PRO GREEN LABS

Pro-GREEN-LABs - 101129466

Promoting Green Competences for Integrated Sustainable Development in Architectural Education through Experiential, Lab-based, Active Learning.

D2.2 | Best Practices:

Relevant Labs and curricula at European HEIs

Lead Beneficiary: BUW

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Abbreviations

EU	European Union
HEI(s)	Higher Education Institution(s)
LABSIMURB	Laboratorio di Simulazione Urbana
MIT	Massachusetts Institute of Technology
PGL(s)	Pro-GREEN LAB(s)
POLIMI	Politecnico di Milano
SDG(s)	Sustainable Development Goal(s)
TU	Technical University
UCL	University College London
WP(s)	Work Package(s)

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Executive summary

This report focuses on the role of urban labs and similar entities affiliated with Higher Education Institutions (HEIs). It explores and documents the transformation of traditional labs into dynamic academic innovation hubs that bridge the gap between academic learning and real-world applications, particularly in the context of sustainable urban development. Specifically, the report presents relevant European labs at HEIs and best practices for implementation, running, and curriculum-integration of labs in the fields of architecture and urban planning. The underlying investigation for that spanned from May to September 2024 and involved coordinated research activities.

The report aims to fine-tune the project's framework by documenting best practices in lab development and integrating sustainability aspects into architectural and planning education. The goal is to learn from existing examples, identify what works well, and explore new innovative approaches for Pro-GREEN LABs. These insights are intended to guide our future project planning and activities, particularly for the Pro-GREEN LABs initiative.

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1. Introduction

This report focuses on the role of urban labs and similar entities[1] affiliated with Higher Education Institutions (HEIs). It explores and documents the transformation of traditional labs into dynamic academic innovation hubs that bridge the gap between academic learning and real-world applications, particularly in the context of sustainable urban development. Specifically, the report presents relevant European labs at HEIs and best practices for implementation, running, and curriculum-integration of labs in the fields of architecture and urban planning. The underlying investigation for that spanned from May to September 2024 and involved coordinated research activities.

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The report is divided into two main sections:

1. **Best practices in lab development:** This section examines exemplary models of lab structures, governance, and funding, as well as their learning approaches.
2. **Best practices in educational program content:** This section highlights curriculum development strategies that align with sustainable urban development and promote key competencies in sustainability.

The report concludes with a summary of outcomes and recommendations for the next steps of the project.

Methodology

This report employs a multi-method approach, including desk reviews, surveys, interviews, and content analysis. This triangulation method ensures a comprehensive understanding of existing practices and potential innovations in HEIs across Europe.

[1] For simplicity, the term "lab" will be used as an umbrella term throughout.

1. **Desk Reviews**: Comprehensive reviews of literature and case studies were conducted to gather data on lab development and curriculum innovation. It involved assessing various case studies of lab experiences and their management frameworks.

2. **Targeted Survey**: A survey was administered to labs and similar entities at HEIs to collect first-hand insights and validate findings from the desk reviews. The survey included questionnaires completed by EU-HEI academic staff and field experts, focusing on general lab information, addressed topics, infrastructure, governance, teaching, and challenges.

3. **Interviews**: Qualitative, semi-structured interviews were conducted with international stakeholders, including heads of schools, professors, and program and course officials.

4. **Content Analysis**: This involved analyzing advanced curricula to identify key elements that contribute to integrating sustainable aspects in architecture education. The analysis focused on master's programs in Europe, with an emphasis on identifying needs and challenges.

Conceptual Framework: A Didactic Workshop on the notion of lab

An important component of this project was a didactic workshop,[2] which offered a theoretical framework for the reconsideration of the role and organization of labs in HEIs. The workshop proposed a shift from viewing labs merely as physical facilities to recognizing them as academic innovation hubs—entities that are multifunctional, hybrid, integrated, and networked. The workshop served as the background and starting point of this study to further develop the project's vision for Pro-GREEN LABs (PGLs). Four key features were identified:

1. **Hybrid Nature:** Each lab is envisaged to serve multiple roles, acting as an enabling learning environment, a networking hub, and a center for further development. This hybrid nature ensures that labs can adapt to various educational and research needs, fostering a dynamic and engaging learning experience.

[2] The workshop was held online on June 2024. Its outcomes are reported in Appendix 1.

2. **Integration and Networking:** Labs should be seamlessly integrated into the organizational structure of their host universities while maintaining robust connections with local, regional, and international stakeholders. This networked approach enhances collaboration and resource sharing, amplifying the impact of each lab.

3. **Autonomy and Sustainability:** Each lab is designed to function as a quasi-independent entity with its own management structure, allowing for a significant degree of self-governance. Financial sustainability is also a key consideration, with labs expected to combine internal and external funding sources to maintain operations beyond the initial funding period.

4. **Ethical and Sustainable Practices:** Upholding principles of sustainability and social responsibility is critical. Labs must ensure that their practices are genuinely compliant with ethical standards, avoiding greenwashing and promoting real, impactful change.

The report's focus includes identifying relevant best practices from EU-HEIs, examining educational program content for curriculum development, and providing a concise document outlining the findings to inform the development of next work packages. The aim is to create a state-of-the-art report that showcases best practices but also provides actionable insights for enhancing HE relevance to the labor market and society.

2. Benchmarking Labs

2.1. Introduction

The aim of the benchmarking labs is twofold: (i) to learn about the best practices of labs in HEIs; and (ii) to collect the necessary information in order to define criteria for a new model of PGLs. The research concentrates on the present state of labs within HEIs, particularly the teaching methods and strategies that were used to incorporate sustainability into the teaching curricula of urban planning and architecture.

Our objective is to gain a comprehensive understanding of HEI labs across Europe, focusing on several key aspects. Specifically, we aim to explore:

- **Infrastructure and Space**: What types of infrastructure and spaces are utilized by these labs?
- **Human Resources**: What is the composition of the teams working within these labs?
- **Topics Addressed**: Which specific sustainability-related topics are these labs tackling?
- **Governance and Management Models**: How are these labs governed and managed?
- **Relation to Teaching**: How do these labs integrate with and contribute to teaching curricula?
- **Perspectives**: What are the future directions and aspirations of these labs?

Methodology

Our approach to mapping these labs was a combination of two methods:

1. **Desk Research**: We conducted a benchmarking analysis using available online information to identify and analyze existing labs in HEIs.
2. **Survey**: We distributed a structured survey to collect data directly from the labs, ensuring a comprehensive and uniform dataset.

This investigation was launched in April 2024 and concluded with the final report in mid-September 2024. In this period, we were able to conduct an in-depth study, collect, process, and compile the data that is necessary to provide a detailed and insightful report. In doing so, we intended to develop a solid educational benchmarking report that will be a significant tool for comprehending the labs' role and impact in HE, especially in sustainability education.

In the following two chapters, we present first the outcomes of the desk research and then the results of the online survey.

2.2. The desk research

The goal of this desk research was to benchmark labs within HEIs. This analysis aimed to identify and understand the scope, structure, and impact of these entities, providing a comprehensive overview of how labs function across different HEIs in Europe. Through the literature review, and informed by our expertise from POLIMI labs, we identified crucial features that we broadly divided into the categories: social and technological (Figure 1).

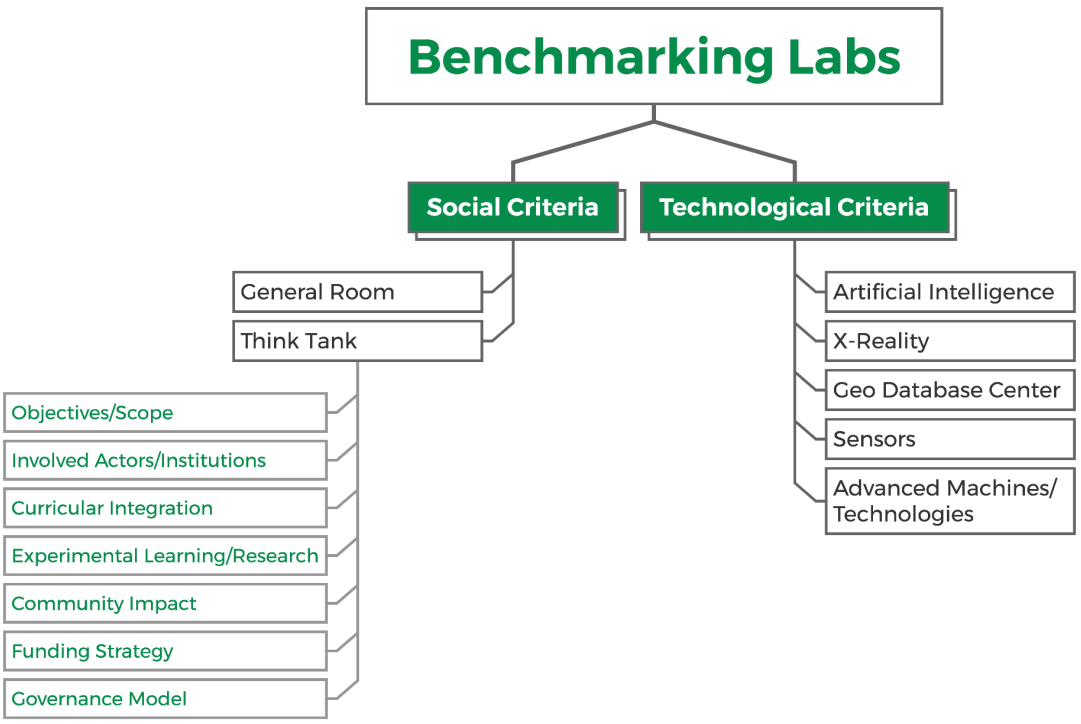

Figure 1: Identified criteria to analyze in-depth different labs (created by F. Werner).

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The selection of our case study labs was based on three different approaches. First, we looked at the top ten universities in the field of architecture and built environment and reviewed the European ones (QS TopUniversities 2024). Secondly, we selected relevant case studies that are mentioned in the literature. Thirdly, we scrutinize the labs from our consortium's European partner universities, i.e. the Bauhaus University Weimar (Germany), Chalmers University of Technology (Sweden), and Politecnico di Milano (Italy). Through this selection process, we analyzed 15 labs within European HEI (Figure 2).

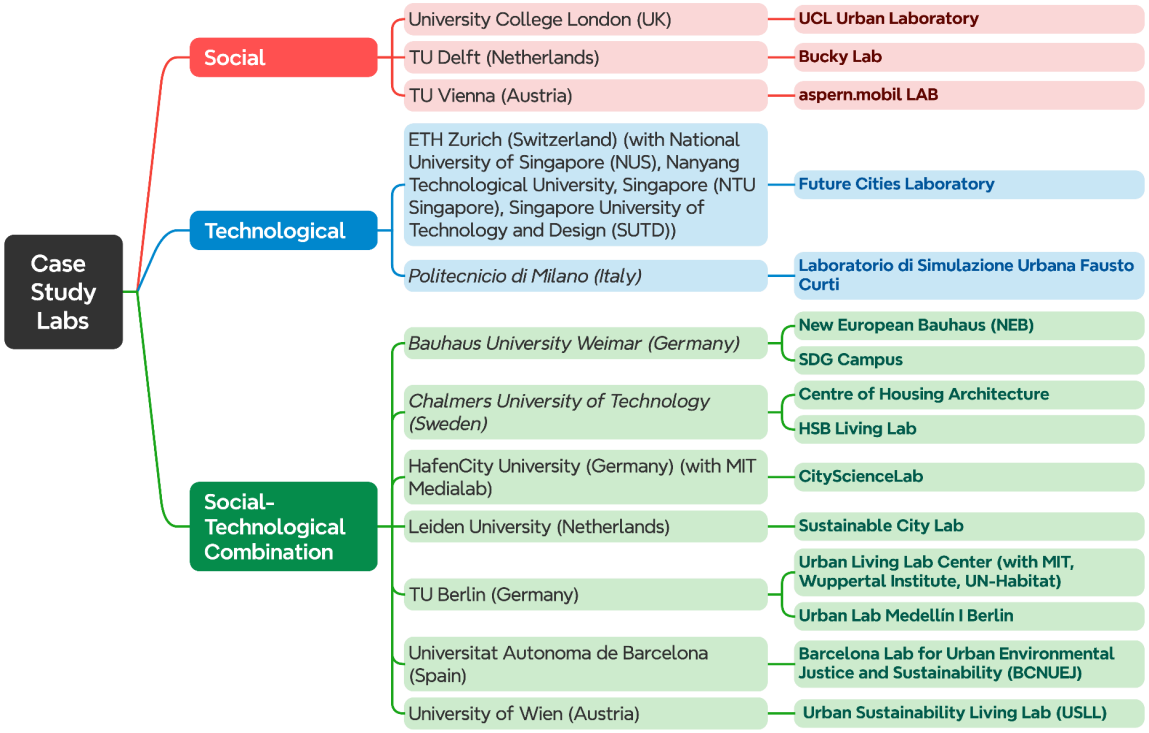

Figure 2: Overview of the 15 investigated case studies, including the differentiation into social and technological foci or a combination of both. The project partner universities are set in italics (created by F. Werner).

The research was conducted through desktop analysis, utilizing publicly available online information on the web pages of the identified labs. This approach allowed for the collection of consistent data. The overview presents the most important results across the various case studies based on the selected criteria.

Social Criteria:

Research and action of the lab focus on the functioning of the city, promoting social participation, building cooperation between inhabitants, and developing grassroots local initiatives. Testing and implementing innovations in the real world also play an important role here. The understanding of labs follows here what Backhaus et al. (2023, p.235f.) describe as "engaging non-academic actors in participatory processes for sustainability transformations."

Think Tank

A think tank is a place for temporary workshops (physical or platform). They are involved in both education and research, stimulating a lively collaboration between students, academics, and public and private partners. It can be used to empower the decision-making processes of architects and urban planners.

Some of the investigated labs do have a kind of think tank in the sense of a physical space for workshops, meetings, and learning. The *Bucky Lab* at the TU Delft inspired this category. This lab is described as "a 'think tank' and a design and engineering course for students following the master's programs Building Technology and Architecture" (Bucky Lab, n.d.). It is a physical space for exchange and teaching as well as hands-on learning. The *UCL Urban Laboratory* is a cross-disciplinary department of the Bartlett Faculty of the Built Environment at the University College London (UCL) that focuses on innovative research, teaching, and outreach in urban studies. In doing so, it provides the *UCL Urban Room*. This is a "space for events, exhibitions, workshops, and engagement with local stakeholders, professional audiences, and the wider public in east London" (UCL Urban Laboratory, n.d.). The purpose of this think tank is "to create opportunities for academics, students, and partners to be exposed to each other's work and initiatives. It operates as a research-led teaching resource for two associated Masters programmes, Urban Lab's Global Urbanism MASc and Public History MA (History), as well as a space for engagement and participation by the wider academic community" (ibid.).

As relevant **subcategories of a think tank**, we identified: objectives & scope, involved actors, curricular integration, experiential learning approach, community impact, funding strategies, and governance model. Based on

these subcategories, the best practices are highlighted and described in more detail. For a few categories, we provide the range of practices that we found. In this case, we were unable to identify any particular best practices based on the information available online.

Objectives & scope: There is a broad variety of objectives targeted in the labs. Some have a more concrete focus (e.g., aspern.mobil LAB) while others cover a wide range of topics (e.g., Future Cities Laboratory). The *aspern.mobil LAB* works specifically on innovative mobility aspects in the location of Seestadt, Austria. The *Future Cities Laboratory* works globally in Zurich, Singapore, and beyond with projects on different challenges of global environmental sustainability in cities. The *UCL Urban Laboratory* brings together expertise from various disciplines such as geography, architecture, engineering, the arts, and social sciences to explore the complexities of cities and urban life. This lab engages in projects related to global urbanization, sustainability, inequality, and cultural diversity. It serves as a platform for critical thinking on urban issues, with a particular focus on social justice and environmental sustainability in cities worldwide. The different scope and focus of the labs partly depend on the size of the lab.

Involved actors: In the labs, there are a broad variety of actors involved. Some involve more and some fewer actors in their daily work and lab projects. Below, we have identified a list of the different actors who are part of the investigated labs, clustered in four broad categories.

Local Actors	Academic Actors	Architectural & construction actors	Administrative & political actors
Residents	Students	Architects	Municipalities
Local communities	Researchers	Architectural offices	Regional authorities
Neighborhood management offices	Academic institutions	Public housing companies	National authorities
Community-based organizations	Other labs	Housing cooperative organizations	
Civil society		Construction companies	

Table 1: Overview of involved actors.

Curricular Integration: The range of curricular integration varies between non-integration (Future Cities Laboratory is only doing research), the supervision of Master theses or PhDs to the integration of case studies, design assignments or analysis from involved projects. The *SDG-Campus* sole focus is on providing various courses on the different SDG goals. One of the main purposes of the *Urban Sustainable Living Lab* at the University of Vienna is giving courses in the fields of geography and urban planning. The *UCL Urban Laboratory* provides the entire study program for the Master of Arts and Sciences Global Urbanism. Other labs are doing lectures or summer schools (e.g., Urban Lab Medellín|Berlin).

Experiential learning approach: Just a few of the labs provide information about their learning and teaching approaches (e.g., SDG-Campus[3], Urban Sustainability Lab[4]). The *Urban Living Lab Center* (ULLC) at TU Berlin has a specific education program and can therefore be considered as a best practice. It is based on seven key aspects: skill development, experiential learning, workforce development, research support, interdisciplinary learning, networking and collaboration, and lastly long-term impact. Hands-on learning in different formats, development of practical skills regarding sustainability are key features. In the real-world-lab, students learn and work within global projects that foster competences useful to meet industry needs. The ULLC education program addresses students as well as future professionals (Urban Living Lab Center, n.d.).

Community impact: Not every investigated lab has stated their impact on local communities. Some of them claim this as a goal, but in their online presence, there is not much information about it. One best practice in this regard is the Urban Lab Medellín|Berlin. The central focus of the lab is on exchanging knowledge between an informal neighborhood, a city in Columbia, and experts and students from Berlin, Germany. The goal is to support the community and involve them in the transformation of their neighborhood. A very concrete local impact due to the lab is described in the following quotation:

[3] https://www.uni-weimar.de/en/university/teaching/interdisciplinary-teaching-and-learning/sdg-campus/.

[4] https://urbanlab.univie.ac.at/en/activities/teaching/.

> "As part of the Spring School Moravia 2017 and within three weeks of collective construction work - as a collaboration between residents, student, artists, craftsman, volunteers, and actors from the public and private sectors - a new connecting link and public space was created: 101 steps were newly poured in concrete, a community garden was planted, urban furniture were added, drainage system and solar-powered night illumination were installed, and all of the walls along the stairs were colorfully painted by neighbors and local artists. The project created overwhelming responses and immediate impacts on local appropriation and microeconomics [...]" (Urban Lab Medellín|Berlin, n.d.).

Another best practice that is more technological-oriented is the *Chalmers HSB Living Lab*. It is a combination of a residential building and research space. In 2016, the building located on the Chalmers Campus was built. It provides accommodation for students and guest researchers and is a place of research. For example, there is a lot of technological infrastructure (e.g., in-wall sensors, solar panels, ventilated wardrobe) already installed during the construction process to test, evaluate, and improve smart technology in a residential context. Due to evaluation processes and the actual living of people there, it has a concrete impact locally (HSB Living Lab, n.d.; Chalmers, n.d.).

Funding strategies: On the web presence of the labs, only a few give some information about their funding scheme. Within the *Urban Living Lab Center* or the *Barcelona Lab for Urban Environmental Justice and Sustainability* projects are funded by the EU. The *aspern.mobil LAB* is funded by the Austrian Federal Ministry of Climate Action, Environment, Energy, Mobility, Innovation and Technology. For the majority of cases, we could not find any information about the funding online.

Governance Model: Similar to the funding strategies, the web pages do not offer much information about the governing structure of the labs. Just a few provide some insights into their governance model. For example, the *Future Cities Laboratory* offers some insights into their organizational structure via an organigram where they display the two hubs of the lab in Zurich and Singapore and the relevant directors.

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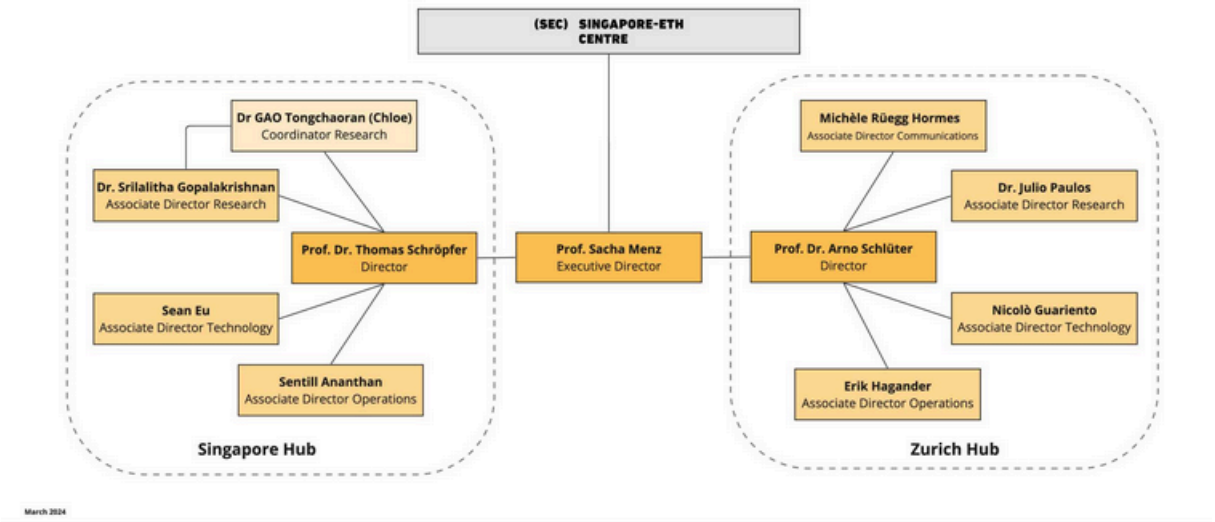

Figure 3: Organigram Future Cities Laboratory Global (Future Cities Laboratory 2024).

General Room

The General Room plays an important role in education, research, and model-making. It helps students understand spatial relationships, material properties, and structural integrity. The General Room can serve as a collaborative workspace where students and stakeholders work together on projects. This fosters teamwork, communication, and project management skills, which are essential in professional practice. It is a space where students can work autonomously on their projects/works and where equipment is made available to students. There, the students are trained to use specific equipment. The General Room contributes to enhancing teaching activities and sustainability content for students and civic society. A best practice for the general room can be found at LABORA at POLIMI. The AULA classrooms in LABORA offers 34 workstations and various tools for model building, with access for students and researchers to specific materials and specialized labs. Special equipment such as electric drill for small holes, guillotine cutter for strips, compass cutter, metal brackets or clamps can be provided by the staff. Recycled materials as well as paper, cardboard, acetate, methacrylate sheets, profiles, veneers, and scraps of expanded plastics are always available for use in this general room.

Technological Criteria:

Research and action of the lab focus on activating an innovative ICT sector, conducting research related to urban technological innovation, and opening and sharing urban data. The understanding of labs follows here what Backhaus et al. (2023, p.235) described as "focusing on the optimization and application or implementation of innovative technologies." Advanced technological features including X-Reality, sensors, 3D printers, a geodatabase center, sensors, and AI, which provide relevant tools for exploration and innovation.

A best practice in this category is the *Laboratories* at POLIMI. A wide range of technological infrastructure is available and used here. LABSIMURB employs cutting-edge investigation and simulation techniques to address urban design and modeling. In AI, the AIRLab conducts research in Artificial Intelligence, robotics, and Human-Robot Interaction. For X-reality, the *Virtual Theatre* promotes research in physical model creation and digital visualization with tools like a hologram table and immersive 360° virtual theater. Furthermore, I.drive provides immersive environments for visual interaction and behavioral modeling in human-vehicle studies. The MAUD lab serves as a geodatabase center, specializing in statistical analysis and urban cartography. Advanced technologies are supported by the 3D PRINT LAB, enhancing modeling with prototype creation. Lastly, the *Indoor Quality Lab* assesses indoor air quality using advanced sensors to measure various environmental parameters. Similar cutting-edge technological features can be found at Chalmers University of Technology at its institutions *Centre of Housing Architecture* and *HSB Living Lab*.

2.3. The survey

To gain insight into the current status of labs affiliated with Higher Education Institutions (HEIs), especially regarding their approaches to integrating sustainability into curricula for urban planning and architecture, we conducted an online survey. This survey aims to collect crucial data that will enable us to assess how these educational initiatives contribute to promoting sustainability. To delve into their operations, challenges, potential solutions, and key aspects, we distributed the survey to 48 such labs. The distribution of different sources used for selecting these labs is as follows:

- Top-ranked universities according to QS World University Rankings (QS): 11
- Literature review: 4
- Project universities: 16
- Google searches for: Sustainable lab + higher education: 5
- Sharing the link with colleagues or partners: 12

The questionnaire was distributed through an online Google Form. The questionnaire was shared via email starting on July 1st, with an initial deadline of two weeks. However, the deadline was later postponed until July 22nd.[5]

It contained 31 questions which were divided into five subsections:

1. **General Information** (8 questions): Collect some general information such as the name, location, name of university, website address, date of establishment, types of spaces, number of staff of labs.

2. **Topics** (7 questions): Questions related to the motivation behind establishing and purpose, scales of the work, technologies, and main topics addressed at the lab.

3. **Governance and Management** (6 questions): Questions related to how to finance, who the participants are, what form of evaluations are used, and main environmental sustainability practices at the lab.

4. **Teaching** (4 questions): Questions related to the way of association with academic teaching, the characterization of the learning approach, and the kind of disciplines and green competencies are mainly involved in the lab

5. **Challenges & Perspectives** (6 questions): Questions related to challenges during the foundation phase and what they are facing now in the lab and also any suggestions if they have for establishing Pro-GREEN LABs

[5] The cover letter and the questionnaire (including the answers) can be found in the appendix (Appendix 2, Appendix 3).

Results and identification of best practices

We received 18 responses from various labs. These entities are involved in diverse areas of sustainability, from health and well-being to mobility and accessibility. The participating labs include (Figure 4):

1. Center for Healthcare Architecture (Chalmers University of Technology, Sweden)
2. Regional Labs (Bauhaus-University Weimar, Germany)
3. SDG-Campus (Bauhaus-University Weimar, Germany)
4. Sustainable Urban Regeneration Lab (Sur Lab) (Bocconi University, Italy)
5. UCL Urban Laboratory (University College London, United Kingdom)
6. Mapping and Urban Data Lab (Politecnico di Milano, Italy)
7. The Green Village (TU Delft, Netherlands)
8. Research Centre for Territory, Transports and Environment (CITTA) (University of Porto, Portugal)
9. Laboratory of Building Materials (Aristotle University of Thessaloniki, Greece)
10. Transport Systems Research Group (TSRG) (Aristotle University of Thessaloniki, Greece)
11. Mobility Lab (University of Tartu, Estonia)
12. Urban Challenge Studios (course) (Aalto University, Finland)
13. LaborA (Politecnico di Milano, Italy)
14. Indoor Quality & Ergonomics Lab (Politecnico di Milano, Italy)
15. i.Drive (Politecnico di Milano, Italy)
16. Building Theory and Design-PhD Programme (Mimar Sinan Fine Arts University, Turkey)
17. Laboratorio di Simulazione Urbana Fausto Curti (Politecnico di Milano, Italy)
18. Chair of Urban Design and European Urbanism (RWTH Aachen University, Germany)

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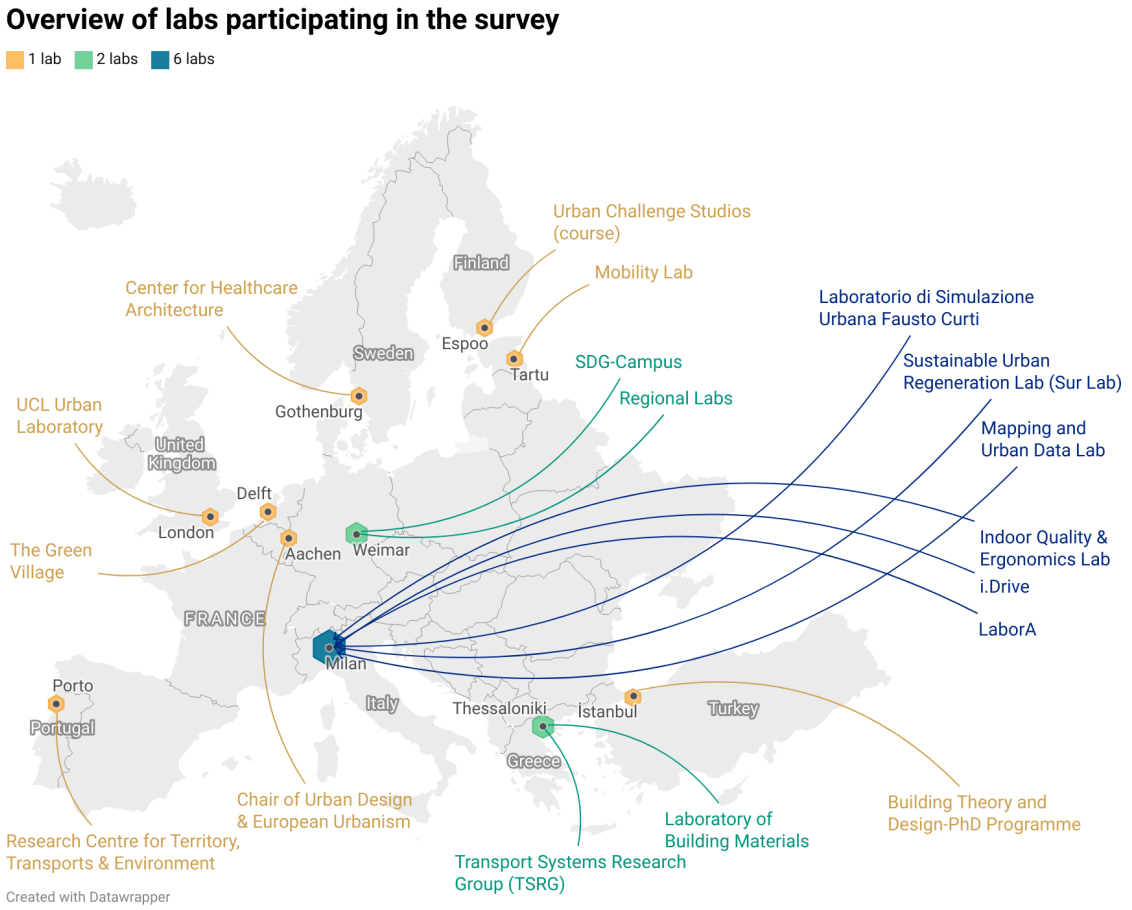

Figure 4: Locations of the Labs (created by F. Werner).

Timeframe: The establishment years of these labs vary, reflecting both long-standing and newly founded entities. The oldest one, the *Laboratory of Building Materials* at the Aristotle University of Thessaloniki was founded in 1960 and the newest labs are the *Regional Labs* and the *SDG-Campus* at the Bauhaus University Weimar, which have existed since 2022.

Spaces and size: The labs used a variety of spaces to support their activities, ranging from physical spaces for workshops, teaching, and collaborative work to digital platforms (Figure 5). Notably: Labs like *The Green Village* (TU Delft) and *Research Centre for Territory, Transports and Environment* (University of Porto) have extensive physical and technological facilities. Some, like the *SDG-Campus*, operate only digitally.

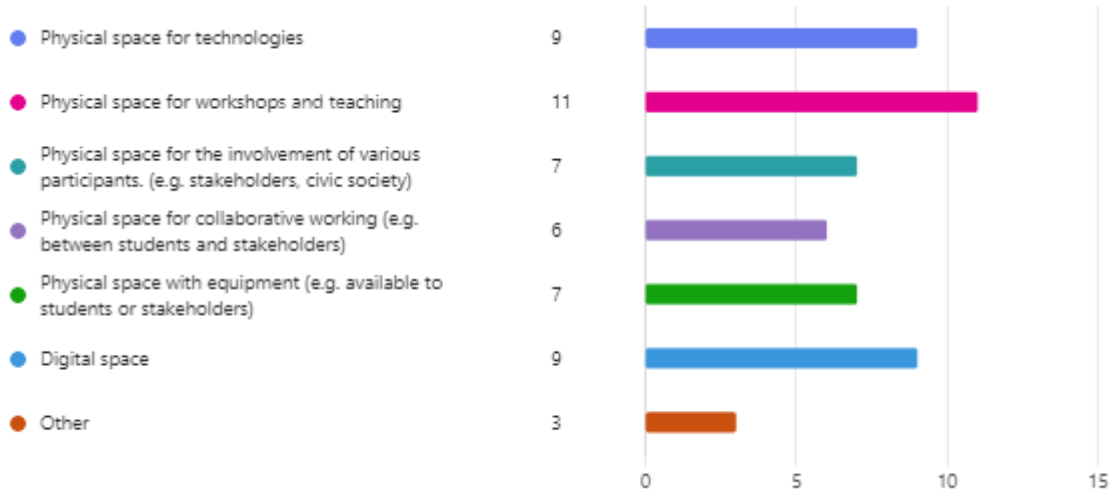

Figure 5: The type of labs' spaces.[6]

The size of the physical spaces varies significantly. The smallest ones have less than 50 m² (seven labs (38.88%)), which is at the same time the majority of labs. The largest ones have more than 500 m² available space (The Green Village, Laboratory of Building Materials (11.11%)).

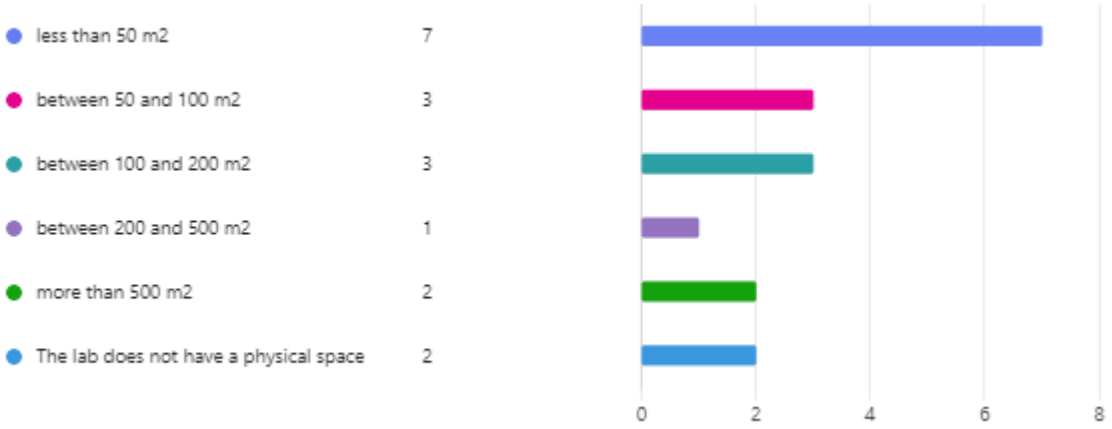

Figure 6: The size of labs.

Staffing: The staffing structures of the labs include a mix of permanent and temporary and full-time and part-time staff. This includes professors, PhD candidates and research fellows, administrative and technical staff as well as interns and trainees. Permanent full-time teaching staff (professors) and temporary full-time staff (PhD candidates, research fellows) show

[6] This and the following figures were created with the Google Form.

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higher counts in the 3-5 range. Part-time staff, administrative staff, technicians, research staff, and interns/trainees are more commonly found in lower numbers, typically in the 0-2 range.

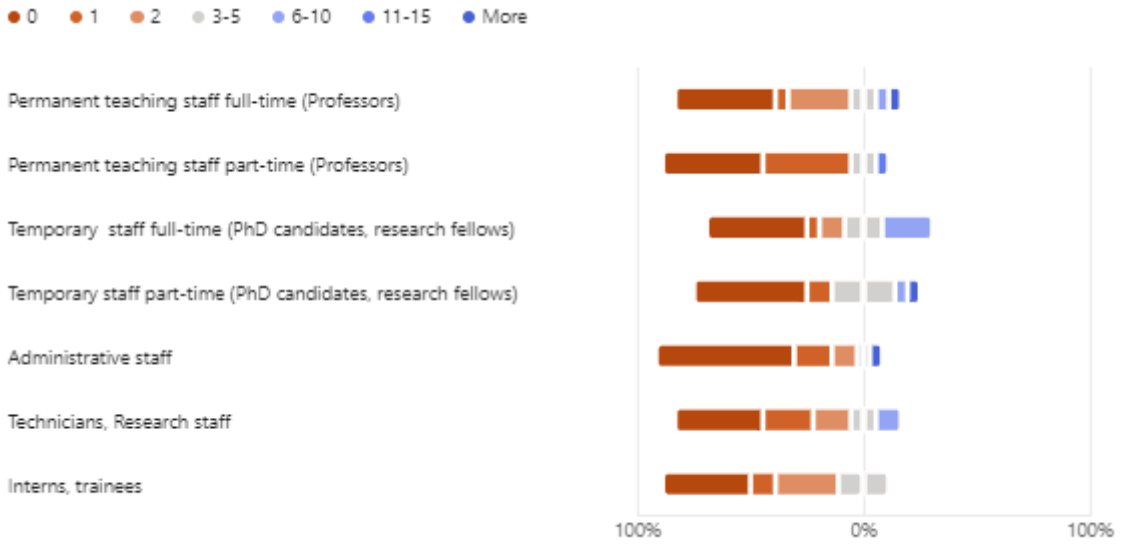

Figure 7: The staffing structures of the labs.

Founding reasons: The primary motivations behind establishing these labs include:

- Promoting interaction between academia and practice
- Fostering interdisciplinary collaboration
- Bridging the gap between theoretical research and practical applications

Topics: The labs focus on various sustainability-related topics. These are the five most prominent topics according to the answers:

- Sustainable urban planning and development (13 labs)
- Social sustainability and equity (10 labs)
- Health and well-being (9 labs)
- Environmental Quality (9 labs)
- Mobility and accessibility (8 labs)

Addressed Scales: The labs address issues at multiple scales:

- Labs focus on: local (14 labs), regional (11 labs), national (12 labs) scale

- Labs focus on: neighborhoods (11 labs), street (10 labs), cities (11 labs)

Technology: The labs employ a wide range of technologies to support their research and teaching:

- Environmental and energy sensors (11.1% of labs strongly used)
- Advanced machines and techniques (e.g., 3D printers, robots) (16.7% of labs strongly used)
- Artificial intelligence (22.2% of labs used)
- X-Reality (e.g., AR, VR, VT, MR) (22.2% of labs strongly used)
- Geo-databases (22.2% of labs strongly used)
- Modeling and simulation software (22.2% of labs strongly used)

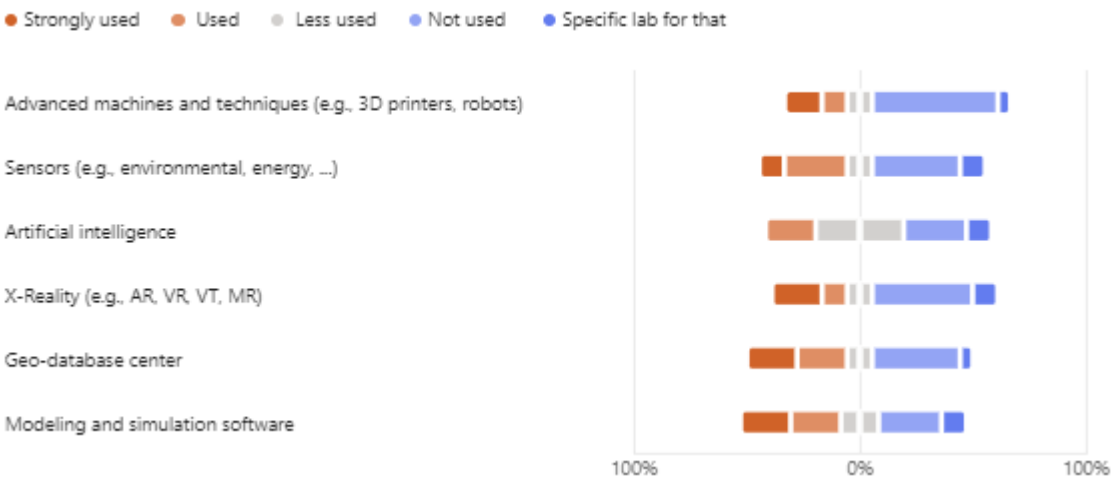

Figure 8: The types of technologies which labs are using.

The answers to another question, asking whether any additional technologies are used, reveal that these categories comprehensively cover all the technologies employed, and there are no other technologies in use beyond those listed.

Funding: The answers illustrate the reliance of labs on various funding sources. Home University funding is the most consistently relied upon source, with 27.7% (5 out of 18) indicating that it is "always relied upon" and 22.2% (4 out of 18) stating it is "often relied upon". National or governmental funding is also significant, with 16.7% (3 out of 18) respondents marking it as "always relied upon" and another 27.8% (5 out of 18) marking it as "often relied upon". Contrary, funding from other universities/academic institutions and international organizations is generally not a primary

source, with the majority of respondents either rarely or not at all relying on them. Private sector funding shows moderate reliance, with 11.1% (2 out of 18) indicating "always relied upon" and 16.7% (3 out of 18) indicating "often relied upon". NGOs and Foundations are the least relied upon, with only 11.1% (2 out of 18) of respondents indicating "always relied upon". European research funding is occasionally relied upon, with about 27.7% (5 out of 18) indicating they "often" or "always" rely on it.

Composition of board members: The largest group represented consists of "academic staff or professors of the same university" (12 out of 18). This is followed by "academic staff or professors outside the same university" (7 out of 18). Students make up the third-largest group (6 out of 18). "University staff or technicians" are represented in four labs, while "external stakeholders" are in three labs part of the board.

Involved entities: Universities and research institutions have the highest engagement, with substantial segments in high (44.4%) and moderate (33.3%) involvement. Public authorities at both national and local levels show significant moderate involvement, though national authorities also have notable segments of no involvement. Entrepreneurs and private companies display a balanced involvement across all levels. NGOs and local activists exhibit considerable moderate and high involvement, while citizens mainly have no involvement, with some participation in minimum and low involvement. Overall, universities and local governments are the most actively involved, whereas national governments and citizens exhibit more diverse levels of engagement.

Focus of evaluation and monitoring: Most of the labs (14 labs) use internal evaluation. About focus areas in the evaluation or monitoring procedures of labs: research (50%), collaboration (50%), and training (41.2%) are the primary focal points, while safety compliance and staff management receive a more varied level of attention.

Sustainable Practices: The three main environmental sustainability practices at the labs are as follows:

- Energy savings (66.66%)
- Recycling of materials and waste (50%)
- Sustainable mobility (44.44%)

Involved Disciplines: The disciplines involved in the labs are diverse, mainly focusing on urban planning (66.66%), urban studies (61.11%), and urban design (55.55%). Many responses also highlight architecture (50%), built environment and engineering (50%), social science (50%), and environmental science (44.44%), emphasizing the integration of technical, social, and environmental perspectives. Geography and transportation and mobility are also mentioned in some labs, indicating a spatial and sustainable transport focus.

Teaching: Furthermore, the responses indicate that academic teaching and labs are closely intertwined in multiple ways. Most notably, many labs offer courses embedded in the study curriculum (72.22%). Additionally, they are involved in supervising theses at various academic levels (BA, MA, and PhD), suggesting a significant role in guiding research and scholarly development (77.77%). Internships are another common linkage, providing practical, hands-on experience in the lab setting (66.66%). Also, the most frequent learning approaches are: active learning (66.66%), which engages students directly in the learning process; problem-based learning (44.44%), which focuses on solving complex, real-world problems; and challenge-based learning (38.88%), which involves tackling significant challenges or questions. Experiential learning is also noted, highlighting a focus on hands-on, trial-and-error experiences. Only some responses indicate the inclusion of technology-based learning and evidence-based design.

Green competencies: About green competencies (knowledge, behaviors, attitudes, and skills) that are necessary to be in the curriculum for achieving a sustainable future of the built environment and society, core themes of answers include an emphasis on knowledge—such as understanding climate change, environmental impacts, and resource limits—and practical skills like systems thinking, interdisciplinary integration, and evidence-based decision-making. Attitudes such as critical thinking, social and political engagement, and a positive mindset toward societal challenges are also highlighted.

Challenges during foundation phase: The answers show that securing funding and grants is the most significant challenge during the foundation phase, rated “high” by most respondents (68.8%). Procuring equipment,

setting up labs, and hiring staff have mixed difficulties, ranging from "low" to "high" Training staff and establishing protocols are generally less challenging but still notable. Integration within the university and working with external stakeholders present minimal to moderate issues. Building collaborative networks with other labs is a significant challenge for many. Overall, funding is the primary concern, while other challenges vary widely among respondents.

Current challenges: Also, about the challenges they are facing in the presence, responses indicate that maintaining funding and grants is a significant challenge (61.1%), with most respondents rating it as "high". Equipment maintenance and upgrades show mixed levels of difficulty, ranging from "low" to "high". Managing lab personnel and dynamics also varied, with some facing high challenges while others experience minimal issues. Securing collaboration with external partners and staying current with new technologies and methods generally present moderate to high difficulties for many respondents. Overall, maintaining funding is the primary concern, while challenges related to equipment, personnel management, collaboration, and technology adoption vary widely among respondents.

The additional challenges identified include a lack of organizational flexibility from university administration, ongoing development and scale-up challenges for labs, and issues related to recognition and securing space within the university. These responses highlight the importance of administrative support, strategic planning for lab growth, and institutional recognition in addressing the comprehensive needs of lab operations.

Recommendation for PGLs: The recommendations for implementing Pro-GREEN LABs at a HEI include hosting international meetings and training sessions, integrating with transportation and mobility, and being clear about key performance indicators. Emphasis is also placed on developing a critical approach to sustainability to avoid greenwashing, promoting action research, and engaging with real-world applications through continuous stakeholder engagement.

3. Relevant Educational Program Content

3.1. Insights from experts into the teaching of sustainability aspects in architectural education

This is the outcome of an investigation into curricula and modules with a focus on architectural design, which include a strong environmental agenda. The method was qualitative, semi-structured interviews on Zoom with international stakeholders in the field. The plan was to have ten interviews with heads of schools, professors, and program/course officials of eight European countries. All interviews got permission to be recorded and can be transcribed. The outcome is, only seven of the ten participants who originally accepted the invitation could schedule the agreed interview until now.

The range of the selected schools is expansive, from strict Technical Universities to Architectural institutions with a strong artistic focus and little technological education, and institutions which combine both. All interviewees were active in Architectural Master education with a focus on sustainability. The countries are Finland, Sweden, Denmark, Austria, Estonia, and Norway.

Out of these seven interviewees, one is the head of faculty, three are professors in sustainable architecture/design, two are program leaders of Master programs in sustainable architecture, one is an associate professor in sustainable design and responsible for the whole institution's environmental program.

The interviews were focusing on three main questions:

1. What is the state/role/relevance of environmental sustainability and programs/ modules/ courses for sustainable architecture, in the architectural education of the interviewee's institution?

2. What are the main achievements/ challenges and obstacles for improvement and progress in the field – in particular in the light of the climate emergency?

3. What can be considered or imagined, to be a Lab for Sustainable Design, like Pro-GREEN LABs?

Apart from the fact that the interviewees, as mentioned before, act in different types of universities, it became visible how education for sustainable architecture to some extent mirrored the practice and some different environmental challenges in each specific country. While in Estonia, the history with and the neighborhood to an aggressive country is a key question of resilience and stands in the foreground of awareness with consequences in spatial education, in Norway one focus was on changed patterns of local tourism after COVID-19.

When it came to answering the three main questions, which were embedded in a number of sub-questions during the interviews, the answers were more homogeneous than it could be expected from the different institutions.

State and relevance of environmental sustainability in architectural programs, modules, and courses

In the answers to question one about the state/role/relevance of environmental sustainability in architectural programs, modules and courses it became apparent, that if the university has an overall policy strategy and focus towards sustainability, this has a strong positive impact to the education in the departments of architecture and civil engineering, the type, and number of courses offered with environmental agendas, the staffing as well as the connection between research in the field and education.

The official for the Master program in Architecture of Chalmers (Sweden) expressed that "sustainability is a main agenda for the whole University, all departments, and all programs need to be aligned, which has increasing visibility."[7] Thus, the master program "*Architecture and Planning beyond Sustainability* offers a large variety of courses, with different perspectives and scales, for the design and transformation of the built environment."

At NTNU Trondheim (Norway), "sustainability is very central in the whole university, in a lot of places, but different groups have different priorities. It does require a lot of rethinking of values, especially in architecture, but also

[7] This and the following quotations in chapter 3.1. come from the (transcribed) interviews with stakeholders.

in engineering. It does require a little bit of value seeking among the engineers."

In contrast, where this "top-down" policy is missing, the courses depend very much on the individual ambitions, competences, persistence, and energies of the course officials and involved teachers, which often generate remarkable results, but remain niche-activities inside an institution, which otherwise appears to be ignorant towards questions of sustainability in the built environment. Or like one interviewee expressed it: "The department educates for the status quo rather than for challenging the status quo […] and there is very little collaboration across the school's departments."

In the institution of one interviewee, there is "a new curriculum starting 2024; the students are demanding it and therefore teachers realize that they have to be able to answer some of these [environmental] questions and provide some of the answers." In this new curriculum "sustainability is supposed to be integrated in all tracks, so there is no specific track anymore, everything and in general is supposed to become sustainable, which very much blurs the concept […]."

It was argued that however desirable an overall integration of environmental questions and assessments in architectural education would be, its mere proclamation and generalization without strong competences and advanced training of the staff rather results in outcomes of greenwash.

Main achievements, challenges, and obstacles for improvement and progress in the field

The answers of all interviewees to the second question - what are the main achievements/ challenges and obstacles for improvement and progress in the field, in particular in the light of climate emergency - can be condensed in one imperative statement: "The (missing) qualifications of teachers in the field are the key challenge for stepping forward and progressing to an environmentally responsible architectural education."

"The main challenge is the missing knowledge of teachers and the motivation to develop their own knowledge and skills"; "make sustainability clearer in our education, I mean more visible, more part of the making. And we have very few courses, where students/teachers in architecture

collaborate in the same project with students/teachers in engineering"; "there is a huge resistance and many teachers don't understand the urgency or the importance of what we do", to quote some interviews.

"Students have kindly complained that they don't have enough sustainability." Or "the main challenge is upskilling both staff but already graduated architects, so I think there's a massive need to bring the knowledge to the people that have already had education. I think the current students, a lot of them just by default, will get a lot more knowledge about sustainability."

One interviewee brought the needs to the point by saying "Upskill! Upskill! Upskill!"

All these responses certainly support the need for building up Pro-GREEN LABs and enhancing the qualification of teaching staff regarding the questions of the impact of buildings on the environment. Some interviewees made clear that many of their fellow teachers are concerned about climate change and resource depletion, but do not connect these existential questions with the discipline of architecture.

Lab for sustainable Design

The third question addressed very directly our goal to build up a lab: What can be considered a Lab for sustainable Design, like Pro-GREEN LAB? Furthermore, here, the answers were quite homogeneous. "A lab is an ecosystem of constant testing and accumulative knowledge. It doesn't necessarily need to be a physical space, but some kind of community of persons, who continue testing things and systematically utilize that information [...]. Super open and collaborative approaches, but rather deep knowledge."

Or a "lab is an intellectual space for trying out things", another interviewee thought that a "Pro-GREEN LAB would be really questioning, what is it to be an architect? And I would throw that completely open and unpick those myths because I also think the students, we get in year one are very open-minded and something happens along the way. They become more closed-minded because they start to think about what it is to be an architect."

Other answers were "the notion of a lab is good, it needs to be interdisciplinary, experimental, connecting architecture with other disciplines" or "a Lab is a space for experimentation, but what is the objective?" One interviewee stated: "I participated in living labs that are so tightly controlled by researchers because the researchers [...] promised results and you know, and then it becomes like, you could basically write down the results beforehand on a piece of paper because you guide everything to get the answer you want, and that's not really a lab, it's more a verification process of a concept."

Openness, inter- and trans-disciplinarity, experimentation, testing, intellectual space could be extracted as keywords from these answers. It is significant that none of the responders mentioned a lab as a space with physical tools and instruments. It must be said that all interviewees were trained architects, and this might be different by asking civil engineers, who also are involved in architectural education.

3.2. Current curricula and modules in architectural education with sustainability aspects

This content analysis involved a detailed web-investigation for advanced curricula, identifying key themes and elements that contribute to effective learning environments and sustainable urban development. The investigation looked at how HEI in architecture, with explicit Master programs in sustainable architecture, present these programs and their curricula on their webpages. Nine institutions were examined, including the ones, which are the workplace of the participants in the semi-structured interviews.

University	City	Country	Master Programme
Technical University of Munich	Munich	Germany	Resource-efficient and Sustainable Building
Aarhus School of Architecture	Aarhus	Denmark	Teaching program "Radical Sustainable Architecture"
Tallinn University of Technology	Tallinn	Estonia	Open Urban Sustainability Hubs

University of Stuttgart / Ain Shams University	Stuttgart/ Cairo	Germany/ Egypt	Integrated Urbanism and Sustainable Design
Sheffield University	Sheffield	United Kingdom	Sustainable Architecture Studies
Chalmers University of Technology	Gothenburg	Sweden	Architecture and planning beyond sustainability
NTNU Trondheim	Trondheim	Norway	Master in Sustainable Architecture
Bauhaus-University Weimar	Weimar	Germany	SDG-Campus
Bergen School of Architecture	Bergen	Norway	Master in Architecture

Table 2: Overview of investigated Master's Programs.

It also looked into the admission criteria for these master programs, which in the majority of institutions are rather strict, with one or two-stage aptitude tests, portfolio reviews and in most institutions explicitly restricted student numbers.

It can be concluded, that the web-presentations of curricula, in contrast to the statements in the interviews, are very heterogeneous: While for instance Technical University of Munich offers five clearly defined specialization fields, where the students must make a choice, other institutions (Tallinn University, Sheffield University) offer rather long lists of different and very specific courses, some of them mandatory, some elective.

Aarhus School of Architecture is one example which stays very general: "The program is passionate about investigating and imagining architectural approaches to societal, climatic and environmental challenges in a rapidly changing world. We explore the making of space and our role within this process through emerging methods and tools both at different scales and in local and global contexts. We design for the needs and well-being of people, which is the foundation of a resilient and

healthy environment. Our emphasis is on examining how trans-disciplinary approaches involving anthropology, sociology, and psychology can qualify architectural design and how contextual influences such as politics, history, culture, ethics, climate/climate change, pollution, inspire rather than inhibit architectural design."

There are no courses specified on the web, but in the master program "Studio 3, students approach how the fragility of our current times affects the ways we design, build and unbuild, reflecting on the qualities of spaces, construction techniques and material properties. Throughout the two-year program, you will be introduced to iterative exercises that will embrace new-build assignments, design new uses through adaptive reuse of existing buildings, and consider design approaches engaging in broader ecosystems."

In contrast, in the Master program *Integrated Urbanism and Sustainable design*, a cooperative and international course between Stuttgart University and Ain Shams University in Cairo, the web presentation is well-structured and clear course modules including their ECTS are presented. Chalmers University of Technology presents environmental studios, which the students can choose on their way to a Master's thesis: "the pedagogical approach is to support students in developing design skills through a series of design studios, dealing with complex design tasks."

The *Master in Sustainable Architecture* of NTNU Trondheim condenses the education to three pillars: environmental performance, environmental impact, integrated energy design processes. The goal is to design "buildings that can establish a symbiotic relation with the natural environment. An architectural design process cannot any longer disregard a deep comprehension of the natural environment's limits and resources, both in qualitative and quantitative terms."

To conclude: All examined institutions present high and ambitious goals on their web pages, the way how to reach them is described very differently, from very general to very specific.

4. Summary

The next two chapters conclude the report by summarizing the key findings of our analysis, which provide valuable insights for the further development of Pro-GREEN LABs (PGLs). First, we examine the critical aspects of lab development and structure. Then, we focus on teaching methodologies and curriculum innovation. These insights will guide the transfer of knowledge, inform strategic project roadmaps, and support detailed action planning for the next phases (WP3, WP4, and WP5). The outcomes of our surveys and analyses will serve as a foundation for the project's core outputs: establishing a network of labs, modernizing curricula, and designing a staff training program.

4.1. Innovative potential for PGLs - lab development and structure

In general, we witnessed very different presentations of the labs. Basic information about the labs like the year of foundation, the coordinators, and their goals were easily accessible through their web presence. But some of them are very generic in their description of what they want to achieve and do. They mostly state a kind of vision for their lab. Other important information about the funding, the governance of the lab or how they interact with other actors and their surroundings was not always available or clearly stated. Especially, the description of the technological infrastructure was in most cases missing, and we retrieved the information only indirectly via their project descriptions or publications. More details about the general administration of labs we gathered through the survey. The labs focus on a variety of sustainability-related topics like sustainable urban planning; social sustainability and equity, health, environmental quality, and mobility. The majority of labs work at different scales: local and nation as well as in neighborhoods and cities. The most commonly used technologies are artificial intelligence, x-reality, geo-databases, modeling and simulation software. Home Universities, governmental funding are widespread funding sources. Universities and local governments are also the main participants in labs. Citizens are rarely involved.

Despite differences and a broad number of investigated labs in this report, we could find some relevant best practices that can guide our project in

the future. It becomes clear that the majority of the case studies are combining both social and technological features together in their work. Considering the range of topics and samples relating to sustainability in architecture and planning education, this seems only logical and does justice to the interdisciplinary and transdisciplinary challenges.

Pro-GREEN LAB should be an innovative blend of social and technological components designed to enhance education and research. This combination would best be implemented through what we called a think tank. The think tank would be the place firstly for the analysis of the current local/global situation to find out what should be addressed in the lab; secondly for engaging with stakeholders and civic society on decision-making, experiments, and goals defining which results of experiments reported to them; thirdly for evaluation of the lab processes to analyze the results, impacts, needs, and alterations.

Recommendation for the project's next steps:

- Combination of social and technological focus with a physical/digital general room and think tank as the basis (about 50m² with 3–4 employees are quite common)
- Productive and comprehensive integration in curriculum (e.g., educational program, courses, supervisions of thesis, internships, fellowships)[8]
- Transparent online presence to address various target groups as well as to network with others (goals, governance scheme, technological infrastructure, funding scheme, exchange platform between labs, addressing different target groups)[9]
- Developing a critical and interdisciplinary approach to sustainability to avoid greenwashing, promoting action research, and engaging with real-world applications through continuous stakeholder engagement

[8] For good examples in this regard see UCLL, SDG-Campus, Urban Sustainability Lab.

[9] Good examples are the aspern.lab homepage (https://www.mobillab.wien/en/info-en/) or the Engagement platform of the Future Cities Laboratory which serves as a tool for dissemination, connecting and sharing of information, data, publications, and news between the partners as well as the interested public (https://futurecitieslab.world/).

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- A university or government funding scheme should be the focus, starting early and always at the forefront of lab work
- Involvement of citizens besides universities and private sector
- Implementation of internal evaluation structures
- Suggested sustainable lab practices should be energy saving, recycling of waste and material, mobility
- Building a network of labs (14 of the survey participants wants to be involved with PGL)

4.2. Innovative potential for PGLs - curriculum development

As for the curriculum development it became evident that education for sustainable architecture often reflects the environmental challenges specific to each country.

Likewise, it is evident that when a university has a strong institutional policy and focus on sustainability, it positively influences education in architecture and civil engineering departments. In contrast, where this kind of "top-down" sustainability policy is lacking, courses rely heavily on the individual ambitions, competencies, and persistence of the course leaders and teachers. While these efforts often yield impressive results, they tend to remain niche activities within the institution.

Main challenge: The most pressing challenge identified was the lack of teacher qualifications in sustainability, which is essential for advancing environmentally responsible architectural education. This outcome underscores the relevance of our project Pro-GREEN LABs to enhance the qualifications of teaching staff in addressing the environmental impact of buildings.

Defining a Pro-GREEN LAB: Keywords such as openness, interdisciplinarity, transdisciplinarity, experimentation, and intellectual space should be central parts in a PGL. So, it is not entirely about having a physical but rather an intellectual space in a PGL.

Recommendation for the project's next steps:

- Local and national environmental issues need to be addressed
- An overall sustainability policy in the institutions is helpful not to be a niche
- Qualification of the teaching staff is key
- Some of the interviewees could serve as experts for the future training programs
- The educational program should address different learning approaches: active, problem based, and experiential learning
- While enhancing green competencies, the focus should be on:

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- Knowledge production about climate change, environmental impacts, and resource limits
- Practical skill development such as systems thinking, interdisciplinary integration, and evidence-based decision-making
- Mindset development in the sense of critical thinking, social and political engagement, and a positive mindset toward societal challenges

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