operations, adopting ambitious standards for buildings, such as BREEAM or LEED, and changing from investment based to total cost of ownership (or use) of financial structures. When operations innovation also involves generating research for scientists and educational values for students, other and more integrated approaches are required, such as Living Labs, for instance in food programs and student community-based initiatives.

Universities as part of their region

The Sustainable Development Goals of the UN make clear that there are several crucial questions that need to be answered. This implies that new political goals are necessary and must be formulated in the quest for long-term sustainability. Furthermore, there is a growing demand for knowledge and expertise in order to utilize resources innovatively and find solutions for society and the economy in an environmentally conscious manner. Moreover, our present way of life and lifestyle must be reassessed with the focus on sustainable impact. Global warming and its effects concerns everyone, as it takes place on a local as well as global level and implies consequences for the knowledge economy and society and challenges of sustainability in the twenty-first century (*Carayannis and Campbell, 2011*).

There are nine areas, which require 'sustained action', political and economic 'leadership' or 'empowerment' and 'intelligent use of technology' (*Carayannis and Kaloudis, 2010*):

- Financial/economic system

- Environmental challenges

- Feed and heal the world challenges

- Energy challenges

- Educational challenges

- Political democratic reforms across the world

- Transformative government across the world

- Equity and security across the world

- Technology, innovation and entrepreneurship as drivers of knowledge societies

To be able to find adequate answers and solutions for those topics and challenges it is imperative to find local solutions, which are scientifically proven to transfer them to other locations and adapt them smoothly to accelerate global action.

Furthermore, universities are knowledge hubs and play an important, often a leading, role in their unique urban, social, economic, ecological and cultural surroundings. Apparently, it is essential that they perform as key players for a local and global transformation. They are able to bring together local stakeholders as they are trustworthy institutions in contra-distinction to political and economic stakeholders, who are at the mercy of election periods or yearly turn over. Considering the quintuple helix innovation model, universities can be the local driving force to foster and guarantee local innovations for sustainability, strongly taking into account the role of local benefit, as this is a key point for acceptance and empowerment.

Beyond this, universities are embedded in complex city systems and often play a major role there. Together with the fact that they are a downscaled city system themselves, they are predestined to use their campus environment to develop solutions, products and services addressing grand challenges but in a local and still more controllable but upscalable environment. Co-produced findings in such surroundings are most likely transferable to larger scale city systems and can therewith have as much of an impact on a global scale.

Community outreach

When looking for innovative leaders and answers to the continuing question of how to achieve social and economic equity, the community building movement has emerged as a promising approach for securing lasting results and systems change. The community building approach has the following characteristics. To find solutions to grand challenges and speed up the sustainable transformation of society, universities need to involve key stakeholders in their unique environment. It is necessary to involve its community residents and professionals working together to take collective action aimed at solving problems and enriching lives (*Bäumer, T. et al. 2017*). Additionally, the approach relies on strengthening existing organizations and networks and creating new partnerships to bring about change and to tackle the challenges. All these efforts are necessary to find user-centered solutions and to create common knowledge as a basis for the sustainable transformation of society, improved lives, greater social equity and new standards for life in community.

- University campuses worldwide are all unique but share similarities: students, real estate and research

- Worldwide, there are 18,500 campuses, with 213 million students and more than 20 million staff

- These campuses form as a group approximately 1.4% of the global CO_2 emissions

- As part of their city and region, they are physically and personally connected with the area

- This local and regional ecosystem can be mobilized for integral problem solving and implementation

Dimensions of Sustainability

Shifting to sustainability
Frameworks for sustainability
Economic dimension
Ecological dimension
Social and cultural dimension

Shifting to sustainability

Our earth is a closed system: almost no materials are coming in or going out. Almost every human activity requires space, energy and materials and all of them as fast turnaround input and output (e.g. coffee), or for longer use (e.g. a house). The materials in this cycle are required to become circular: closing the materials loops. A radical shift is required: from linear thinking to circular thinking, where end-of-life products must be considered as a resource to form a closed cycle. That means that products should be purchased from sustainable sources, used in a way and amount appropriate to the function and discarded into another use or demolished sustainably: Reduce, Reuse and Produce.

Frameworks for sustainability

Sustainability has been researched for many years, resulting in many definitions and approaches. A physical definition is *'avoidance of the depletion of natural resources in order to maintain an ecological balance'.* A social aspect and profitability aspects have entered into the realm and a balance between people, planet and profit is seen as the good approach.

There are many frameworks developed to achieve or measure sustainability and various scientific disciplines have conceptual descriptions of these issues, to name a few: Urban Metabolism, Industrial Ecology, Civil Engineering, Circular Economy and Water Management. Different approaches are taken to solve sustainability issues:

- Goals: The UN sustainability goals are an all-encompassing system, but not easy to handle on a local scale.

- Indicators: In terms of economic indicators, the Natural Capital or EcoCosts are emerging as ways to calculate in all our activities.

- Checklists: In buildings, LEED, DGNB or BREEAM methods provide clear checklists and give certification of the result.

- Assessment: In projects or systems with clear boundaries, Life Cycle Assessment (LCA) and Mass Flow Accounting (MFA) provide good guidance. LCA for instance uses the very clear parameters such as climate change, depletion of material resources, land use impacts and water use impacts as well as toxicity and acidification impacts *(Curran, 2015)*.

For this handbook, it is too far-fetched to describe and introduce all of these. Rather, a short description is given of what elements play an important role in approaching sustainability in buildings:
- economic dimension
- ecological dimension
- social and cultural dimension

Economic dimension

With regard to the economic dimension of sustainability, the investment and construction costs are considered in addition to the follow-up costs, which are incurred over the entire operating life or service life. As practical examples show, the follow-up costs can exceed the construction costs by a multiple. Therefore, extensive life cycle cost analysis can identify significant savings potential. The following lifecycle costs (LCC) are important to consider:

- Construction costs, such as land (with development costs), planning costs, buildings (with construction site operating costs), construction supervision and documentation costs, brokerage costs, notary costs, insurance costs during the construction period.

- Usage costs, such as energy and water consumption: heating, hot water, lighting (electricity), water, sewage, building and component-specific expenses: cleaning, maintenance and servicing, modernization.

- Dismantling costs: Demolition, removal, reuse or recycling, disposal.

Ecological dimension

The ecological dimension of sustainability aims to conserve resources by optimizing the use of building materials and construction products and minimizing media consumption (e.g. heating, electricity, water and wastewater). At the same time, minimization of environmental pollution is usually associated with this (e.g. greenhouse potential with regard to climate change, acidification potential with regard to acid rain, etc.).

Since every construction and operation of a building creates emissions to the environment, the question arises as to how building variants can be objectively evaluated and optimized in ecological terms. First, indicators must be defined, which describe the different environmental impacts. According to the current state of the discussion, the following global, quantifiable indicators for ecological building assessment are identified nationally and internationally, typically embedded in the mandatory national building code or in voluntary systems such as LEED, DGNB or BREEAM:

- Land use
- Primary energy consumption (renewable/non-renewable)
- Global Warming Potential
- Ozone Depletion Potential
- Acidification Potential
- Over-fertilization Potential
- Ozone Formation Potential

Social and cultural dimension

In the social and cultural dimensions of sustainability, the aspects of aesthetics and design are important and, in particular, the aspects of health protection and comfort are important as well. The same also applies to indoor climate.

Heat protection in both winter and summer also contributes to comfort, such as the sound insulation etc. Selective selection of building materials (e.g. low-emission products) can be used to avoid possible health impairments even for sensitive persons, such as children or the elderly. By optimizing the building design, the choice of materials, the construction and the HVAC technology, these aspects can already be addressed and considered during the planning phase. At the same time, the design of the building is so flexible that it can easily be adapted to the changing boundary conditions of the user.

Within the social and cultural dimension of sustainability, protection goals are defined in the following areas:

- Design, aesthetics, architectural and urbanistic qualities (design, spatial geometry, materiality, coloring, etc.) as well as questions of identity and acceptance are not quantifiable but can only be described qualitatively.

- User satisfaction and social acceptance work in the sense of sustainability and lead to a special appreciation and value stability of the building.

- Accessibility, which has a direct impact on the usability of buildings for people with limited mobility. Indirectly it increases the comfort for these users and reduces the health risk in terms of danger of falling. Taking current demographic trends into account, a barrier-free building increases adaptability to different user requirements, thus making appropriate conversion measures in the future unnecessary. This in turn influences the life cycle assessment.

- Health and comfort, which includes: thermal comfort (room temperature, room humidity), hygienic comfort (indoor air quality, air movement), acoustic comfort (building acoustics, noise) as well as visual comfort (lighting).

- Hazards to health caused by hazardous substances or by environmental or building exposure (such as noise, drafts, insufficient lighting) must be reliably excluded.

☐ To achieve sustainability world-wide, a radical shift is required: from linear thinking to circular thinking

☐ Three key dimensions in approaching sustainability are recognized

☐ Economic dimension:
lifecycle costs (LCC) are important to consider

☐ Ecological dimension:
conserve recources by optimizing the use

☐ Social and cultural dimension:
important protection goals are aesthetics, accessibility, health and comfort and hazards to health

Living Labs

What are Living Labs
Methodology
To solve complex problems
In real life
By co-creation and co-production

What are Living Labs

Living Labs (LLs) are new ways of innovation and are defined as user-centered, open innovation ecosystems based on a systematic user co-creation approach, integrating research and innovation processes in real life communities and settings. Living Labs are approaches based on change management, fast prototyping of services, co-creation and other innovation management systems. They are practice-driven organizations that involve real-life environments or arenas, where both open innovation and user innovation processes can be studied and subjected to experiments and where new solutions are developed. Living Labs have an environment and an approach in common. When talking about sustainability, the name Sustainable Living Labs is used.

Besides Living Labs, there are other approaches to sustainable campus development. A recent overview by *Schäpke et al. (2018)*, describes Real World Laboratories (when more freedom of the research form and participation is given), Urban Transition Labs (when more selected front-runners are approached as participators) and Transformation Labs (a more facilitator-driven approach, where social issues and the role of the ecosystem for humans are predominant). In a special issue to Real World Laboratories of GAIA (2018)[7], the editors summarize the main lessons: that researchers need to have familiarity with the community in which the lab is located, they should put a major effort into stakeholder selection and all actors should deliberate on what kind of knowledge they can offer.

Methodology

Quite some reviewing and systemization literature exists on Living Labs:

Recently, *Steen and van Bueren (2017a, 2017b)* have come up with a detailed and knowledgeable organizational and management approach for the development and implemen-
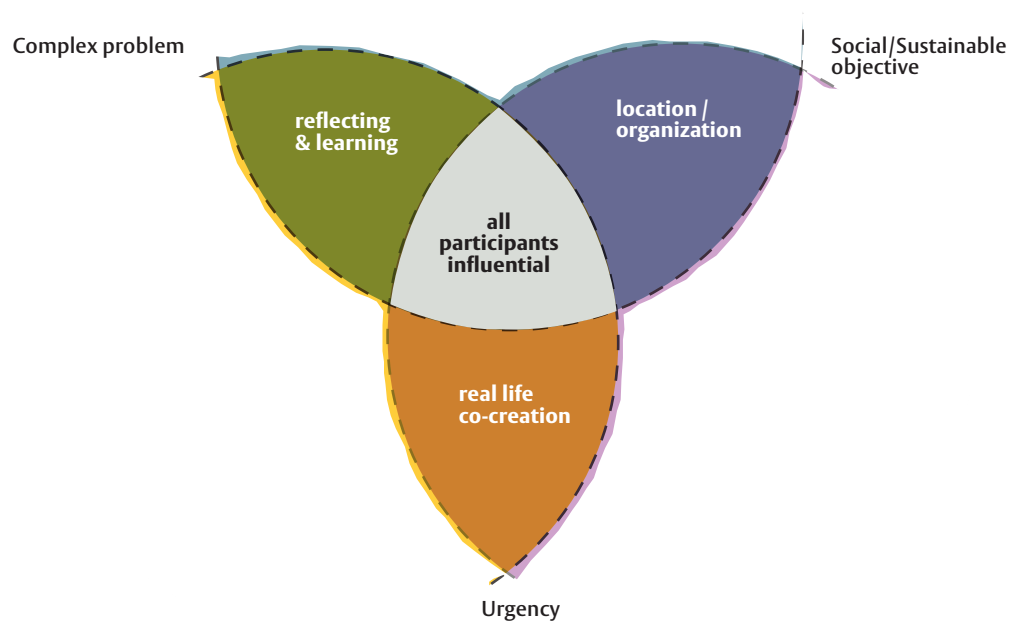
tation of Urban Living Labs. They based it on an analysis of 90 innovation projects around Amsterdam. *Maas, et al. (2017)* provided typologies to distinguish Living Labs from field labs and open access laboratories: Living Labs should have a large amount of user co-creation and should be in real life settings.

Keyson et al. (2017) have compiled the wealth of knowledge in development in the European SusLab project, focusing on 'Sustainable Living' in and around households. They stipulate the importance of (wireless) and self-reporting personal electronics and household appliances. The project 'provides a platform for large scale demonstration projects supporting co-creation by experimenting and demonstrating new business models addressing all forms of innovation, combining technological, organizational, societal, cultural and behavioral innovation and strengthening the participation of civil society'.

McCormick et al., (2017) developed a checklist for Urban Living Labs. As literature on Living Labs points out, only complicated challenges and multi-stakeholder problems or solutions warrant choosing the adventurous and complex approach of Living Lab. A location, budget and goal should be provided. Living Labs can speed up development and adoption of new technologies.

In all cases, the user groups are not an educational or research group and they are mainly built on lessons learnt from ongoing or finalized innovation programs.

Summarizing the findings and methodologies, Living Labs should have: Learning as an integral element, Involvement of users as crucial, (rapid) innovation as a goal. Living Labs should co-create research questions, goals and common definitions and reflect them iteratively as well as on the value, influence, openness, sustainability and realism.

Complex problem

Social/Sustainable
objective

reflecting
& learning

location /
organization

all
participants
influential

real life
co-creation

Urgency

In a Living Lab urgent, complex problems connected with societal challenges are tackled. Key elements in these Labs are co-creation and experimentation in real life setting, a location, an organization and reflection and learning. All active participants have influence and decision power in the Lab.

To solve complex problems

The Living Lab approach is not a simple problem-solving technique, such as brainstorming, or a stringent management approach such as project management. It requires time, change of attitude and prolonged attention to succeed. Therefore, especially complex problems should be tackled with it. The complexity can lie in a wide range of participants, disciplines and resources. Moreover, in a visionary or societal greater goal, not within short-term reach.

If the problem is simple, straightforward, time-constrained and financially programmable, project management techniques could be much more preferred. If the problem is large and complex but well-known, agile project management techniques, program management techniques or urban planning techniques could be much better. If the focus is on changing the organization, change management or process management approaches are preferable. Having said that, to learn Living Lab management and techniques, simple problems are more appropriate.

In real life

The transition towards the sustainable use of the Earth's resources can only be reached through deliberate processes of transformation, which have to be managed creatively by societies based on sound scientific knowledge. This calls for new research strategies and methodologies with a strong focus on joint efforts by science, business, government and civil society.

The fact that sustainable development and global change are common scientific challenges that bring together people with very different values and worldviews it is even more important that those experiences are assembled together to cooperate in research. Based on this the exploration of

suitable institutional, economic and behavioral changes towards global sustainability will lead to solutions that are highly dependent on and tailored to, local, national and regional cultural, economic and natural contexts.

The Integration of research questions, from the local to the global and back, means considering those other scales when carrying out research on the one scale (be it local, national, regional or global). This ensures that differences in cultures, interdependencies between regions and institutional dependencies are adequately taken into account.

Carrying out research in the context of sustainability transformation means committing to do science together with society: in other words, to commit to transdisciplinary and thus integrated processes of co-designing research agendas and to co-producing knowledge with researchers, decision makers and stakeholders for addressing challenges for global sustainability and developing possible solutions. Integrated research provides a better understanding of the multiple drivers, interdependencies and complexities of global sustainability challenges. It provides knowledge that is better able to contribute to the development of robust policy solutions and their effective, equitable implementation.

By co-creation and co-production

Integrated research works across scientific disciplines, across regions and across societal groups. It is problem-oriented, driven by contexts of application and starts with the joint framing (co-creation) of research topics and questions. It requires the involvement of researchers, stakeholders and decision makers throughout the entire research process, from co-design through co-production to effective delivery and thus demands clarity about the roles and

responsibilities of those involved (*Zimmermann et al., 2018*) Integration upholds scientific integrity in reflexive learning processes that bring together different actors and knowledge practices. It builds on and supplements traditional processes of disciplinary research, see also *Mauser et al. (2013)*.

The case for experimenting in real life is as follows: First, in real life issues emerge and can be tested which are impossible to test in a confined laboratory environment. Second, stakeholders identified and not identified may perform research, and third, real actions and decisions are taken in real contexts, thereby increasing the validity of the outcomes and improving the impact for replication and upscaling. In other words: real life testing for realistic results!

☐ Living Labs are user-centered and open innovation eco-systems

☐ Living Labs are effective in solving complex problems in a multi-stakeholder context

☐ Especially societal/sustainability problems benefit from involving all stakeholders for co-creation and co-production

☐ A real-life setting is beneficial to simultaneously encounter all relevant foreseen and unforeseen circumstances

☐ A real-life setting improves the impact for replication and upscaling

The University Campus as Living Lab for Sustainability

What is a university campus as Living Lab

Creating valuable outcomes

Users are participants

Optimizing scarce resources

A framework for Living Labs

What is a university campus as Living Lab

It was explained how urgent the societal challenges are and the importance of universities taking the lead and taking action. The campus and the university community are great assets to use. Combining these with the transdisciplinary and transformative approach of Living Lab, leads to the synthesis described below: the University Campus as Living Lab for sustainability.

Campus as Living Labs can be defined as follows: *"A Campus as Living Lab is the integrated organizational, technological and socio-economic approach in which a university uses its assets and facilities to investigate, test or demonstrate innovative technologies or services by, with and for their community."* *(Verhoef et al., 2019)*. When the innovations being tested are concerned with sustainability, it is called Campus as a sustainability Living Lab. These Living Labs are combining education, research and campus operations.

Quite some universities have started Living Lab-like activities in the past. Some examples of Living Labs projects are:

- Harvard Living Lab initiative: campus as a test bed to generate solutions that enhance the health of people and the planet[8]

- EnSign Reallabor: transformation process towards a climate neutral inner-city university campus (*Botero et al., 2016*)

- The Green Village at TU Delft, to accelerate the development and implementation of radical innovations[9]

- KTH Live-In Lab: Testbeds for accelerating innovation rates in the construction and real-estate sectors[10]

- MIT Office of Sustainability (MITOS), a 'Living Lab' is a place-based research concept that utilizes the college campus as a test-bed for innovation and knowledge generation[11]
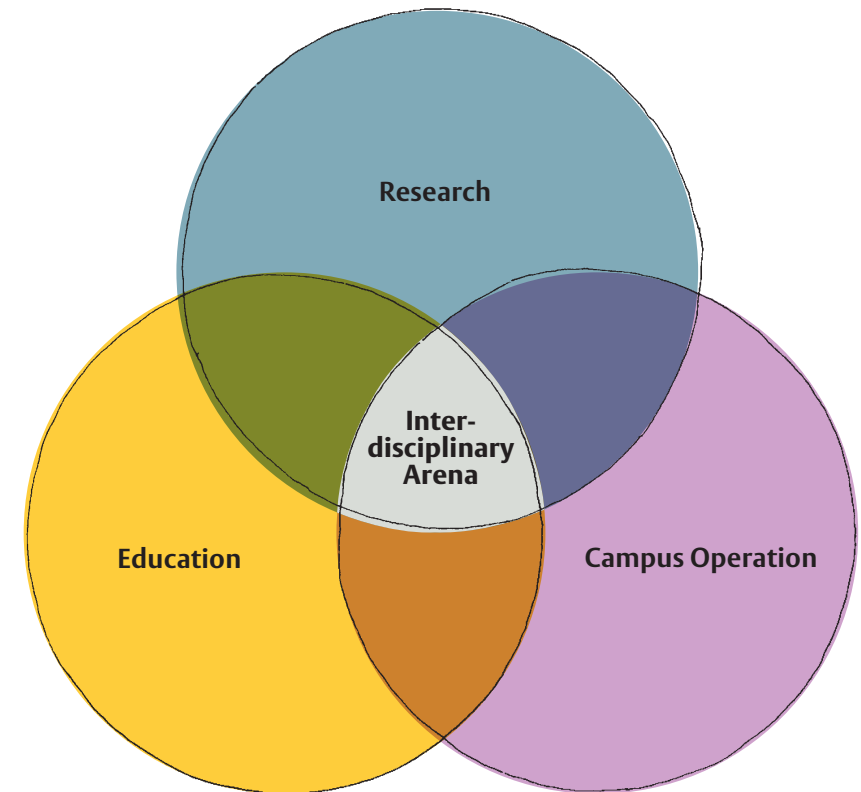
Primary functions of universities (education and research) can be connected to campus operations in the Living Lab. Education and Research overlap in reflection and learning. Students and Operations can connect through real life co-creation. Operations and research connect in the opportunity of the location. Extending the overlaps and connections is at the heart of making the Lab successful.

8 www.green.harvard.edu/series/living-lab
9 www.thegreenvillage.org
10 www.liveinlab.kth.se
11 www.sustainability.mit.edu/living-labs

Creating valuable outcomes

The significant question, which arises, is that how university communities can play a catalytic role in the transformation of global sustainability. There is a paucity of research to provide a compelling answer to this question where the role played by universities as catalysts for deep global sustainability transformation is investigated and based on which interventions can be undertaken. An emerging approach is connecting education, research and campus operations in Living Labs.

There is a strong belief that 'Living Lab' approaches are effective and will lead to facilities, students and research with greater impact on our common future. However, academic institutions can also contribute by rigorously defining the desired methodology and the impacts on the whole, monitoring the successes (and failures) of all approaches and analyzing, understanding and falsifying the factors behind these successes. Only in that way, can recommendations for continuation and towards other institutions become of value beyond case study descriptions.

There are five main outcomes in a campus as Living Lab innovation program:
- on research,
- on education (both formal and informal),
- on campus operations,
- on the community (around the campus) and
- on (connections with) industry.

In this book, the campus operations outcomes solely focus on sustainability and include behavioral changes by the university community.

Users are participants

In the very diverse university community of faculties, science groups, individual professors and PhD's, all users are very strongly motivated to compete in a worldwide competitive field. As a consequence, time and space are limited to distractions from their mission. Therefore, community members may not be very interested in making themselves available for experimentation, as their 'primary processes' should not be endangered. On the other side of this spectrum are those research groups and individuals, whose direct field of interest is the built environment, energy system, infrastructure, mobility and behavioral change for sustainability. This encompasses the fields of urban development, sustainable energy technology, innovative and sustainable buildings, electrical engineering etc. on the technical side, but also (business) psychology. These groups are inherently more interested and benefitting from experimentation on their own premises.

The solution lies in a segmentation of university stakeholders and tuning into their respective interests and responsibilities:
- Research community: Part of the research community can gain by experimenting and testing their ideas and findings on the campus. With benefits in additional funding, real-life data, results display and exposure and nearby or real-world projects.
- Student community: Part of the student community wants experimentation to increase their educational experience. Others want to be activated and contribute out of social responsibility and activities rather than through their studies. All can be incorporated in the design.
- Operation community: Staff, facility providers, from very hierarchical operators to adaptable providers of temporary space and facilities.
- Non-university stakeholders: such as the neighborhood, the municipality or companies operating/innovating on the campus

Lastly, communications between scientists and administration staff can be a major gap, because of lack of understanding of each others work challenges, operating principles and intrinsic drivers. The project/real estate management work from an operation that is fixed and mostly under strict time and cost constraints.

Optimizing scarce resources

University sustainable coordination officers around the world, experience two problems with implementing sustainability on campus: capacity (time availability) and capability (education and training) of operations staff[12]. Implementing innovative solutions (i.e. with low Technology readiness levels[13]) and/or more than legally required solutions, leads to a higher risk perception and cost issues as predominant objections.

Universities as Living Labs offer very interesting opportunities. Universities have (vast) campuses. The real-estate community is increasingly interested in fully operating sustainably, but lacks knowledge and sometimes interaction with the research community. University populations: the research and education communities are, by definition, interested in developing and disseminating knowledge. Moreover, students are, by definition, interested in gaining knowledge.

The community on a university campus is very diverse, and so the Living Labs emerge and come in various forms. In starting and setting up a Living Lab, two questions should be addressed as to the feasibility:

- Who initiates and drives the project (students, real estate, researchers, board, city)?

- What is the physical dimension and associated time/budget frame: real estate, services or event?

Not all combinations are feasible. For instance, longer time frames, higher budget scopes are hard to be initiated and driven by students. In addition, shorter time frames may make it harder for scientists to be involved.
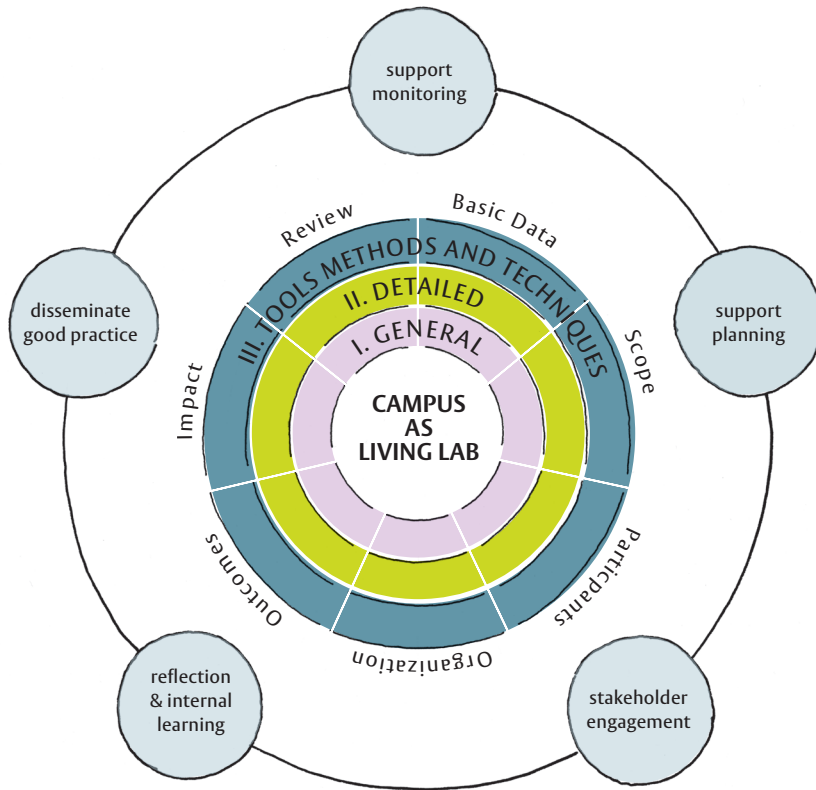
A framework for Living Labs

A number of higher education institutions have started a co-creating process for a Campus as Living Lab learning system, recently culminating in an initial framework (*Verhoef et al., 2019*), summarized as follows:
"This (…) describes a living, shared framework and methodolgy, the 'Campus as Living Lab' learning system, created through global participatory workshops and Living Lab literature, aimed at supporting universities and their Sustainability (Coordinating) Offices in the development and monitoring of Living Lab projects."

The relevant categories for a Campus as a Living Lab description were given:

- **Basic Data:** a summary of the Living Lab location, key contacts, status, timelines and budget

- **Scope:** the problem being addressed, historical details to the problem, the context and the key sustainability 'theme' being addressed

- **Participants and Co-Creators:** different stakeholders and ways in which they are engaged

- **Organization:** leading organizations, partnerships, potential risks

- **Outcomes:** anticipated (and actual) sustainability outcomes in relation to the problem being addressed, as well as anticipated (and actual) educational, research and engagement outcomes

- **Impact:** wider impacts outside of the Living Lab boundaries

- **Reflection and Review:** evaluation of the Living Lab products and processes

The Campus as Living Lab Framework, with its seven categories: basic data, scope, participants, organization, outcomes, impact and reflection. See also Verhoef et al., 2018.

The framework "... *aims to create value and help universities maximize the benefit of Living Lab projects within an institution, support monitoring, reflection and learning from projects and facilitate communication with stakeholders and the sharing of practices and learning between peers across the globe. As a living shared framework and learning system, the framework will adapt and develop over time and within different contexts. To provide feedback and fast (practical) learning from users, the system will be further developed to facilitate transparent peer reviewing*" (*Verhoef et al., 2019*). To avoid being tangled up in too much detail, they recommend a phased approach:

- **Phase I. General.** Containing basic information about the Living Lab. This assists in the initial description of the Living Lab, including outlining of the 'problem' being addressed and the anticipated broad outcomes and user groups.

- **Phase II. Detailed.** This refers to the collection of more precise information and parameters for the project, including specific outcome metrics and anticipated numbers from different stakeholder groups.

- **Phase III. Tools, Methods and Techniques.** This refers to guidance provided within the framework as to the tools, methods and techniques that can support setting up, running, communicating, monitoring and reviewing a Campus Living Lab with various stakeholders from inside and outside the university community.

Chapter 6 provides a structure, the Living Lab Canvas, for Phase I.

Checkpoint: The University Campus as Living Lab for Sustainability

☐ The university community and campus are great assets for action research on sustainability

☐ View all stakeholders as potential participants and empower them for co-creation processes to build trust and provoke knowledge transfer to generate win-win situations

☐ Accept and foster the wide variety of potential outcomes for all: education, research, campus operations and community

☐ Optimize (scarce) resources: operational staff time and skills, research potential and student enthusiasm

☐ Establish or use a framework of how to structure campus as a Living Lab and take a phased approach from general to detailed to toolboxes

☐ Consider a higher communication expenditure than on normal research projects

The Campus as Living Lab Canvas

The Living Lab Canvas
How to fill the Canvas
Example of using the Canvas

The Living Lab Canvas

The Business Model Canvas was developed by *Osterwalder (2004)* as a template to develop novel or describe existing business models. Its strengths are that it is a visual, one-page document with the main elements pertaining to the business model. Based on the Living Lab framework a Canvas was developed based on the idea of a Business Model Canvas to use for creating a Living Lab project on a university campus.

This Canvas offers the possibility of focusing on the key points, which need to be considered to set up a Living Lab in a transdisciplinary way and based on the quintuple helix innovation model (*Carayannis, E.G., 2012*). However, it is imperative to start the whole process in the awareness that the following criteria are key elements framing a Living Lab in general:

- All affected persons/groups and stakeholders need to be considered as co-creators to identify, describe and frame the complex problem, which underlies the Living Lab. The mindset needs to follow the idea of Empowerment.

- The identified problem is a complex, societal and urgent (global) problem, which demands a transdisciplinary approach to be solved in a sustainable way. Complex problems require a well-defined and shared vision.

- Real-world experimentation is needed to simultaneously address all relevant aspects of the problem and the solution.

The Canvas can be viewed as a Jigsaw puzzle. One can start with any element and slowly build it up. While filling and getting more precise and clear about certain topics, it will be easy to jump to other elements. The sequence of completing the Canvas might look very different in each case but will most probably always be iterative. The main point is to get a clear picture about the idea, structure and impact of the Living Lab while bringing all the elements of the Canvas together.

General		
Identification and Ideation	**Participants**	**Outcome**
Scope	**Planning and Organization**	**Impact**
Review and Evaluation	**Internal Learning**	
Instructions		

Campus as Living Lab Canvas, forming a complete, communicable, general description for a Living Lab: the scope, the participants, their desired outcomes and roles, how to reflect and the impacts beyond the lab itself. Its completion and approval is to be done with all participants in several iterations.

General

- Give easily understandable title
- Contact details (name/location/phone/e-mail/website)
- Optional: acronym and/or logo

Identification and Ideation

- Describe the process of how to identify the problem in all its facets and stakeholders
- Pose and answer questions such as What, Why, Who is affected, who is part of the problem?
- Describe the cause of the problem/origin of the idea or the facts on which it is based

Participants

- Identify all potentially affected persons/stakeholders/authorities by type and/or by name
- Identify their potential contribution to co-production

Outcome

- Describe exactly all expected benefits and results for all participants
- Assess that all participants understand the outcomes for the others

Scope

- Formulate a precise research question in common language
- Include the core of the problem
- Explain why (and if) the problem is complex and why it is not yet solved

Planning and Organization

- Describe all major organizational, planning and network management issues

Impact

- Describe which of the grand challenges of our century can be affected by this Living Lab
- Describe the possibilities of replication to other locations, situations, problems or issues

Review and Evaluation

- Decide on adequate indicators to measure success for the process
- Define the review process, how often it is performed and who participates
- Decide on adequate persons for a peer review process

Internal Learning

- Describe key learning objectives of the team
- Describe key learning objectives of each participant group
- Describe how learning may influence future actions of participants
- Decide on format and frequency of learning process

Instructions

- Start in any element and complete iteratively, inviting all potential participants
- When finalized, all participants should agree on all elements and on their contributions
- Check if it is a multidisciplinary, co-creative, co-productive real-life approach leading to outcomes and impacts on urgent societal problems

How to fill the Canvas

General

Within this element the title and contact details of the Living Lab should be mentioned in a short and easy to understand way to attract the potential co-creators and funding organizations. It is also helpful to have an acronym and/or logo, which highlights and communicates the idea.

Identification and Ideation

The intention of this element is to make the persons who fill in the Canvas aware of the process of identifying the problem with all its facets and affected stakeholder groups. The easiest way to fill this element with details is during one or more co-creation workshops with relevant and most affected stakeholders, who may frame the complex problem slightly differently and give additional points of view about a probably already identified problem. All relevant statements or problem descriptions that mark the foundation of the Living Lab can be filled in this field.

Relevant questions and initial points are:
- What is the idea?
- Why is it interesting?
- What causes the problem?
- Who is affected/part of the problem?

Scope

This element comprises the translation and fusion of the various descriptions, which are mentioned in the element 'Identification and Ideation', into a precise research question. It is therefore very important to use a common language and to avoid a specific professional terminology.

Relevant questions and initial points are:
- What exactly is the core problem?
- What makes the problem so complex?
- What makes the problem a societal issue?

Participants

Within this element, all potentially affected persons/stakeholders/authorities etc. should be identified and acknowledged as co-creators, who may have an important point of view in the identified complex problem. It is essential to carefully consider all affected parties as this will be relevant to including them in co-creation and co-production processes to solve the problem with their very specific knowledge.

Furthermore, all stakeholders are potential multipliers for outcomes and impacts as soon as they are part of the Living Lab. This is exactly the core objective in performing Living Labs as an instrument for societal transformation. In every meeting, check if participants are missing and if participants are not affected or contributing anymore.

Relevant questions and initial points are:
- Who is included in the emergence of the problem?
- Who is affected by the problem?
- Who is involved and why does this make the problem so complex?
- Why this is and what exactly makes it a societal issue?

Planning and Organization

This element should comprise the major organization and planning aspects of the Living Lab, such as:
- organizational aspects: project structures and rules, core-team, communication plans, co-creation and co-production processes or procedures,
- planning aspects: iteratively approved timelines and milestones, financial contributions and balancing and
- network management aspects: resources and time slots to generate win-win situations to keep all stakeholders connected to the Living Lab, and the organization and connection to an external advisory panel.

Management issues:

- What structure does it need to face the real-world problem?
- How can a project management team set up and guarantee that the processes and developments can be tracked and steered?
- How can the processes of the Living Lab lead to co-creation innovations, sustainable solutions, products and services?
- How can these solutions be co-produced transparently and everyone kept informed about relevant developments?
- What do the reporting and documentation of the processes look like?

Stakeholder issues:

- How will it be possible to keep the process running while new stakeholders are joining and others disappear?
- How does the project stay attractive over a longer period to keep stakeholders interested?

Financial issues:

- Who gets payed for what and what consequences does it have?
- How are contributions (in time, in kind or in cash) valued and compared?
- What are the expectations of possible funding entities?

The detailing of these aspects is to be done in separate documents/financial systems.

Outcome
This field is supposed to trigger thoughts about the potential lessons and expected results for the different stakeholder groups. This means based on those identified groups it makes sense to explore what exactly is the expected benefit

for them and motivates them to keep connected to the activities of the Living Lab. It also serves to communicate and discuss between all the different participants what each finds important.

Relevant questions and initial points are:

- What are the benefits for each stakeholder group?
- What is the (intrinsic) motivation that makes the stakeholder group participate and co-create/co-produce with the others in the Living Lab?
- What (additional) effects can the Living Lab have on each stakeholder group?
- How can lessons learned be documented and multiplied?
- Do all participants understand the outcomes for the others?

Impact
This element spotlights the topic of potential impact on society and the consequences of the Living Lab concerning any relevant effects for the transformation of society as regards the grand challenges of our century. Therefore all (side-) effects of the Living Lab should be considered as possibilities for transferring the achieved knowledge about it to other locations, situations, problems or issues. Compared against the element 'Outcomes' this element focuses on indirect and large-scale impact.

Relevant questions and initial points are:

- How can the outcomes and the acquired knowledge be transferred to other situations?
- What effect could the Living Lab have on a big scale/societal scale ?
- How do the Living Lab and its outcomes address the grand challenges?
- What impact can the Living Lab have in an up-scaled version?

Review and Evaluation

The element 'Review and Evaluation' comprises process learning during the phase of performing and actively running and or participating in a Living Lab. This is a crucial and often skipped element, which, however, is very important, as it is the essence of optimizing a comparable process and/or learning to perform any other process with the same or comparable partners. Therefore, it is important to carefully document all success and failure stories and analyze them objectively. Those lessons will be very helpful for any stakeholder and it is necessary for replication and multiplication. With the aid of those insights and lessons, a societal impact is quickly realizable and a social transformation can be speeded up.

Relevant questions and initial points are:

- What went well or wrong in the process of setting up/performing/monitoring/disseminating/transferring the knowledge of the Living Lab?

- Where, when and how did critical situations pop up?

- What kind of tools were used in which phase?

- What impact can the Living Lab have in an upscaled version?

- Success/failure stories concerning communication, project management, co-creation/co-production, implementation etc. marked crucial points or caused important changes?

Internal Learning

This element is supposed to highlight the learning achievement within a stakeholder group, university, company, organization etc. In distinction from the element mentioned before, it is not about the success and failure stories, it is about the methodological knowledge and the essence for each specific participant/stakeholder/person and what consequences the lessons learned will/can have for future activities.

Relevant questions and initial points are:

- How the Living Lab and the lessons learned will change future action and behavior for each and every stakeholder?

- What actions need to follow based on the outcome of the project?

- What consequences does the Living Lab have for the university, education, research, production, procurement, governance, the innovation system, resource management etc.?

More information can be found at the website: campusaslivinglab.org
Here you can download the Canvas and future updates. It also provides a downloadable pdf-version of this book. To increase experience and exchange, you can upload your own Canvas and in future find Canvases of other universities.

Example of using the Canvas

General
- Title: Real-world Lab for the transition to a carbon neutral Campus of HFT Stuttgart
- Contact details: Michael Bossert, Schellingstr. 24, 70174 Stuttgart, Germany, michael.bossert@hft-stuttgart.de, www.hft-stuttgart.de/Forschung/Reallabor
- Acronym: Campus Reallabor

Identification and Ideation
- Describe the process of how to identify the problem
- Open space workshop, with divers partners to discuss research questions
- Identification of additional and affected stakeholders
- In a synthesis all aspects were put together

Participants
- Roughly the stakeholders were identified by the quintuple innovation helix:
- Academia
- Industry
- State/government
- Civil society
- Natural specific environment of Stuttgart

Outcome
- Outcomes were discussed and created continuously in co-production
- One of the most important recognition is that only universities can think and make long-term strategies
- The main outcome: it is possible to create a carbon neutral campus in an inner-city area

Scope
- The scope and the precise research question were biannually discussed after presenting results
- It is important to frame new research questions/tasks and definitions in such a way that everyone has the same picture

Planning and Organization
- A Campus Living Lab is an ongoing process
- Communication is a mayor task
- A project management team kept track of all activities and to informed all stakeholders

Impact
- Curricula got modified
- New courses got implemented
- Energy Masterplan was developed
- A redevelopment plan got set up
- Long-term cooperation with the state and the city is established
- A lot of new research projects get set-up by new research questions

Review and Evaluation
- Evaluation can be only as good as before chosen indicators
- Inter- and transdisciplinary research got mayor elements but are highly demanding
- Communication was identified as a key element

Internal Learning
- It is all about creating win-win situations
- Once you gained trust, you need to take care that it gets not lost anymore
- Networks of real exchange and without competition boost the activities and the outreach

Instructions

Example of using the Canvas

To get an impression of how the canvas is used in practice, the initiation and operation of the *Campus Reallabor* at HFT Stuttgart is described. Below you will find the process roughly in the sequence with which it was undertaken, and the status, after being in operation for 4 years.

Identification and Ideation
This topic was addressed in four main steps:

- Before applying to a funding program, long-term partners were invited to an open space workshop, to discuss, describe and define the topic and research question for the Living Lab on campus, which addresses the topic of energy transition and carbon neutral operation in an inner-city campus.

- During the discussions, additional stakeholders were identified to answer the question: Who is affected and who is involved in getting things done?

- In additional meetings and discussions, the different facets and interests were framed and defined.

- In a synthesis, all aspects were put together into an overall shared vision based on the grand societal challenges
  - Sustainability Transformation of Society
  - UN SDGs
  - Energy Transition
  - national, regional and local energy and sustainability goals
  - regulations and strategies

- This overall vision was to create a masterplan and to start the realization of CO_2 neutral inner-city campus in close cooperation with the neighborhood, as a pilot project to demonstrate ways and potentials for further public and private real estates and urban quarters.

Participants
After the Identification and Ideation steps all stakeholders who could be affected and contribute were identified.

- The goal was to get their interest by creating win-win situations and to make them participants for the transformation process. With their knowledge and their ideas, possi-

bilities and wishes they are potential change agents and can multiply the insights and discoveries and transform them according to their needs and requirements. Furthermore, additional scenarios and cases can be investigated within the Living Lab. As one stakeholder put it: *"During the process of the Living Lab, we could bring together our knowledge and create transferable solutions. It was eye opening which possibilities are there, while thinking beyond the own real estate and creating energy networks. We can operate so much more effective and profitable while shifting loads."*

- Five stakeholders groups were identified roughly corresponding to the quintuple innovation helix.

- Within these stakeholder groups many subcategories were identified to be able to create specific win-win situations and to understand more about competences, transfer-potentials and interests.

- Depending on the willingness to participate we had up to ten appointments a year to meet and discuss ways and scenarios how to proceed. Especially the building owner (state of Baden-Württemberg), planners and facility managers from industry were highly interested to discuss about requirements and co-create potentials and solutions for energy networks.

Scope
The scope and the precise research question were discussed minimum twice a year, after presenting results and thinking about further proceeding.

- New aspects and new questions came up repeatedly as new insights changed points of view or further questions popped up. This iteratively culminated in new investigations, cases or ideas. Two examples are:
  - How does an effective cooling system for a midsize public data center look like?
  - how to integrate a high percentage of renewable energy supply in such a system?

- As professional fields have their very own specific language it is important to frame new research questions/tasks and definitions in such a way that everyone understands the same, which requires time and attention (e.g. Carbon Neutrality, transdisciplinary research, sustainability).

Planning and Organization

Such a Campus Living Lab is an ongoing process. Once it was started, it should not be stopped until all relevant issues are solved. Relevant organizational items were:

- The most important element of the organization/management of such a Campus Living Lab is to understand that communication is a mayor task, much larger than in any other (research) project.

- To frame the organization, focal areas were identified and these were coupled to work packages and working groups:
  - Communication, Participation, Transfer
  - HFT as a neighbor, urban analysis, energy masterplan, spatio-functional analysis
  - Energy management, user behavior
  - Redevelopment strategy and energy efficiency
  - Integration of renewable energy and potential of district networks
  - Sustainability indicators and evaluation of the process
  - Sustainable Finance

- A core Living Lab management team of 4 persons was created, responsible for management, to organize and keep track of all activities and to inform all stakeholders about developments, decisions and the possibility to participate. Besides that, a academic team of 20 persons from different professional field was installed.

Outcomes

Desired outcomes were discussed beforehand and created continuously in the co-production activities. The process aspect of outcomes management were:

- In workshops outcomes and findings were presented twice a year and discussed within open spaces or other creative formats.

- Once we won trust and once persons got interested in the iterative knowledge generation the project became circular: New ideas and research questions kept coming up. These were handled within the Campus Living Lab or (if more complicated) in concomitant research projects. An example of the latter is the integration of a maximum renewable energy percentage for data centers and requirements therefore in an inner-city context. As an example the complex topic of load shifting scenarios between different real estates and the urban quarter was further developed in a separate research project.

- Many research questions came up by the problems of the Living Lab partners and their everyday issues, for instance visualizing real time operation of the campus and what influence the own behavioral change would have to sensitize users on their acting.

- Some research questions could not be analyzed or solved within the conditions on site. Therefore it was very helpful that partners made it possible to conduct research within their real estates or surroundings.

The main outcomes related to the scope of the Lab were:

- The recognition that only universities can think and make long-term strategies. State and government acts according to election periods and lobby influence. Industry thinks in annual turnover. Civil society is influenced by the focal area of media and current conditions. Nevertheless universities as neutral entities can bring all of them together on the table and make them participators in creating future strategies based on a common understanding of problems and tasks.

- It is possible to create a carbon neutral campus in an inner-city area while thinking on neighborhood scale and district networks, with existing technologies, but that implementation requires a long-term acting and partnering with decision-makers who have the resources and decision making power.

Impact

This Living Lab addresses many of the grand societal challenges. Looking backwards after several years of operation, several foreseen and unforeseen impacts were generated:

- By making affected parties and persons into participants, they were engaged and automatically became change agents. While co-creating a common knowledge and understanding the Living Lab became an important factor of the sustainability transformation, the energy transition and the process to find local answers to the SDGs.

- The participating stakeholders communicated their interests and their key points for successful transfer of solutions. This leads to development of user-centered solutions, services and products. Once more, this underlines the role and the necessity of the third mission universities as knowledge hubs with and for society. An example was the fact that different neighbors were happy to finally be more connected to the university and that we took them with us on the longterm journey to create a CO_2 neutral campus. They are still close connected with university and address their needs and thoughts about different developments in different meetings.

- Beyond single Campus as Living Lab initiatives, a network between those knowledge hubs can actively boost the transformation of society. In this manor, it makes no sense that each university develops their very own solutions just for themselves. Competition is irrelevant only cooperation counts as all universities and their neighborhoods face the same problems and potentials.

- In education, curricula got modified and new courses got implemented e.g. Studium Integrale, cross-disciplinary courses and interdisciplinary seminars.

Review and Evaluation

The result of the evaluation process, done by the academic team, was:

- Communication is a key point.

- Building trust needs time and a long-term thinking.

- Evaluation depends on good indicators. It is crucial to discuss indicators before each task.

- Inter- and transdisciplinary research needs different process es and is highly demanding for everyone. However it offers as well more cross-disciplinary learning for everyone.

Internal learning

The Living Lab core team organized the internal learning process. The lessons on the process were:

- It is all about creating win-win situations

- Stakeholder-centered communication/language is the most important element.

- Once you gain trust, you need to take care that it gets not lost anymore. Otherwise, you lose more than you gained.

- Inter- and transdisciplinary research causes friction and needs to grow on trust as well.

- This way of performing research is highly demanding and not a solution for each problem.

- New ways of how to publish interdisciplinary results needs to be established as it goes far beyond disciplinary research outputs.

- Networks with real knowledge exchange without competition boost the activities and the outreach.

- The format of a Campus as Living Lab needs a long-term thinking/strategy and adequate funding scheme.

- Support of the president is a mayor point.

☐ A Canvas is a practical, mixed visual and textual, way to develop and communicate a (business) plan

☐ The Living Lab Canvas contains seven project- and result-oriented elements: General, Ideation/ Identification, Scope, Participants, Organization, Outcomes and Impact

☐ The two elements Review/Evaluation and Internal Learning complete the Canvas

☐ The elements should not be filled in consecu- tively, but iteratively and with all (and increasing number of) participants involved

Operation in Practice

Towards mutual understanding

From commitment to action

Towards mutual understanding

The idea to start a Living Lab can come from any part of the organization or stakeholders. The first thing to do is to ascertain that the idea/problem benefits from a Living Lab approach. The main question to be answered is: Does the idea benefit from a Living Lab? Basically, the Canvas should be completed leading to a go-no go decision.

The lead in this stage of the process is the problem owner/initiator. The problem owner identifies and sets up a small team consisting of at least one representative of the stakeholders to be involved.

Filling the Canvas
In our experience, approx. four 2–3 hour meetings are needed, with associated preparatory and analysis work:

- The first meeting with a core group to start-up/scope and understand the Living Lab approach, identify the difference in knowledge and approaches and identify additional stakeholders

- The second meeting to onboard the new participants and align the approach; if needed: give training/role playing on Living Lab participation

- The third meeting to make a first draft of the Canvas, identify additional or abundant participants and agree on balanced roles and contributions

- The fourth meeting to confirm the Canvas and go/no-go. In this meeting, it should be ascertained that:
  - all have common understanding of the the desired outcomes
  - all agree on the Living Lab set-up and the participants
  - all agree and confirm their roles

From commitment to action

Governing the Lab
This stage should give a formal commitment for support by all participants. The conditions to be met at the end of this step are:

- Establish governance model/business plan

- Appoint a Living Lab experiment/manager

- Learning Activities (formal/informal) described

- (Internal) Communication/feedback, continuous development and regular review;

- If needed, make/perform (external) communication campaign

Implementation
A project developer will lead this task, together with the legal and financial specialists of the various stakeholder and user groups. Important aspects are:

- Location well defined

- Context (real-world approach) provided

- A process design (a Working Plan) detailed with division of task equipment needed

- Financial resources secured and commitment given

- Legal and risk documents prepared and approved

- Reservation of finance for research time/tools/reflection

Checkpoint: Operation in Practice

☐ Setting up the Living Lab takes four meetings of
2 – 3 hours each

☐ All participants should understand and agree
on desired outcomes, contributions, roles and
impact for and by all

☐ Putting the commitment into action, requires
a governing model, a project leader and a living
lab manager, as well as a number of practical
conditions

Keeping the Lab alive

Running a Living Lab
Cultivating a culture
Matching with university profile
Learning to reflect
Roles and goals

Running a Living Lab

As described in chapter 6 it is important that the idea and process of a Living Lab is based on a common understanding of the problem and a transparent and co-created strategy of how the process looks to approach the problem. It might be important not to speak about problem solving, but about a process to find user-centered answers to a research question.

After a hopefully enthusiastic start of the process, it is important to constantly keep alive a positive and empowering communication. The only way is a continuous generation of win-win situations for different stakeholder groups. Only thus a long-term, trusting relationship can be established and stakeholders keep cooperating and sharing. With this in mind, the tailored communication will be a major task throughout the process and needs to be recognized as a basic need to keep a Living Lab ongoing.

Based on a larger number of case studies it seems to be a successful approach to have bi-annual meetings to present developments and results and to put them up for discussion. Based on this co-creation and or co-production process, changes, new strategies and further research question can be defined. However, this iterative and transdisciplinary process can perform as a key element that various stakeholders get in contact, exchange thoughts, ideas, doubts and wishes and collaborate interdisciplinarily to define new important next steps.

It is exactly this process that makes it hard to treat the Living Lab as a project. Things can pop-up in co-creation sessions and will pass over to projects. Other projects will fail early, as the potential was overrated. In this sense, a Living Lab cannot fail, as it will generate common knowledge based on transdisciplinary co-creation and co-production processes.

Cultivating a culture

As trust is the essential key element of a Living Lab it is important to have a smooth process to gain, keep and foster or empower trust in the process of performing a Living Lab. Therefore, transparency, fairness, open mindedness and an atmosphere of curiosity to work together with other stakeholders with different backgrounds is a necessity.

It is important to bring together different persons without the expectation that a few key players will perform as game changing agents. Furthermore, it is important to know that the inter- and transdisciplinary co-creation process is the driver. This is a crucial point, as in many cases it was a major development to pull down the barriers of silos and to understand that campus borders are not walls against the real world. It is important to understand that the driving force of a Living Lab is collaboration in the frame of the quintuple helix innovation model that all relevant stakeholders collaborate with respect and open mindedness to co-produce user-centered solutions.

This means for all participants to cultivate a new way and methodology of problem-solving and research. Such a culture is necessary to find solutions for the grand challenges and to speed up the sustainable transformation of society.

Matching with university profile

The commitment of departments as stakeholders can't be overestimated, as they produce the primary outcomes for the university. Or, in the words of *Verhoef et al., (2019)*: *"In the area of educational and research outcomes questions arise about how to use campus-based sustainability projects to maximize educational outcomes, for example how can we make 'invisible' sustainability improvements 'visible' and a source of learning for both the student and staff population, through what is referred to as the 'hidden' or 'subliminal' curriculum (…) and how do we engage the breadth of the research community?"*

Universities cover a range of scientific disciplines. Some universities are technologically oriented, whereas others are stronger in the life sciences or the social sciences. Mobilizing scientists for a Living Lab on their own campus will have a higher success rate if the problems addressed resonate with the focus of the university faculty and departments. There have been repeated comments that universities of technology are more capable of making their campuses sustainable, which may be true, but it is often forgotten that the alpha and gamma sciences are crucial and better equipped, in paying attention and exploring the behavioral and user-interaction side of the experimentation and thus in Living Lab design and implementation.

Another opportunity, which can be deployed, is to display the technologies and knowledge of the department in the Living Lab, as proposed by *Verhoef et al (2017)*. For instance, a university with a prominent position on the global solar energy research stage can show that in a building with state of the art solar facades. For social science, this may be somewhat more difficult, but can be further explored as well. Displaying the activities for all is a good way to identify Living Lab projects with university profile, for instance using the mapping approach.

Coupling of Living Lab programs to these central research themes will help in keeping the Lab alive. The challenge is how to do that during operation of the Living Lab. Some tips are:

- Communicate, how the Living Lab contributes to the primary process and the specific research and education profile of the University

- Acknowledge, how the participation of the various departments and scientists have made the Living Lab a success

- Quantify, the outcomes in terms which resonate with the primary processes.
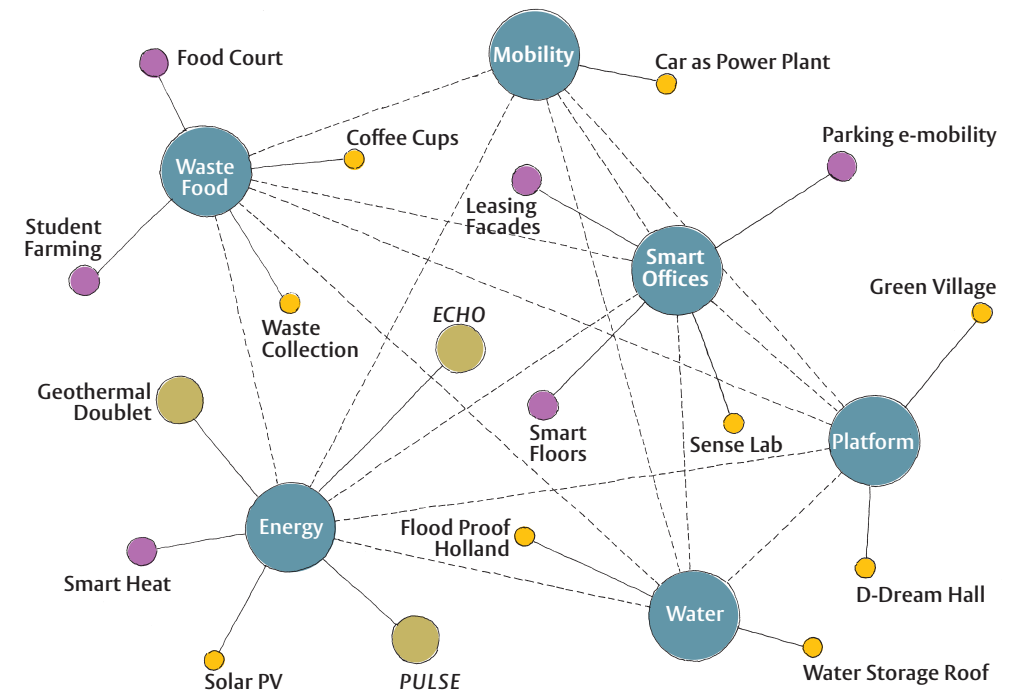
Portfolio of innovation projects and programs on the campus of TU Delft, together forming a Campus as Living Lab. Many sustainability aspects are addressed (e.g. energy, food, wellbeing). A range of scales is covered: from small (student farming) to medium (coffee cup collection) to large (energy-zero buildings Pulse and ECHO), to full-fledged platforms containing their own projects (The Green Village).

Learning to reflect

By definition, the results of a Living Lab experiment come in three ways: in its outcomes, its impacts and its reflections:

- The outcomes are expected to emerge during and after the first feedback of users.

- The impacts typically have longer time frames: 1 – 3 years after the first successful experiments.

- The reflection is actually the lessons learnt by the operation of the Living Lab itself and will probably be obtained after completion. In an optimally functioning team, this reflection takes place both on content and process during the Living Lab itself.

Roles and goals

As university communities are quite diverse, as is the real world, it is valuable to sort out roles/tasks in sustainability implementation.

It seems to be of great value to have a closer look at the roles and goals of different stakeholder groups, as it is very important to create adequate communication strategies and to build trust and win-win situations, to keep a Living Lab ongoing.

Depending on the Living Lab, its setting and the environment in general it makes sense to distinguish, at a minimum, the following stakeholder groups:

- University and Academia

- Industry and Enterprises

- State government, political system

- Media based and cultural based public

- Natural environment of the university

The more detailed the analysis of each stakeholder group is the more useful information about win-win situations based on interest and common goals can be derived. And therewith the role and participation can be advantageously deployed.

As an example for universities, it is important for academia to extend knowledge, to educate future leaders, to get third party funding, to create scientific publications, etc. But with a closer analysis it becomes obvious that the different stakeholder groups in a university have even more diverse interests. Simply going down one more step helps to get more details about potential drivers for the subgroup:

- Presidency: wants to be high ranked, connected and influencing political decisions on a regional scale, etc.

- Administration: wants to have easy and proper processes that all rules and regulations are considered, and things are running smoothly in a legal manner, etc.

- Faculty: wants to be famous for fantastic education and research and that the best students apply to be educated by this faculty, etc.

- Real Estate and Operations management : the whole complex mini city system needs to perform with high efficiency, with minimum maintenance effort and minimum monitoring/control.

- Students: want to have the best education, access to the best professional and social networks and to have well-equipped and comfortable surroundings to undergo their studies

Based on this rough and, maybe, prejudicial analysis, it is already so much easier to understand the goals, the drivers and the role for the particular stakeholder group and it exposes a couple of points, which can be taken into account to create win-win situations.

Checkpoint: Keeping the Lab alive

- ☐ Generate win-win situations and keep communicating results and success and the contributions of the Living Lab

- ☐ Cultivate cultures of experimentation, testing and learning together

- ☐ Match and prioritize Living Lab projects with the university profile and vision on research and education

- ☐ Respect and mobilize university stakeholders in their roles and ambitions

- ☐ Implement a positive failure culture to learn about mistakes while sharing them

- ☐ Celebrate success stories

Why it will happen

Our universities are leading the way
Global community of practice
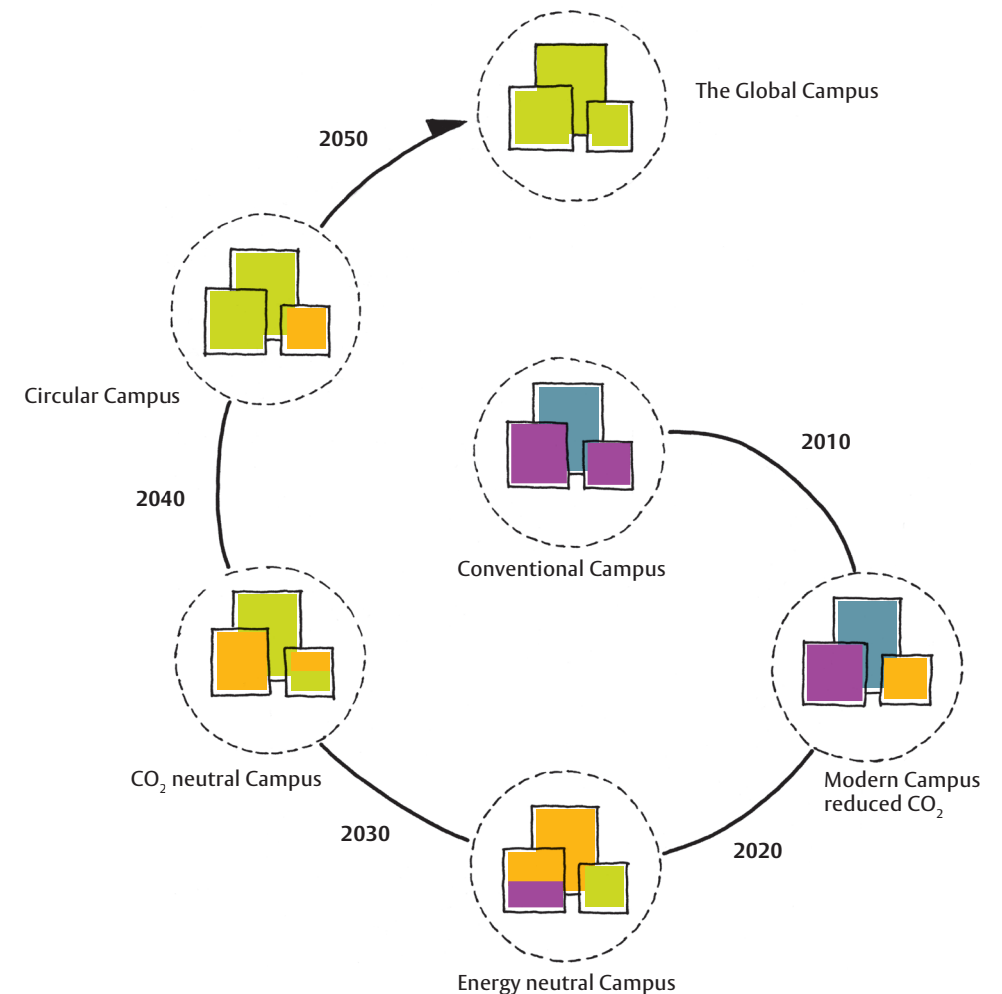Student engagement increases
Universities connected to cities

Our universities are leading the way

Many universities are improving the footprint of their campuses, progressing from conventional to a modern CO_2-conscious campus. Frontrunners are approaching energy-neutrality and preparing to take the next steps: carbon-neutral campuses, including embedded emissions, to 'circular' campuses (all materials circular) and finally UN-SDG responsible campuses. That it has to happen is evident and when also: before 2050 all universities should have achieved that final stage. More and more universities are recognizing their own potential and obligations to be ahead of society in their educational fields and adopt the knowledge of other fields.

Global community of practice

Universities have a key role to play within communities to engage with stakeholders and to contribute to capacity building (*Shiel et al, 2016*). Therefore, many universities subscribe to the importance of working towards the UN SDGs. Emerging experience of mixed and holistic approaches to combining research, education and campus operations have been discussed in various workshops of the International Sustainable Campus Network (ISCN) and during the 2017 WSSD. University communities' networks are excellent venues for testing, validating and replicating solutions. All universities' sustainability practitioners together are one (world-wide) community of practice. These networks also exist and operate on a regional, national or continental scale, e.g. the AASHE, the ISCN, the IUSDRP and HOCH-N. All of those networks embrace exchange of experiences or are increasingly focusing on frameworks and shared practices.

The Global Campus

2050

Circular Campus

2040

Conventional Campus

2010

CO_2 neutral Campus

Modern Campus reduced CO_2

2030

2020

Energy neutral Campus

All universities will develop into fully circular campuses. By 2020, modern campuses address energy conservation and reduced CO_2 emissions. By 2030, many will be energy neutral and carbon neutral. By 2040, most will be circular. Beyond that, all will have implemented all UN SDGs.

Student engagement increases

The sustainability educational experience, both formal and informal, becomes increasingly central to the study experience sought by our students. The world's leading universities have incorporated that into their curriculum, campus development and research approaches. Many have subcribed to the Charter of the Global Universities Leaders Forum and are member of networks, such as the International Sustainable Campus Network.

Universities connected to cities

Around the globe, universities are strengthening their relations with their communities. And they are challenged to contribute to solve urban metropolitan and regional problems. As a result, a multitude of Urban Living Labs can be found around Europe, many of these connected to metropoles. In many of these, universities are not only asked to contribute to the solution but are also asked by cities and regions to assist in the process of innovation and the challenge of replication and scaling. Campus Living Labs can have three main scalability aspects:

- **Process level:** Living Lab processes on how university communities connect, share knowledge and collaborate can be replicated

- **Outcome level:** Living Lab approaches result in specific solutions to tasks, problems and challenges, which can be transferred

- **Impact level:** the impact in regional or national contexts can be replicated.

Cities and universities are finding it more and more natural and necessary to form coalitions and are testing new ways of forming relationships to tackle this challenge. A few examples for new roles of universities mixing campuses with regional connections are the AMS Institute for Advanced Metropolitan Solutions and Stuttgart's i_city WerkStadt and M4_LAB.

- The HFT Stuttgart research joint venture, intelligent city (i_city) works on solutions to central societal challenges of sustainable city development. Six cross-linked fields of action from urban planning, architecture, IT, energy, mobility and finance are addressed. Cooperation with SMEs, industry and regional authorities has been established to develop innovative concepts of the intelligent city of the future and to transfer them into practice in the metropolitan region of Stuttgart.

- M4_LAB focuses on innovations at the interface of sustainable metropolitan development, digitalization and industry 4.0 and their direct transfer into society and the economy. The aim is to expand the transdisciplinary research in real-world laboratories already established at the HFT Stuttgart in a targeted manner, to support it consistently with software tools for city modelling and to open up new dimensions of participation. The process of the International Building Exhibition 2027 in Stuttgart is used as an example to advise and accompany innovative implementation projects in the metropolitan region and to test and optimize all elements of the transfer strategy.

- AMS Institute is an international institute where talent is educated and engineers, designers and both natural and social scientists jointly develop and valorize integrated urban solutions. Its mission is to develop a deep understanding of the city (sense the city), design solutions for its challenges, and integrate these into the city of Amsterdam. AMS Institute was founded in 2014 by TU Delft, Wageningen University & Research and MIT.

Checkpoint: Why it will happen

- [ ] The only future is that of CO_2 neutral, circular, societally engaged and sustainable campuses

- [ ] Working the campus in harmonized approaches, will foster joint learning, for instance, through an international community of practice

- [ ] Putting the commitment into action requires a governing model, a project leader and a Living Lab manager, as well as a number of practical conditions

- [ ] Students are increasingly engaged with societal challenges and solutions and will increasingly require or expect action in their own study environment

- [ ] Smaller scale campus experimentation can feed into replication and scaling to cities and metropoles

Summary

Abstract
Checkpoints

Abstract

This book has illustrated how to look and work at university campuses as testbeds for sustainability transformation; for their own sustainability and beyond. Summarizing the chapters:

The Vision: The problems, which the world faces, are large and urgent. The UN SDGs set targets and timelines, as does the Paris Agreement on Climate. Universities are well suited and should take up these challenges in all ways possible.

Our Campuses: Universities are very well suited to study global problems. They research, educate and interact with their communities and industries. They can provide a learning, working and practising setting ranging from short-term projects, via buildings and campus developments to regional issues and global development. More and more campuses are becoming integrated with their cities, exchanging cultural facilities, parking facilities and energy flows.

Dimensions of Sustainability: A very concise overview of sustainability issues and indicator systems was given, helping to understand the dimensions and metrics of sustainability: economic, ecological and social-cultural.

Living Labs: They were explained, as a transdisciplinary approach to solving complex, urgent issues in a co-creative, iterative way including stakeholders in real-world situations.

The University Campus as Living Lab for Sustainability: Combining the knowledge on campuses, the definitions of sustainability and the approach of Living Labs, the Campus as Living Lab was introduced and explained: science and education being used to implement sustainability on campuses, and vice versa. Getting it done is the hardest part in life and this booklet describes the first steps: a framework for description and a three-stage approach to designing and developing a Campus as Living Lab were introduced.

Campus as Living Lab Canvas: Attention was given to the first stage: does the idea or problem benefit from a Living Lab approach. If the problem is not complex or urgent, it may be better to solve or approach it with a simpler problem solving or management technique. To streamline the design, the Campus as Living Lab Canvas was introduced and its workings explained.

Operation in Practice: Getting it into practice requires action and meetings to create mutual understanding on scope, outcomes and input. Transforming that commitment and understanding into practice can be achieved by creating a governing structure and appointing and training a Living Lab manager.

Keeping the Lab alive: The start of a Living Lab is a tedious process, but once successful, a challenge arises in keeping it alive: is the culture of the university receptive of the peculiarities of the Lab, can people stick with the changed approach and is civil society connected and satisfied.

Why it will happen: Why universities will become sustainable testbeds, leading the way to solving and scaling for the UN SDGs is explained: universities are a world-wide closely-knit system, students don't expect anything less, and the connection to cities and regions will be more important for the university community as a whole.

The proof of the pudding is in the eating. Use the handbook, as a guideline, a checklist, or a prescription. Create a Canvas and use it to communicate. Your using will help strengthening, learning and improving the Living Lab approaches and the value for solving urgent societal problems. By doing so and by sharing your experiences, you will join an active, vibrant and responsible community of practitioners, which take the lead in using the university campus strengths for the future of our world.

Checkpoints

The Vision

☐ The world is facing a number of urgent, grand challenges, described in the UN Sustainable Development Goals

☐ Universities should take a leading role in solving these, because of their know how and research capabilities

☐ On top of that, students are the leaders of the future

☐ In a turbulent world, the universities can be trustworthy wayfarers

Our Campuses

☐ University campuses worldwide are all unique but share similarities: students, real estate and research

☐ Worldwide, there are 18,500 campuses, with 213 million students and more than 20 million staff

☐ These campuses form as a group approximately 1.4% of the global CO_2 emissions

☐ As part of their city and region, they are physically and personally connected with the area

☐ This local and regional ecosystem can be mobilized for integral problem solving and implementation

Dimensions of Sustainability

☐ To achieve sustainability world-wide, a radical shift is required: from linear thinking to circular thinking

☐ Three key dimensions in approaching sustainability are recognized:

☐ Economic dimension: lifecycle costs (LCC) are important to consider

☐ Ecological dimension: conserve recources by optimizing the use

☐ Social and cultural dimension: important protection goals are aesthetics, accessibility, health and comfort and hazards to health

Living Labs

☐ Living Labs are user-centered and open innovation eco-systems

☐ Living Labs are effective in solving complex problems in a multi-stakeholder context

☐ Especially societal/sustainability problems benefit from involving all stakeholders for co-creation and co-production

☐ A real-life setting is beneficial to simultaneously encounter all relevant foreseen and unforeseen circumstances

☐ A real-life setting improves the impact for replication and upscaling

The University Campus as Living Lab for Sustainability

☐ The university community and campus are great assets for action research on sustainability

☐ View all stakeholders as potential participants and empower them for co-creation processes to build trust and provoke knowledge transfer to generate win-win situations

☐ Accept and foster the wide variety of potential outcomes for all: education, research, campus operations and community

☐ Optimize (scarce) resources: operational staff time and skills, research potential and student enthusiasm

☐ Establish or use a framework of how to structure campus as a Living Lab and take a phased approach from general to detailed to toolboxes

☐ Consider a higher communication expenditure than on normal research projects

Campus as Living Lab Canvas

☐ A Canvas is a practical, mixed visual and textual, way to develop and communicate a (business) plan

☐ The Living Lab Canvas contains seven project-and result-oriented elements: General, Ideation/Identification, Scope, Participants, Organization, Outcomes and Impact

☐ The two elements Review/Evaluation and Internal Learning complete the Canvas

☐ The elements should not be filled in consecutively, but iteratively and with all (and increasing number of) participants involved

Operation in Practice

☐ Setting up the Living Lab takes four meetings of 2 – 3 hours each

☐ All participants should understand and agree on desired outcomes, contributions, roles and impact for and by all

☐ Putting the commitment into action, requires a governing model, a project leader and a living lab manager, as well as a number of practical conditions

Keeping the Lab alive

☐ Generate win-win situations and keep communicating results and success and the contributions of the Living Lab

☐ Cultivate cultures of experimentation, testing and learning together

☐ Match and prioritize Living Lab projects with the university profile and vision on research and education

☐ Respect and mobilize university stakeholders in their roles and ambitions

☐ Implement a positive failure culture to learn about mistakes while sharing them

☐ Celebrate success stories

Why it will happen

- [ ] The only future is that of CO_2 neutral, circular, societally engaged and sustainable campuses

- [ ] Working the campus in harmonized approaches, will foster joint learning, for instance, through an international community of practice

- [ ] Putting the commitment into action requires a governing model, a project leader and a Living Lab manager, as well as a number of practical conditions

- [ ] Students are increasingly engaged with societal challenges and solutions and will increasingly require or expect action in their own study environment

- [ ] Smaller scale campus experimentation can feed into replication and scaling to cities and metro-poles

References

Bäumer T., Worm D., Müller P., Zimmermann S., Popovic T., Pagel C. (2017)
So Tell Me What You Want, What You Really Really Want. In: Leal Filho W., Skanavis C., do Paço A., Rogers J., Kuznetsova O., Castro P. (eds) Handbook of Theory and Practice of Sustainable Development in Higher Education. World Sustainability Series. Springer, Cham

Beynaghi, A., Moztarzadeh, F., Maknoon, R., Waas, T., Mozafari, M., Hugé, J., Leal Filho, W. (2014)
Towards an orientation of higher education in the post Rio+20 process: How is the game changing?, Future s,Volume 63, 2014, Pages 49-67, ISSN 0016-3287, https://doi.org/10.1016/j.futures.2014.08.004.

Botero, L., Bossert, M., Eicker, U., Cremers, J., Palla, N., Schoch, C. (2017)
A Real-World Lab Approach to the Carbon Neutral Campus Transition: A Case Study. In: Leal Filho, W., Mifsud, M., Shiel, C., Pretorius, R. (eds). Handbook of Theory and Practice of Sustainable Development in Higher Education. World Sustainability Series. Springer, Cham

Carayannis E.G., Campbell D.F.J. (2011)
Mode 3 Knowledge Production in Quadruple Helix Innovation Systems. In: Mode 3 Knowledge Production in Quadruple Helix Innovation Systems. SpringerBriefs in Business, vol 7. Springer, New York

Carayannis, E.G., Barth, T.D., Campbell, D.F. J. (2012)
The Quintuple Helix innovation model: global warming as a challenge and driver for innovation. In: Journal of Innovation and Entrepreneurship, December 2012, 1: 2. https://doi.org/10.1186/2192-5372-1-2

Cortese, A. D. (2003)
The critical role of higher education in creating a sustainable future. Planning for Higher Education 2003; 31(3), p. 15-22

Curran, M.A., ed. (2015)
 Life Cycle Assessment Student Handbook, Scrivener Publishing

Daneri, D. R., Trencher, G., Petersen, J. (2015)
Students as change agents in a town-wide sustainability transformation: the Oberlin Project at Oberlin College. In: König, A., Budwig, N. (eds) Current Opinion in Environmental Sustainability, Volume 16, 2015, Pages 14-21, ISSN 1877-3435, https://doi.org/10.1016/j.cosust.2015.07.005.

Goddard, B., Making a Difference: Australian International Education (2012).
http://www.wolframalpha.com/input/?i=how+many+students+in+the+world, retrieved 19 march 2018

Leal Filho W., Brändli L. (2016)
Engaging Stakeholders for Sustainable Development. Engaging Stakeholders in Education for Sustainable Development at University Level. World Sustainability Series. Springer, Cham. https://doi.org/10.1007/978-3-319-26734-0_21

Leal, W,. Embly-Perry, K, Molthan-Hill, P., Mifsud, M.C. Verhoef, L., Boddy, J., Mitsus, M., Azeiteiro , U.M., Bacelar-Nicolau, P., de Sousa ,L., Castro, P., Beynaghi, A. (2019)
Implementing Innovation and Sustainability at Universities Around the World, Journal of Cleaner Production, to be submitted Keyson D.V., Guerra-Santin, O. (Eds), Living Labs, Design and Assessment of Sustainable Living, Springer, 2017, ISBN 978-3-319-33526-1, ISBN 978-3-319-33527-8 (eBook)

Maas, T., van den Broek, J., Deuten, J. (2017)
Living Labs in Nederland - Van open testfaciliteit tot levend lab (dutch). Den Haag, Rathenau Instituut

Wolfram Mauser, Gernot Klepper, Martin Rice, Bettina Susanne Schmalzbauer, Heide Hackmann, Rik Leemans, Howard Moore (2013)
Transdisciplinary global change research: the co-creation of knowledge for sustainability, Current Opinion in Environmental Sustainability, Volume 5, Issues 3–4, 2013, Pages 420-431

McCormick, K., Hartmann, C. (2017)
The Emerging Landscape of Urban Living Labs: Characteristics, Practices and Examples, GUST project report, Lund University. http://lup.lub.lu.se/record/77262ed5-1219-4798-89d9-872286efdb7b, retrieved 06th December 2018

Mowery, D. C. (2007)
University-Industry Research Collaboration and Technology Transfer in the United States since 1980. In: Yusuf, S., Nabeshima, K. (eds) How Universities Promote Economic Growth. The International Bank for Reconstruction and Development / The World Bank, 2007, Pages 163-181, DOI:10.1596/978-0-8213-6751-3

Olivier, J.G.J., Schure, K.M., Peters, J.A.H.W. (2017)
Trends in global CO2 and greenhouse gas emissions. 2017 Report, PBL, December 2017

Osterwalder, A. (2004)
The Business Model Ontology - A Proposition in a Design Science Approach. PhD Thesis University of Lausanne.

Shiel, C., Leal Filho, W., do Paço, A., Brändli, L. (2016)
Evaluating the engagement of universities in capacity building for sustainable development in local communities, Evaluation and Program Planning. Volume 54, 2016, Pages 123-134, ISSN 0149-7189, https://doi.org/10.1016/j.evalprogplan.2015.07.006.

Steen, K.Y.G., Van Bueren, E.M. (2017a)
Urban Living Labs: A Living Lab Way of Working, AMS Research report, AMS Institute, June 2017

Steen, K.,Y.G, Van Bueren, E.M, (2017b)
The Defining Characteristics of Urban Living Labs. In: Technology Innovation Management Review, 7(7), 21-33

Trencher, G., Bai, X., Evans, J., McCormick, K., Yarime, M. (2014)
University partnerships for co-designing and co-producing urban sustainability, Global Environmental Change, Volume 28, 2014, Pages 153-165, ISSN 0959-3780, https://doi.org/10.1016/j.gloenvcha.2014.06.009.

Trencher G., Bai X. (2016)
The Role of University Partnerships in Urban Sustainability Experiments: Evidence from Asia. In: Brauch H., Oswald Spring Ú., Grin J., Scheffran J. (eds) Handbook on Sustainability Transition and Sustainable Peace. Hexagon Series on Human and Environmental Security and Peace, vol 10. Springer, Cham

Verhoef, L.A, Graamans, L., Gioutsos, D, van Wijk, A.J.M., Geraedts, J., and Hellinga (2017)
ShowHow: A flexible, structured approach to commit university stakeholders to sustainable development. In: Handbook of Theory and Practice of Sustainable Development in Higher Education (Volume 6), eds. Walter Leal Filho, 2017, p.491. DOI 10.1007/978-3-319-47877-7_33

Verhoef, L.A., Bossert, M., Newman, J. Ferraz, F., Robinson, Z.P., Agarwala, Y. Wolff III, P., Jiranek, P., Hellinga, C. (2019)
Towards a learning system for University Campuses as Living Labs for sustainability. In: Universities as Living Labs for Sustainable Development: Supporting the Implementation of the Sustainable Development Goals-Volume 2. Springer 2018

Verhoef, L.A. (2018)
De Campus als Living Lab voor de Circulaire Economie (dutch), In: Circulariteit, op weg naar 2050?, ed. P. Luscuere, June 2018, Pag. 261, ISBN 978-94-6366-054-9

Wagner, F.; Schäpke, N.; Stelzer, F.; Bergmann, M., Lang, D. J. (2016)
BaWü-labs on their way: Progress of Real-world Laboratories in Baden-Württemberg. In: GAIA - Ecological Perspectives for Science and Society, Volume 25, Number 3, 2016, pp. 220-221(2). oekom Verlag, https://doi.org/10.14512/gaia.25.3.21

Watson-Capps, J.J., Cech, T.R., (2014)
Academia and industry: Companies on campus, Nature, Volume 514, Pages 297–298. DOI:10.1038/514297a

WorldBank, EdStats, retrieved 19 march 2018
source: UNESCO Institute for Statistics

Zimmermann, S., Bäumer, T., Müller, P. (2018)
Achieving a Climate-Neutral Campus: A Psychological Analysis of the Participation Process with the Stage Model of Participation. In: Leal Filho, W., Marans, R., Callewaert, J. (eds). Handbook of Sustainability and Social Science Research. World Sustainability Series. Springer, Cham

Acknowledgements

About the Authors

Leendert Verhoef

Program Lead Living Labs at AMS Institute and Partner in New-Energy-Works. He has worked for three years at the Green Office at TU Delft, where he developed the concept Campus as Living Lab. He is strongly driven to bridge the gap between science and society by implementation and transdisciplinary and transformative approaches.

Over his career, he has developed multidisciplinary system integration and circular economy programs and Living Labs frameworks, integrating mobility, sustainable energy, buildings and other sustainability issues. He has worked with municipalities in national and international projects, gave seminars and trainings and published about them in books. Besides that, he has started several companies and advised broadly in the field of sustainability, innovation and strategic marketing helping start-ups, multinationals, local governments and international institutes such as European Commission and the World Bank. He serves in the advisory boards of the German Network of Sustainable universities (HOCH-N) and the International Sustainable Campus Network.

Michael Bossert

Managing Director for Innovation and Transfer in Research at the Hochschule für Technik Stuttgart. In his many years as managing director of an interdisciplinary research centre, he coordinated applied research on sustainable energy concepts and solutions for buildings, districts and cities. Motivated by complex tasks, he developed and managed several national and international interdisciplinary and transdisciplinary research and practice projects, always in the role of bridge builder between different professions and interest groups. In his current position he is responsible for innovation and knowledge transfer from the university to industry, civil society and government and vice versa. He also serves on the advisory board of the International Sustainable Campus Network to position himself among the world's leading universities, which act as key players and accelerators for the sustainability transformation of society.

Notes

Universities are very well suited to help
solve urgent global challenges through
their ongoing research, education
of future leaders and value added to the
community. Furthermore, universities
aim to lead by example by developing
CO_2-neutral or circular campuses.

This handbook is for those who want to
transform their campus into a sustainable,
trend-setting innovation ecosystem.
It provides a guideline and checklists for
practitioners and change-makers to
develop their campus into a Living Lab.

By using the Campus as Living Lab Canvas,
activating the campus community,
and further sharing the experience with
an active, vibrant and responsible
community of practitioners around the
world, you engage with those taking
the lead in using the strengths of university
campuses for the future of our world.

The authors, Leendert Verhoef and Michael
Bossert have experience with innovation
and transition methodologies and setting
up Living Labs. Both are active in the
global campus sustainability community.