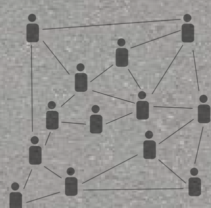
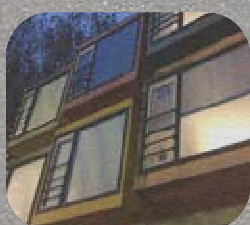
Adaptable Design for the HSB Living Lab

flexible, co-created spaces in student housing





Master Thesis Architecture

Chalmers University of Technology

Sweden Gothenburg 2014

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Master of Science Thesis in the Master's Programme
Design for Sustainable Development

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flexible, co-created spaces in student housing

Flexible.
Movable.
Adaptable.
Education.
Innovation.
Living Unit.
Co-Creation.
Experimentation.
Student Housing.
Construction Systems.

Abstract

This thesis aims to provide a collection of materials for use as a resource to catalyse the creation and design of the HSB Living Lab.

The HSB living lab is an on-going project for the creation of a 'living laboratory' that will take the form of student-housing and be built in the coming year on the Johanneberg campus of Chalmers University of Technology in Gothenburg, Sweden.

The Information and materials included in this report were collected through stakeholder interviews and literature review. Throughout this work key elements of the HSB Living Lab project are presented and discussed including organisational structure, the concepts of innovation, co-creation and adaptability as well as the potential research and stakeholder prerequisites that may impact the building design.

This thesis contributes to the general reflection around the HSB Living Lab by proposing both concrete design solutions and laying out a framework for design. The specific needs of the stakeholders have shaped the methodology and approach to design, resulting in adaptable design solutions for the HSB Living Lab infrastructure.

Contents

Many have supported this thesis: professors, PhDs, researchers, professionals, friends and administrators. It has been a great pleasure to work with all of you and we want to thank everyone who has been a part of this thesis work.

We want to thank first our supervisors, Pernilla Hagbert and York Ostermeyer, for their constructive advice and involvement.

Lena Falkheden for having made this thesis possible.

Maria Nyström and Holger Wallbaum, our two examiners.

All the researchers, professors and PhDs that have shared their knowledge and projects with us.

And last but not least our studio colleagues and friends for their cheerfulness and free coffee…

Thank You, we had a great time.

Preface

The aim of this master thesis is to propose design solutions for the HSB living lab that will be built on Chalmers University of Technology Johanneberg campus in Gothenburg, Sweden. In close collaboration with the Civil Engineering Department, Architecture Department and Homes for Tomorrow, the thesis defines the co-creation network around the project that include various stakeholders from university, research and industry as well as students, to understand the needs and goals of the future HSB Living Lab.

The thesis period ran from September 2013 to January 2014, where theoretical literature reviews and stakeholders interviews were conducted as a methodological approach to the design and conceptualization of a student housing living lab.

This project was done as a collaboration between the Architecture and Engineering departments at Chalmers University through the Master Program of Design for Sustainable Development program (MPDSD). This thesis takes part within the MPDSD program, and was produced by Paul Balaÿ and Shea Hagy.

Paul Balay has a Bachelor of architecture from Grenoble National School of Architecture, in France and Shea Hagy has a bachelor degree in Environmental Science and Ecological Design from the University of Vermont, in the USA and professional experience as builder and project manager.

We met through a student project, The Solar Decathlon China 2013 competition, in the Spring of 2013 as a part of the HALO Team Sweden entry. Shea Hagy was the project manager for this student project, where we designed and built a plus energy solar home around the concept of student housing exploring new ideas for a more sustainable built environment and way of living.

We had been introduced to the HSB Living Lab project through the thesis of Eva Pirri and Galini Afentoulidou who were involved in the Halo project as well, and were exploring student-housing evolution in the framework of the HSB Living Lab. We became interested in the HSB Living Lab project as it represented for us a great initiative and trans-disciplinary project that questions the future of our built environment. The project was also in-line with our personal backgrounds in architecture, construction and interest in developing new ideas for the housing sector. Being a part of the HSB Living Lab project also provided the opportunity to use our skills and continue working on the future of the building sector for a more durable society.

Moreover, it was a great chance for us to be a part of an on-going project, which set up a professional framework where the thesis could be used to contribute towards the design and realization of the HSB Living Lab project.

"The convergence of globalization, changing demographics, and urbanization is transforming almost every aspect of our lives. We face new choices about where and how we work, live, travel, communicate, and maintain health. Ultimately, our societies are being transformed." [1]

MIT Living Lab

1 "About MIT Living Labs," accessed December 27, 2013, http://livinglabs.mit.edu/

1. Introduction

The HSB Living Lab, a facility to be built on the Chalmers University campus in Gothenburg, Sweden, will be the first ever 3rd generation living lab taking the form of student-housing. A 3rd generation living lab is a research platform for testing and prototyping in 'real-life' conditions.

The objective for the University and its partners is to have a space for the creation, prototyping, and testing of sustainable living technologies as well as behavioral practices in order to develop innovative products and systems to reduce energy consumption in the home environment.[2] The latent progress of the building sector to innovate in combination with global environmental and social challenges associated with the built environment, make such a living lab facility essential to more rapidly integrate innovative building and living solutions into the marketplace.

For the purposes of this thesis, the question; 'How can the HSB Living Lab be designed to facilitate a flexible use of the building and support a co-creation process in research for sustainable living?' was used as a framework for the design of the HSB Living Lab.

1.1 Background and Context

Energy consuming technologies and living habits on a global scale are placing increasing demand on natural capital, which is clashing with the planet's ecological capacity to regenerate. Reducing natural resource demand and developing less energy consuming alternatives is an urgent challenge, specifically for the building sector. To answer the need of innovation in the building sector the European Union, through initiatives such as Climate-Kic European Network of Innovators[3], began supporting initiatives that intend to develop innovative products and systems in sustainable living technologies. In this context, Chalmers University of Technology has made a proposal for the construction of a temporary living laboratory on Chalmers' Johanneberg campus in Gothenburg,

2 "Suslab: Suslab," accessed October 18, 2013, http://suslab.eu/home/.
3 "Climate-KIC | The EU's Main Climate Innovation Initiative," accessed December 27, 2013, http://www.climate-kic.org/.

Sweden. This project evolved out of European Network of Living Labs (ENoLL)[4] and SuslabNWE[5] and is currently under the umbrella of the Climate-Kic's Building Technology Accelerator program.

The HSB Living Lab is a collaborative project between Chalmers University of Technology and HSB, one of Sweden's largest housing cooperatives. Homes for Tomorrow (H42)[6], an interdisciplinary group within Chalmers, have been the driving force of the HSB Living Lab Project from the side of the University. H42 provided the starting point for this thesis through a list of research projects that was previously collected from researchers interested in having their experimentation take place within the future HSB Living Lab. York Ostermeyer, assistant professor in the Department of Civil and Environmental Engineering's Building Technology Division, brought a request for the investigation into how these research projects may impact the design of the HSB Living Lab infrastructure.

Currently the main partners are engaged in defining a management structure, initial experimentations that will be performed, and selecting the design team to develop construction documents for the building. Construction is expected to begin towards the end of 2014.

There has been extensive research and much literature exists surrounding the concept of 'living lab', however, there are limited resources available in regard to 3rd generation living labs and more specifically living labs that take the form of student housing.

Stanford University through its Lotus Living Lab initiative has plans to build a 'Green Dorm'[7], which will be an infrastructure with similar aims as the HSB Living Lab. More specifically, Afentoulidou and Pirri (2013) have made an investigation into the HSB Living Lab project, in their Masters' thesis, Student Lab: Experimental Sustainable Housing. Their design proposals and solutions for the HSB Living Lab facility focus on, "how to increase socialization and decrease energy consumption through behavioral change."[8] This Masters' Thesis differs as it has been undertaken to investigate stakeholder needs and propose design solutions and constructive details for the HSB Living Lab.

1.2 Aims, Methods and Limitations

This work aims to begin the co-creative design process and provide an information resource to facilitate a more holistic understanding of the concepts surrounding the HSB Living Lab.

4 "Open Living Labs | The First Step towards a New Innovation System," accessed December 27, 2013, http://www.openlivinglabs.eu/.
5 "Suslab: Suslab," accessed October 18, 2013, http://suslab.eu/home/.
6 "Homes for Tomorrow - H42," accessed December 28, 2013, http://www.homesfortomorrow.se/.
7 "Lotus Living Laboratory | Green Dorm," accessed December 27, 2013, http://www.stanford.edu/group/greendorm/greendorm.html.
8 Galini Afentoulidou and Eva Pirri, "Student Lab: Experimental Sustainable Living" (Masters' Thesis, Chalmers University of Technology, 2013), 8.

The methodological approach towards design was informed and shaped by the research that will potentially be performed within the living lab, the prerequisites outlined by HSB, and the essential organizational elements and concepts needed to create a 'living lab' environment. Although some consideration was given to economics, unknown research, market dissemination of innovations and others, these were not the main focus. The proposals and discussions within this report have been focused on providing a platform for co-creation and innovation to take place. The design proposals do not specifically intend to include the research or innovations but rather provide the opportunity and space through adaptable design strategies to allow for the research to be performed co-creatively, producing innovation.

1.3 Thesis Outline

The following chapter explores the concept of 'living lab' and identifies key elements such as co-creation and innovation.

In chapter three, information is presented more specifically about the HSB Living Lab, the partners involved, the potential research projects as well as discussions surrounding the organizational structure and adaptability as a design tool. Chapter four includes the design solutions and proposals for the HSB Living Lab infrastructure.

Finally conclusions are made based on the investigations and design framework, outlining what elements are necessary for the HSB Living Lab project to be successful.

"Architecture should offer an incentive to its users to influence it wherever possible, not merely to reinforce its identity but more especially to enhance and affirm the identity of its users."[9]

Herman Hertzberger

9 Herman Hertzberger, *Lessons for Students in Architecture* (Rotterdam: 010 Publishers, 2005), 148.

2. Living Lab: A Tool for Innovation

A living lab can be seen as a tool that can support a co-creative process to facilitate innovation. Living labs aim to bring research into a real-life context, where experimentation can be performed to develop innovation to more directly meet the needs of the market.

A market in need of rapid innovation is the housing market. Currently, there are major challenges in housing on a global scale. One billion people live in substandard housing. This population, according to the UN, needs to be brought into more adequate housing, now measured to be how we live in western society. A lifestyle characterized by a low density, energy intensive built environment with high resource consumption.[10] If the global housing issues are to be solved by bringing developing nation's living standards up to the standards of the OECD, world resource consumption will continue to increase.

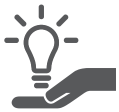
Therefore the need to redefine 'adequate' housing in the western world is necessary to limit the global impact on resources and energy use in the future. Smaller per capita space, reduced consumption, and resource use is needed. Can this be done while not sacrificing quality and at the same time fostering community?

To reduce the environmental impact of the built environment a radical change is needed. There is a global need for innovation in the development of sustainable living technologies that can promote a more durable, low impact society. A living lab can be a platform for this innovation.

Research innovation within the HSB Living Lab will focus on the housing market, and the fields of research are expected to be limited to this sector. This chapter will focus on understanding the role and function of a living lab in this context and briefly investigate the concepts of co-creation and innovation. A general understanding of the background of living labs will help to approach the design of the HSB Living Lab.

10 "UN-HABITAT: Strengthened Human Settlements Finance Systems," accessed September 25, 2013, http://www.unhabitat.org/content

Definitions: Living Labs...



"is a user-driven open innovation ecosystem based on a business – citizens –government partnership which enables users to take an active part in the research, development and innovation process"[11]

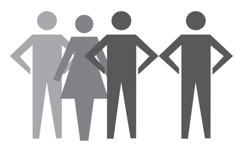
-2009 European Commission

Are identified and qualified by five key dimensions, (1) innovation settings ('open innovation environment'), (2) operating environments ('real-life settings'), (3) affecting innovation processes ('user-driven innovation" and 'co-creation process'), (4) related to user engagement and (5) from which innovation outcomes are expected ('new services, products and societal infrastructures').[12]

-European Network of Living Labs

"Bring together interdisciplinary experts to develop, deploy, and test, in actual living environments, new technologies and strategies for design that respond to this changing world."[13]

-Massachusetts Institute of Technology



11 European Union, European Commission, and Directorate-General for the Information Society and Media, *Living Labs for User-Driven Open Innovation: An Overview of the Living Labs Methodology, Activities and Achievements January 2009* (Luxembourg: EUR-OP, 2008), 7.
12 "Open Living Labs | The First Step towards a New Innovation System." Accessed December 27, 2013. http://www.openlivinglabs.eu/.
13 "About MIT Living Labs," accessed December 27, 2013, http://livinglabs.mit.edu/

2.1 A Brief History of 'Living Lab'

The concept of living labs emerged in the early 1990s and was originally used to describe the areas used by students to perform real-world projects at Massachusetts Institute of Technology (MIT), in Boston.[14] The concept has been found to originate from MIT professor William Mitchell with his work with the MIT MediaLab leading to the development of the current House_n PlaceLab at MIT.[15]

The term "lab" refers to laboratory, which can be defined as a room or building with special equipment for doing scientific experiments and tests.[16] A living laboratory aims to bring experiments out of the traditional controlled environment and into a real-life context.

Today Living Lab also refers to a European program created in 2006 to develop a network between the different living lab initiatives around the world. In recent years several living labs have emerged taking many differing forms and focus. Currently there are over 300 registered at the European Network of Living Labs.[17]

It can be difficult to find an overarching definition for living labs as the concept is used across disciplines and industries. However, the following is a fairly thorough description regardless of which specialization or discipline the living lab was created for.

'A living lab aims to turn users into active co-creators of emerging ideas and innovative concepts. A living lab is an experiential environment, physical or virtual, where users are immersed in a creative social space for designing and experiencing their own future.'[18] According to this definition innovation, experimentation and co-creation are at the heart of a living lab.

Exploring the theories of open innovation, a system for innovation development, in the context of the construction sector will set a foundational understanding of the need for the HSB living lab.

2.2 Innovation in the Construction Sector

Innovation in the building sector is of high relevance on a global scale in connection to both climate change and the economy. Approximately 10% of global Gross Domestic Product (GDP) and roughly 8% of all jobs globally are connected to the construction industry. At the same time, the environmental impact contributes to 40% of global anthropogenic greenhouse gases and 70% of landscape change.[19] This is a massive challenge of our time both

14 "About Us | Open Living Labs," accessed October 23, 2013, http://www.openlivinglabs.eu/aboutus.
15 A. Oliveira, E. Fradinho, and R. Caires, "From a Successful Regional Information Society Strategy to an Advanced Living Lab in Mobile Technologies and Services" (IEEE, 2006), 83a–83a, doi:10.1109/HICSS.2006.189.
16 "Definition Laboratory," accessed October 4, 2013, http://www.merriam-webster.com/dictionary/laboratory.
17 "About Us | Open Living Labs."
18 C. McPhee, M. Westerlund, and S. Leminen, "Editorial: Living Labs," *Technology Innovation Management Review* no. September 2012: Living Labs (2012): 3–5.
19 Greg Morrison, "Flagship Proposal BTA-Business Plan 2014" (Unpublished Manuscript, 2013).

ecological and social in nature. Creating new strategies for living is needed to reduce environmental impacts and social inequity and presents an opportunity to bring new ideas and technologies into a market that is in need of innovation.

However, the expansion of new sustainable building technologies is currently slow. There is great need for innovation and knowledge dissemination in the building industry. This latent progress of the sector to develop innovations and possible solutions, in its current state, will not be able to keep up with the societal needs for equitable, livable housing along with the global need for reduced resource use.

The investigation into innovation within the construction sector is complex. Jan Bröchner, Professor of Technology Management at Chalmers University of technology, in his article, *Innovation in Construction*, uses a comparative evaluation to the services industry to explore the state of innovation within the construction sector. Through his comparison the construction sector is characterized as having, "values that are low for cooperation, low for increase in range of goods, low for acquisition of external knowledge, as well as low for the market expenditure."[20] This 'low' classification of innovative progress is supported by a 2002 survey by the European commission, which compared innovation in the construction sector to the manufacturing, services and trade industries, as seen in table 2.1.

Table 2.1 Construction Innovation Aspects Compared to Industry (Manufacturing), Services and Trade

	Construction **Lowest** of all four Sectors	Construction **Highest** of all four Sectors
Importance of Innovation	Percentage of turnover from new or renewed products or services introduced during the last two years.	
Share of Investment	Percentage of investment dedicated to innovation in products, processes or organization.	
Focus	Percentage for new products.	Innovation efforts more concentrated on new organizational changes.
Access	Importance of in-house R&D.	Acquisition of machinery or equipment.
Needs	Feeling access to innovative markets as a need.	Feeling unsatisfied needs for finding and mobilizing financial resources. Need to improve basic skills of the workforce
Training		Popularity of semi-public institutions for training.
New Approaches (Next 2 yrs)	Developing new products or service characteristics.	Developing the relationship to suppliers or users.
Advice		Importance of public and semi-public advisory centers for advice on new methods or approaches to management.
Cooperation w/ other firms	Will become more useful in subsequent years.	To launch new products or services or to introduce new processes.
EU Single Market Effects	Improved regulations, cheaper or better available supplies, better access to new technologies.	Better access to new markets, better cooperation to innovate.

Adapted from F. Gallouj and F. Djellal, The Handbook of Innovation and Services: A Multi-Disciplinary Perspective (Edward Elgar Publishing, 2010).

20 Jan Bröchner, "Innovation in Construction," in The Handbook of Innovation and Services: A Multi-Disciplinary Perspective, by F. Gallouj and F. Djellal (Edward Elgar Publishing, 2010), Page 748.

The construction sector in this context includes the construction industry as well as the related fields of architecture, engineering and urban planning. The comparative data presented in Bröchner's article include both innovative products and processes. Although innovation is relatively slow in the construction sector it has been supported with the increasing use of communication technology, which has also brought about increased cooperation.[21]

Bröchner, goes on to describe why the building industry differs from other industries in regards to innovation: "One-way of explaining why construction firms deviate from other firms is to consider the characteristics of constructed facilities: immobility, complexity, durability, costliness, and high risk of failure."[22]

A living lab has the potential to address some of these issues such as the 'high risk of failure' by allowing for technologies to be full-scale tested and protoyped before going to market. Within a living lab setting the users are actively involved in the testing, cutting feedback time and increasing efficiency. This may be why in Bröchner's article user-builders were found to be more innovative compared to component manufacturers.[23]

The trend towards increasing cooperation within the construction sector, as described by Bröchner, as well as evidence that user-builders are efficient innovators shows that there is potential within the sector towards cooperative innovative processes.

2.3 A Home for Open Innovation

Innovation within a living lab follows the concept of open innovation. Open innovation is a concept developed and popularized by Henry Chesbrough, professor and executive director at the Center for Open Innovation at the University of California, Berkley.[24]

The term open innovation is most often used in relation to economic markets, management processes and industrial production systems. The main concept focuses on the sharing of knowledge and skills in order to develop innovative opportunities, through the use of external resources. "Open Innovation is a paradigm that assumes that firms can and should use external ideas as well as internal ideas, and internal and external paths to market, as they look to advance their technology."[25]

The aim of open innovation is to bring a project to life by bringing together companies, with complimenting resources and techniques within an industry in order

21 Jan Bröchner, "Innovation in Construction," in The Handbook of Innovation and Services: A Multi-Disciplinary Perspective, by F. Gallouj and F. Djellal (Edward Elgar Publishing, 2010), 744–763.

22 Ibid. 755

23 Ibid.

24 Henry William Chesbrough, Wim Vanhaverbeke, and Joel West, Open Innovation: Researching a New Paradigm (Oxford: Oxford University Press, 2006).

25 Ibid. Page 2

to drive innovation.

Figure 2.1 is a visual representation comparing the concepts of closed and open innovation, illustrating the different impacts on market innovation. Closed innovation is a closed, internal process where an organization uses it's own resources and has targeted one market. While open innovation is a process where through collaboration with exterior actors, opportunities are created to more quickly get ideas and products into the market. Open innovation provides opportunities to both reach a previously unknown or unreachable market as well as create new markets.

The Living Lab concept attempts to facilitate and promote open innovation systems and initiatives by offering a co-creative platform for experimentation. Living labs are thus spaces of co-creation which promote open innovation processes.

2.4 Co-creation for Innovation

Looked at through the lens of an open innovation network then co-creation is an essential element in facilitating innovation. Living laboratories are co-creative in nature. They are an interactive platform for collaborative research where users play an active role. Living labs focus on co-creation within the framework of innovation to create new products that are more relevant, innovative and can be introduced to the market at a faster pace.

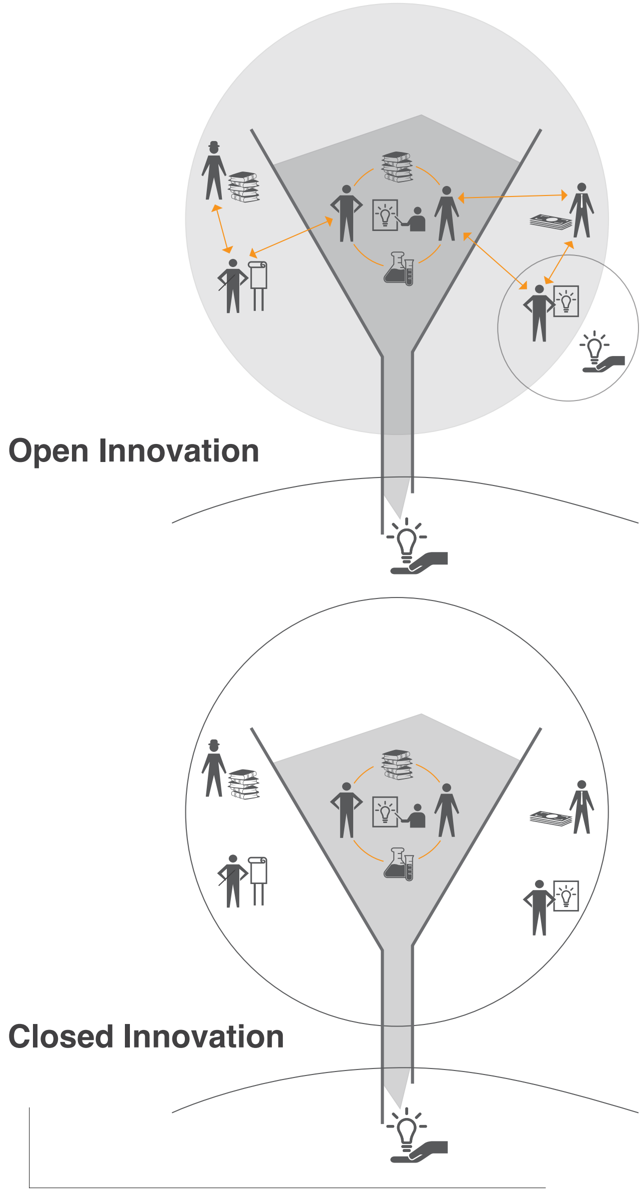


Figure 2.1 Open vs. Closed Innovation.
Adapted from "Open Innovation: Renewing Growth from Industrial R&D," by H. Chesbrough, 2004, 10th Annual Innovation Convergence, September 27, 2004.

For the purposes of this thesis co-creation can be understood as a process that provides an opportunity for on-going interaction between partners, clients and users, allowing collaboration and fostering innovation. [26]

Inside the HSB Living Lab, two levels of co-creation need to exist, one being the actual project leadership, which involves multiple actors working together on the financing, prototyping and management of the living laboratory. The other involves the innovation processes that will take place within the lab; the interaction between research, experimentation and users.

2.4.1 User Involvement

As has been described living-labs are important, especially in the construction sector, as they provide the real life environment that the research needs to test products and systems, which can lessen 'the risk of failure' currently hindering innovation within the sector. For the design of the HSB Living Lab the role of the user and the interaction with the research is essential. As a co-creator, the "user/performer" is as important as the research itself. In the framework of the HSB Living Lab, students will be the inhabitants/users and should play a major role in innovation.

Student/user involvement in experimentation within the Living Lab can take place on various levels. For instance, students can be seen as participants in the research. As participant users they will provide feedback to researchers on their experiences with the technology being tested. One example of this level of user engagement could be the 'alternative heating' project headed by Phd Sara Renström at the Design and Human Factors Department at Chalmers where new hydronic radiator designs will be tested to engage users to understand and interact with their heating systems (see figure 2.2). For this project designs such as a radiator bench or a system where small phase change heat modules are heated by the radiator and then removed by the user will be tested with the aim to reduce energy use by more localized focused heating experiences.

Users could also be expected to have a more active role, helping to develop, experiment, modify or create innovative products in their home environment in collaboration with research projects taking place within the lab. As an example, the department of Chalmers Industriteknik wants to develop and test a new direct current electrical system where all appliances and products are powered by a direct current (DC) electrical system. The inhabitants of the apartments with this experimentation should then be students who have a background in electrical engineering as many appliances are run on alternating current (AC) and would need to be modified to work on a DC system.

26 Nicholas Ind and Nick Coates, "The Meanings of Co-creation," European Business Review 25, no. 1 (January 4, 2013): 88.

The students would, in this case, be co-creating products for use on the DC system along with the researchers developing the prototype system (see figure 2.3).

Even more active, students can act as the drivers of innovation. Through their studies and courses they become the head researchers testing their ideas for sustainable living in collaboration with their professors and other industry partners, as envisioned by the 'Design/Build/Live' research project. In this scenario the spaces in which they live would need to be highly adaptable to allow for the students to reshape and test new situations of living and systems.

Stakeholder collaboration in both the construction and use of the space must be considered throughout the design process as a living lab by definition aims to engage users and stakeholders in co-creation of technologies, services, and systems. Therefore, the design of space should be informed by the perceived future collaborative creation of technology by the users and partners and the potential interaction of this technology with the users. In a co-creative environment the user should be aware of the functions, experimentation and possibilities around them to actively engage with their living environment.

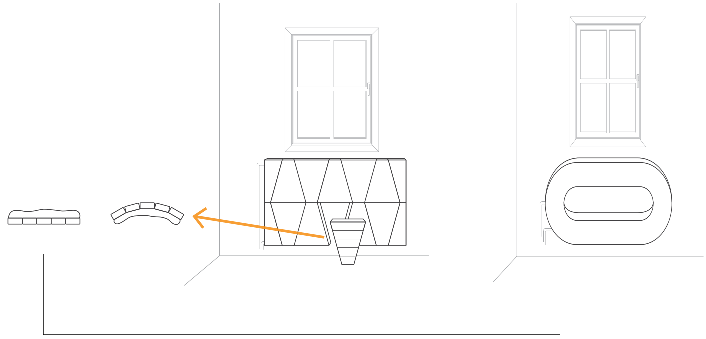


Figure 2.2 Sensing Radiators, Project Prototypes
Adapted from presentation given by Sara Renström on November 26th, 2013.

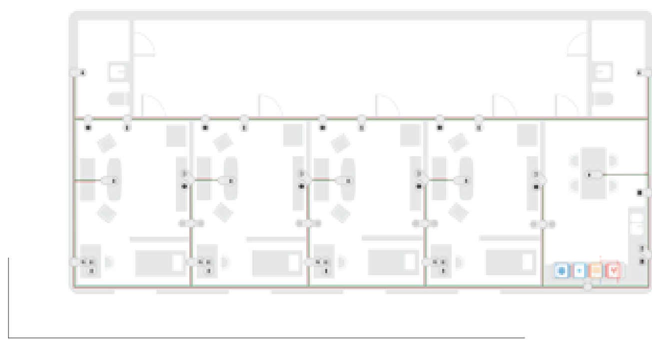


Figure 2.3 Direct Current Wiring Scheme, Zentigo
Sourced from documents recieved during interview with Stephan Mangold and Harald Merkel at Chalmers Industriteknik on October 14th, 2013.

2.5 Five Key Elements of a Living Lab

To conclude this chapter, it is interesting to note the five key components of Living Labs, according to Bergvall-Kåreborn, as shown below in figure 2.4.

As this chapter has shown, the concept of a living lab is very broad. To narrow the concept towards the HSB Living Lab certain aspects can be extracted from the previous chapter to help guide the design for the future project.

The HSB Living Lab will be a physical structure that aims to be a co-creative social space for experimenting with sustainable technology and lifestyle in order to develop innovative concepts and products.

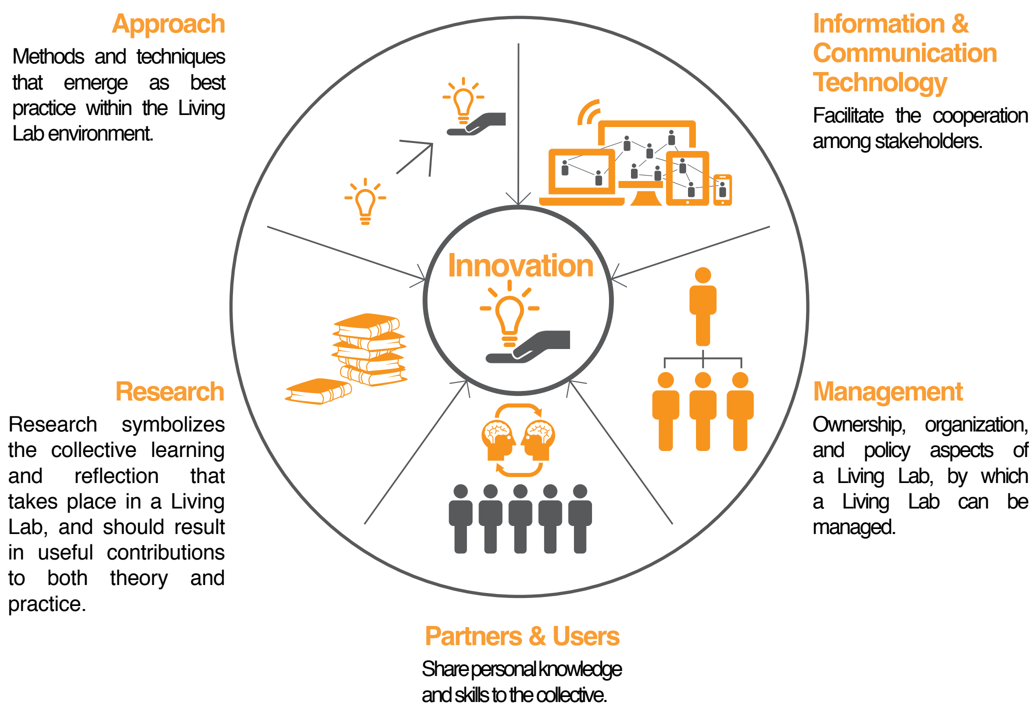


Figure 2.4 *Key Components of Living Labs.*

Adapted from BHMSA Bergvall-Kareborn, M. Hoist, and A. Stahlbrost, "Concept Design with a Living Lab Approach," in System Sciences, 2009. HICSS'09. 42nd Hawaii International Conference on, 2009, 1–10, http://ieeexplore.ieee.org.

There have been many examples of various forms of experimentation where researchers, architects, engineers, artists, and others have transformed their personal space to test and develop new innovations, one example being Alvar Alto's experimental house (see case study).

However, what makes a living lab unique is the co-creative innovation that by definition must be present. It is important to keep in mind that innovations have to meet the needs of the market, if not the resources put into development are wasted. "The best way to make sure the resources are used effectively and that the developments meet market needs, is to test and develop the products and services in the real use environments."[14] Living Labs provide that real life environment.

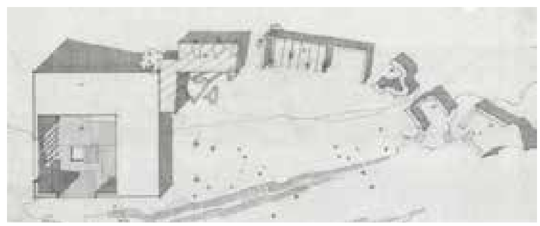
The next chapter will explore the current status of the HSB Living Lab and approach the design through the potential research and partner needs.

Case Study: Aalto, Experimental House

Built in Muuratsalo, Finland, in 1954, the house was conceived as an experimental laboratory where Aalto tested materials, construction systems and architectural theories

Aalto's summerhouse, Muuratsalo, Finland (Photo:mimdap.org)

The main experimental areas were experimenting with building without foundations, free-form brick construction, free-form column structures, and solar heating



Plan View (Photo: the189.com)

Aalto described the building as having the advantage of being the 'experimental game' of the own architect, where he could freely deal without worrying about the constraints of usual project requirements

Source: Guimarães Marcos. "Bioclimatism and Space Use in Alvar Aalto's Summer House." Polytechnic University of Catalunya, Barcelona, Spain, 2007.

"Alvar Aalto Museum."Accessed November 21, 2013.http://www.alvaraalto.fi/experimentalhouse.htm.

27 BHMSA Bergvall-Kareborn, M. Hoist, and A. Stahlbrost, "Concept Design with a Living Lab Approach," in System Sciences, 2009. HICSS'09. 42nd Hawaii International Conference on, 2009, 1–10, http://ieeexplore.ieee.org/xpls/abs_all.jsp?arnumber=4755508.

"In the 'concept house' prototype, we challenged all of our partners, suppliers and designers to innovate in at least one aspect of the project ."

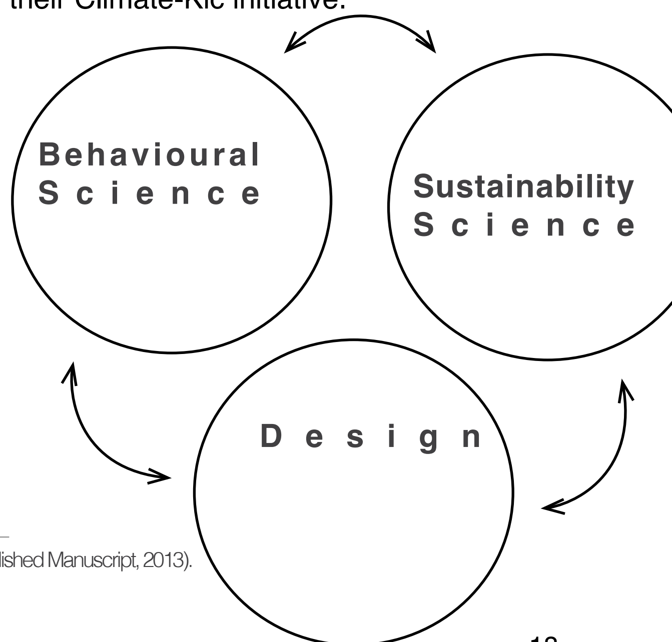
Mick Eekout, TU Delft

3. HSB Living Lab: Project Overview

The HSB Living Lab at Chalmers will be a three-floor, approximately 1200 square meter, 3rd generation living lab facility for studying and understanding sustainable living in the form of student apartments. [28]

A 3rd generation Living Lab is a 'real-life' environment with a long time perspective, in this case student housing, where 1st and 2nd generation living labs are testing environments with shorter time implications.

The development of this living lab aims to provide a setting for full-scale experimentation through the engagement of users, researchers and industry partners in the co-creation of knowledge, strategies, products, and services. The HSB Living Lab will draw upon three scientific fields; sustainability science, behavioural science and design in order to develop and provide solutions and services which will enable sustainability in the home.[29] The development of ENoLL in 2006 contextualized and further defined the concept of a living lab, placing it into the global arena. The progression of the living lab concept has taken more tangible steps since the ENoLL project. The HSB Living Lab is affiliated with two of these progressive networks through Chalmers University of Technology. Chalmers is a member of both the SusLabNWE Network and a main partner in The Building Technology Accelerator Flagship program funded by the European Union through their Climate-Kic initiative.



28 Greg Morrison, "Infrastructure Proposal: The Sustainable Living Lab" (Unpublished Manuscript, 2013).
29 Ibid.

3.1 SuslabNWE Network

SuslabNWE (Sustainable Labs North West Europe) is a collaboration between eleven main partners. The aim of SusLabNWE is to offer international infrastructure and support for developing, testing and promoting innovation within a real-life context to create new ways of improving sustainability within the home environment.[30]

SuslabNWE works with a three tier approach performing insight research, then performing prototyping and finally field testing the prototype innovations.

The HSB Living Lab can be used within this framework most specifically in the second level of prototyping.

3.2 Building Technology Accelerator

Recently, the Building Technology Accelerator was created within the European Union's Climate-Kic Initiative. The network consists of many partners; Chalmers University along with three other main partners will be the innovation hubs hosting various living lab projects (see figure 3.1). The platform for this network takes the SuslabNWE three-tier system one step further.

The HSB Living Lab will be one platform within this initiative available for both prototyping and real-world testing and connecting with industry partners which will allow for dissemination of technology and knowledge innovation into the market.

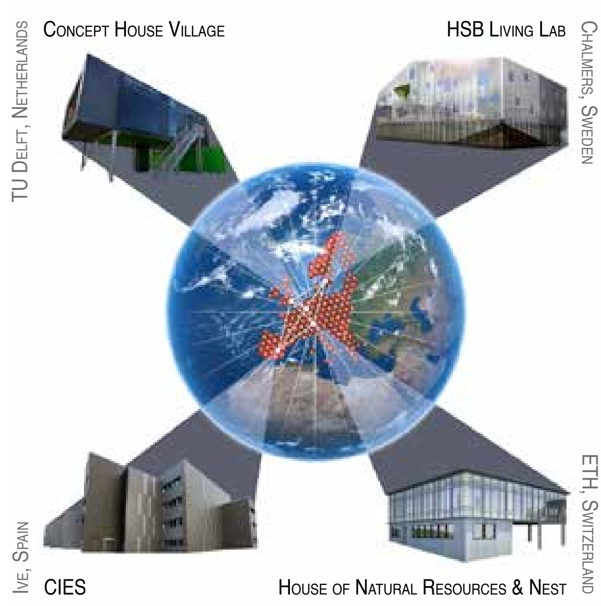


Figure 3.1 *BTA Innovation Hub Network*
Adapted from BTA Climate-Kic presentation by Greg Morrison, 2013.

30 "Suslab: Suslab," accessed October 18, 2013, http://suslab.eu/home/.

3.3 Partners and Organizational Structure

The development of the HSB living lab project is a collaboration between three main partners Chalmers University of Technology, HSB, and Johanneberg Science Park.

3.3.1 HSB Housing Cooperative

HSB (Hyresgästernas Sparkasse och Byggnadsförening/ The Tenants' Savings and Construction Association) is one of the largest housing cooperative organizations in Sweden and is owned by over 550,000 members. HSB aims to be a model within the housing industry in addressing climate issues associated with housing and to be a leader in the development of sustainable housing. HSB builds, owns and manages tenant owned properties as well as rental housing. The organizational structure of HSB allows all members to be a part of the decision-making process as well as allows for the reinvestment of profits back into the homes.

HSB has recently organized seven focus groups to begin looking into the design, construction and research possibilities of the HSB Living Lab. These focus groups have been divided into the following categories 1) Rethinking, 2) Innovation, 3) Testing environment, 4) Flexibility, 5) Energy efficiency, 6) Measurability, and 7) Security, all trying to answer the guiding questions of; What challenges are we facing, what is happening in society and what will we be able to develop within HSB Living Lab? [31]

HSB has brought in architectural and engineering firms not in a normal client-consultant relationship but as a long-term partnership. HSB's role goes beyond just a property developer, they are hoping to use the living lab and its co-creative environment to test the limits of housing in Sweden and use innovations from living lab experimentation for their members in the future.

3.3.2 Johanneberg Science Park

Johanneberg Science Park (JSP) is an organization formed by Chalmers University of Technology and the City of Gothenburg with the aim, "to develop an environment which stimulates collaboration between academia, industry and other players in society at Chalmers Campus Johanneberg." [32]

JSP's role is expected to be connecting industry with the HSB Living Lab and bringing in partners to support the project and collaborate towards innovation. JSP is part owned by both Chalmers and HSB.

31 "In English / Fakta / Om HSB / HSB - Där Möjligheterna Bor," accessed October 22, 2013, http://www.hsb.se/omhsb/fakta/in-english.
32 "What We Do | Johanneberg Science Park," accessed November 4, 2013, http://www.johannebergsciencepark.com/en/what-we-do.

FIELD STUDY: HSB ARCHITECTURE & MOVEABILITY WORKSHOP


Visit to future site of HSB Living Lab


Collaborative brainstorming session


Presentation on movable structures, Larry Toups (NASA)


Presentation on history and evolution of Swedish housing

Workshop was held on November 20th, 2013

3.3.3 Chalmers University of Technology

Chalmers University has been the driving force behind the HSB Living lab project through Homes for Tomorrow. Homes for Tomorrow (H42) is a research environment which aims to foster the multi-disciplinary collaboration between researchers at Chalmers creating a environment for experimentation on the future of buildings and homes based on a design systems approach where external partners link the research to society.[33]

Two other organizations at Chalmers play a less prominent role in the organizational structure. Akademiska Hus is the property owner, which will lease the land for the HSB Living lab, and Chalmers Studentbostader is the student housing company that will manage the renting of the HSB Living lab apartments to students.

Chalmers' influence on the design and construction of the HSB Living Lab comes from both the funding contributed to the project as well as the research that will be performed. This thesis is part of that as an exploration into the design while considering stakeholder wants and needs. The complete organizational structure and partnerships have not been fully formed as of yet, figure 3.2 is an interpretation of what the structure could look like based on field research and interviews.

A key component of the future organizational structure lies in the 'Knowledge Innovation Selection Committee'. This is a suggested and currently non-existent organizational element based on the research conducted for this thesis. It is proposed to be a group made up of members from all stakeholder organizations including a member representing the students who reside in the HSB Living lab. This group is envisioned to coordinate the research projects and ensure the true co-creative process.

3.4 An Approach Towards Design

Understanding the concept of a living lab and the organizations involved has provided a foundation to begin to explore how the HSB Living Lab can be designed to facilitate a flexible use of the building and support a co-creation process in research and innovation for sustainable living.

Various methods were used to investigate which criteria would guide the design process and which features were most essential to include within the design of the HSB living lab. Two other designs have been proposed for the HSB Living Lab, one by Chalmers Teknologkonsulter AB (CTK)[34] and the second by Afentoulidou and Pirri in their thesis project *Student Lab: Experimental Sustainable Living*.[35] The approach presented in this thesis

33 "Homes for Tomorrow," accessed November 4, 2013, http://www.chalmers.se/en/areas-of-advance/builtenvironment/research/strategic-research-project/Pages/homes-for-tomorrow.aspx.
34 "Chalmers Teknologkonsulter AB," Chalmers Teknologkonsulter AB, accessed December 30, 2013, http://ctk.se/.

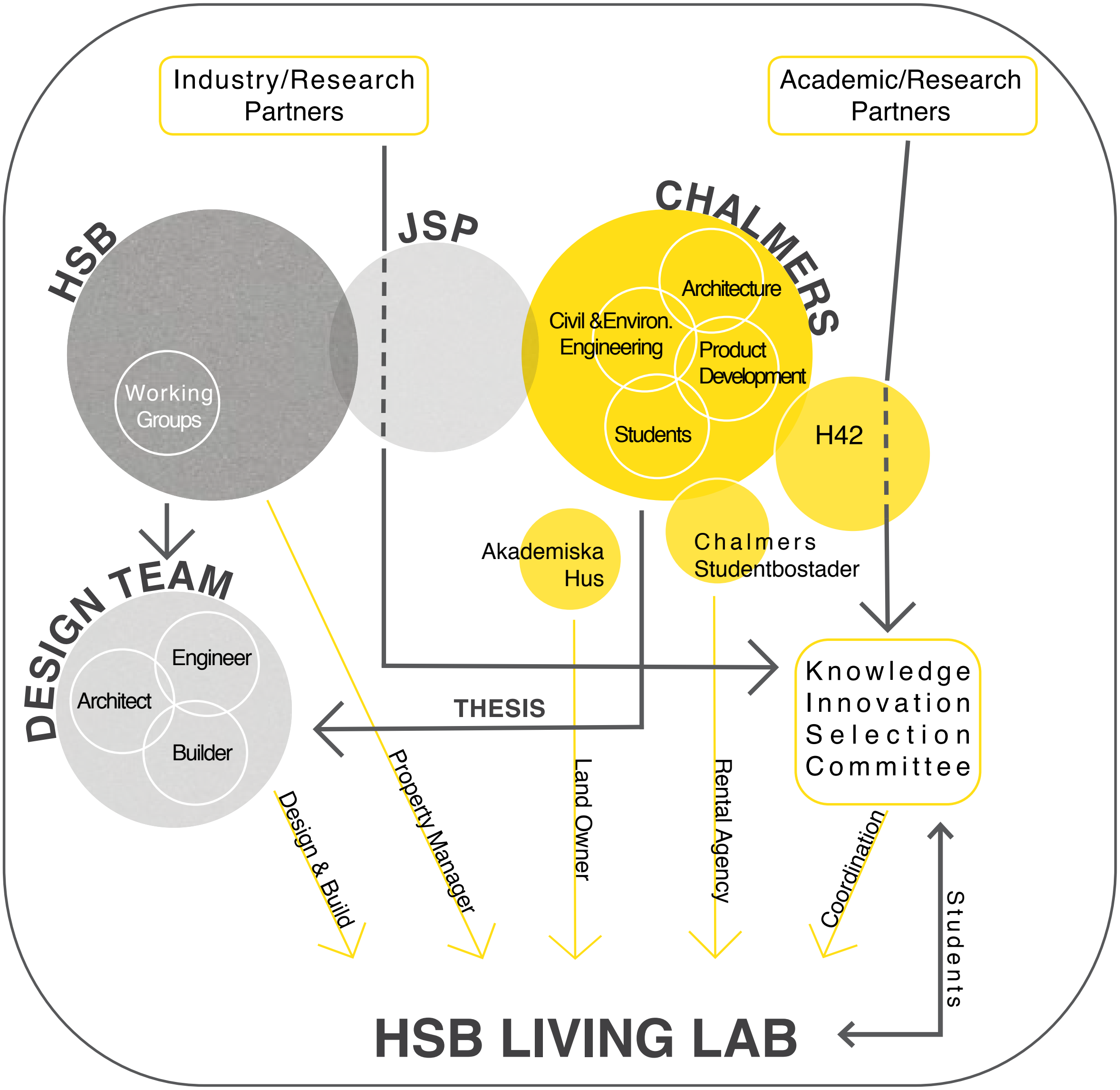


Figure 3.2 Current Understanding of HSB Living Lab Organizational Structure

work differs as the previous proposals had very little insight information into the stakeholder wants and needs as well as took a more focused strategy towards student living and student housing.

3.4.1 A Starting Point: Research Projects

A list of potential research projects, from different departments at Chalmers as well as some outside organizations, previously collected by Homes for Tomorrow was used as a starting point for investigation into the functional design of the HSB Living Lab.

This list included 33 research projects categorized into six groups; building envelopes, housing services, appliances, behavioural science, consumption, and a category ‘special’ for projects that did not fit into the other categories. The original list of projects can be found in the Appendix.

The first round of analysis narrowed down those 33 projects into 20 potentially relevant projects by briefly categorizing the projects based on their potential to impact the building’s physical structure and space. Those determined to have a larger impact on the structure and spaces were separated from those that were assumed to have little affect. The researchers for the ‘impact’ projects were then contacted for interviews to gather more specific information about their projects and understand more fully how the research needs might affect the design.

The interviews were conducted over the course of one month. A form was used as guide to help standardize the questions and responses (see Appendix). Through these interviews a deeper understanding of the research projects gave insight into stakeholders needs and opinions. 17 projects were discussed through the interviews. Some researchers however, were unresponsive to interview requests, in these cases the projects were not analysed further as there was not enough information available to continue investigation. The collection of projects can be seen in figure 3.3.

The interviews were crucial to better understand the needs of the research and the potential impacts they may have on design. This qualitative analysis, however, could have been conducted in a more standardized fashion to more thoroughly analyse impact. Another limitation was the preliminary nature and uncertain future of many of the research projects, and time constraints did not allow for more in depth analysis.

35 Galini Afentoulidou and Eva Pirri, “Student Lab: Experimental Sustainable Living” (Masters’ Thesis, Chalmers University of Technology, 2013).

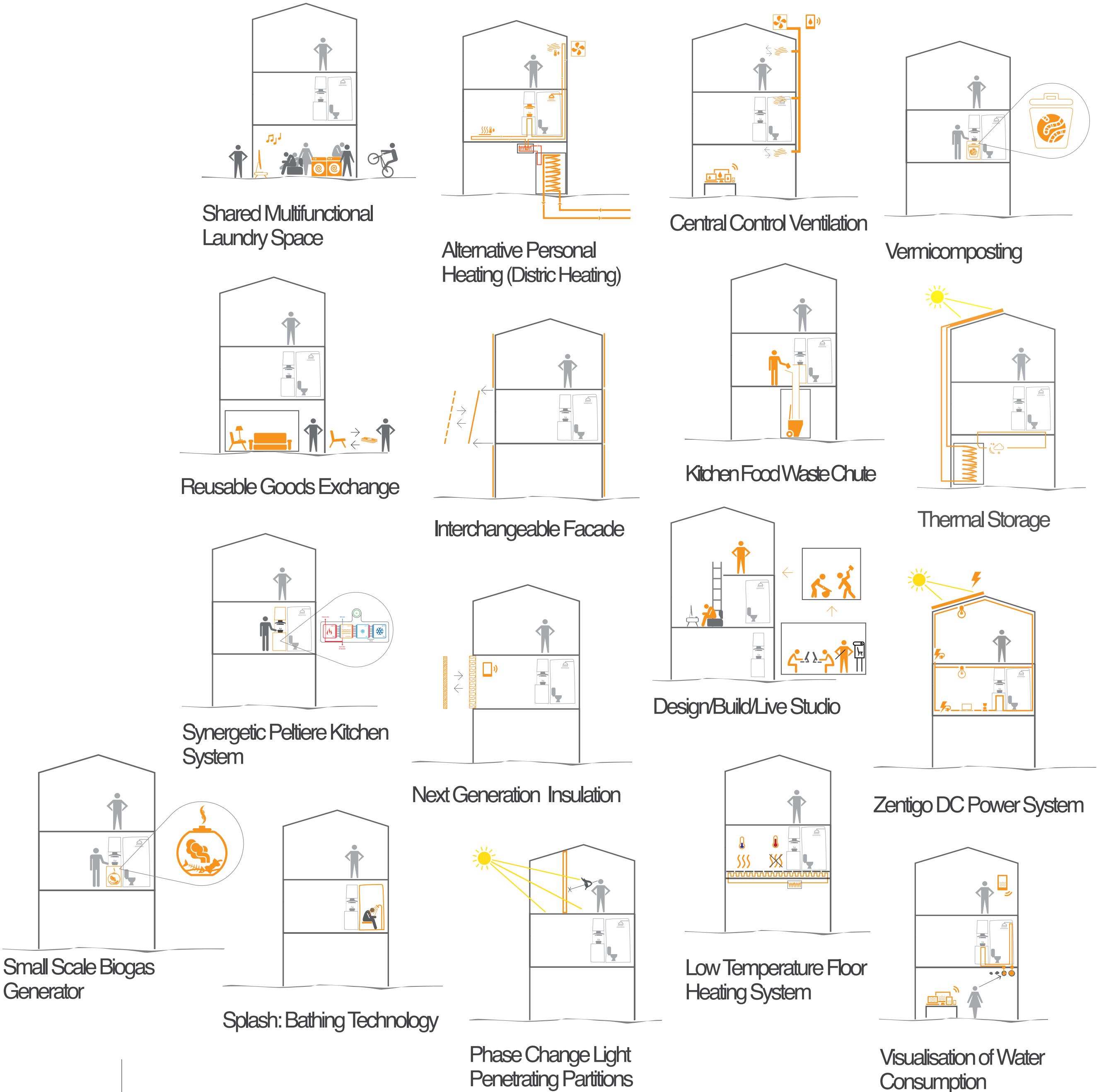


Figure 3.3 *Illustrated Summary of Research Projects*

Field Study: Interviews

Isabel Ordonez and Ulrike Rahe, Design and Human Factors

Anders Carlsson, a-hus Teknik Chef

Stephan Mangold and Harald Merkel, Chalmers Industriteknik

Paula Wahlgren, Byggnadsteknologi

A list and summary of all interviews can be found in Appendix

3.4.2 HSB PreRequisites

The research projects and associated interviews provided inputs from mainly Chalmers researchers. To understand the needs of another main partner, HSB, an interview was conducted with Sanna Edling, the HSB Living Lab Project Manager. From this interview a list of prerequisites was determined (figure 3.4).

The prerequisites of size, and number of occupants are assumed to be be based on economics. The common areas, kitchens and bathrooms fall under the category of research that HSB would like to do within the living lab, which they hope will translate into innovations they can incorporate into their other buildings. The requirement of movability may have the greatest impact on design and is based on the temporary nature of the living lab facility, Akademiska Hus will lease the land for the project for only ten years.

These requirements help to define the program for the design and when combined with the research project information can be used as a guide towards an effective, relevant design of the HSB Living Lab.

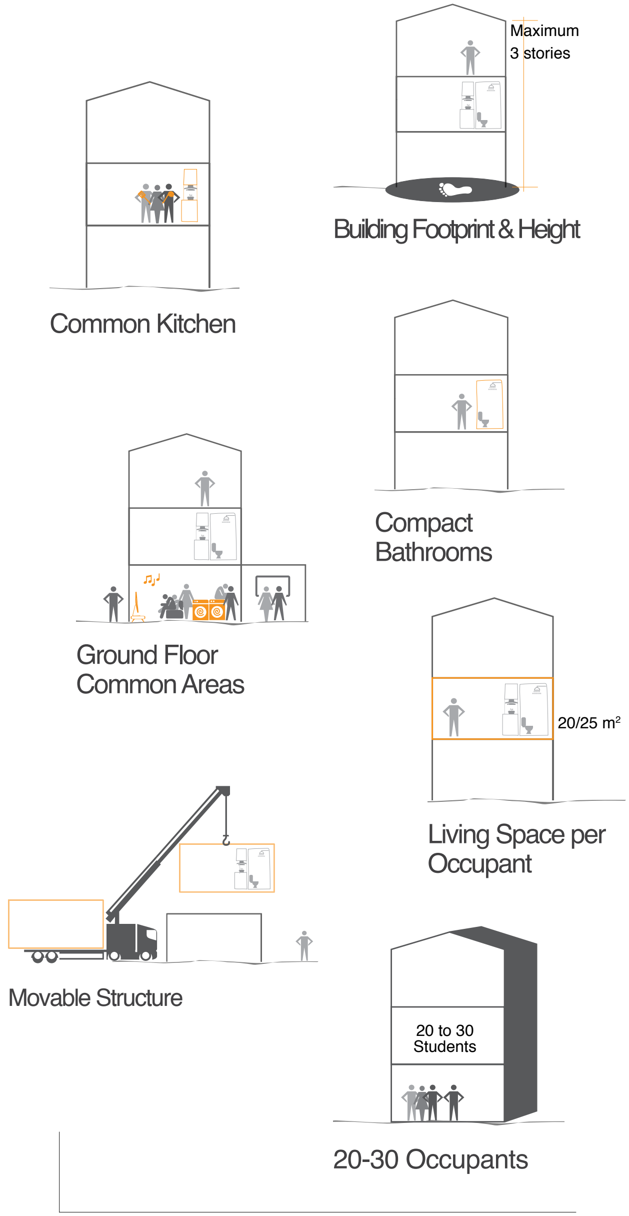


Figure 3.4 *Illustrated Summary of HSB PreRequisites*

3.4.3 Criteria Analysis

Through the field studies and interviews, two groups of information was collected, the expectations and needs of Chalmers through investigation into the potential research (figure 3.3) and the required criteria from HSB (figure 3.4).

The research projects were then categorized and weighted to distinguish their relationship and relevance to the user. This was done as an excercise to understand how the research could be more specifically categorized in the future. Items that are deemed to have higher need for user input and collaboration for prototyping, feedback and innovation should take precedence. Research where user interaction may not be essential to test and innovate can and should be done in more traditional lab settings (figure 3.5).

This investigation approach bring to the conclusion that the potential research project are not all defined yet and will evolve over the years as well as new projects and partners will be involve in the Living Laboratory. Looking at this information on a wider level two basic assumptions were made. The building design will need to permit evolution in space and function and adapt to changing needs of the research and users. These conclusions led to an investigation into the concepts of adaptability as adaptable design strategies have the potential to permit evolution and provide flexibility in function within the built environment (see figure 3.6).

Adaptability, as a concept, is too large to apply to design thinking within the framework of this thesis. However, in the next chapter adaptability is explored with a more focused relevance towards the design of the built environment.

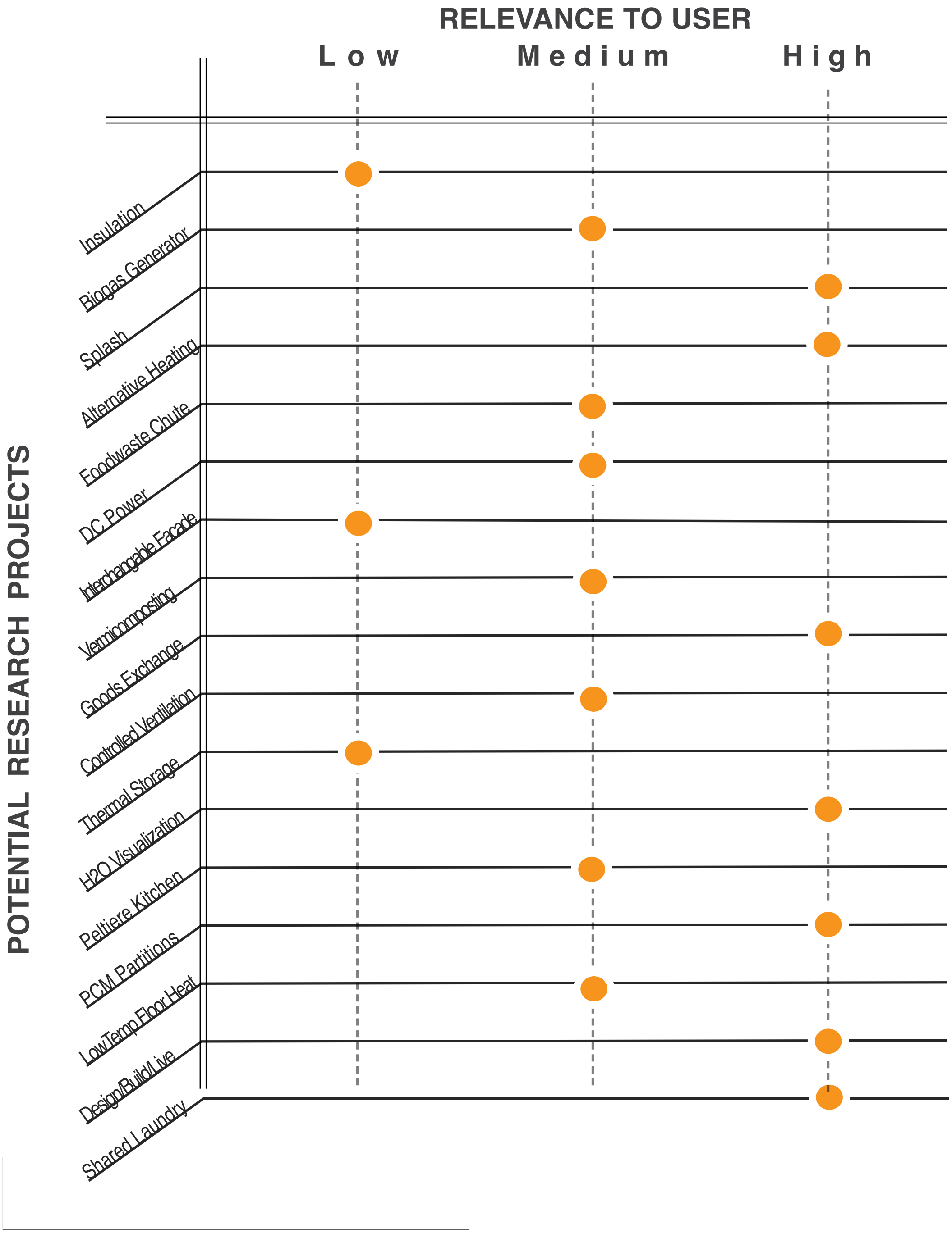


FIGURE 3.5 *RESEARCH PROJECT USER RELEVANCE*

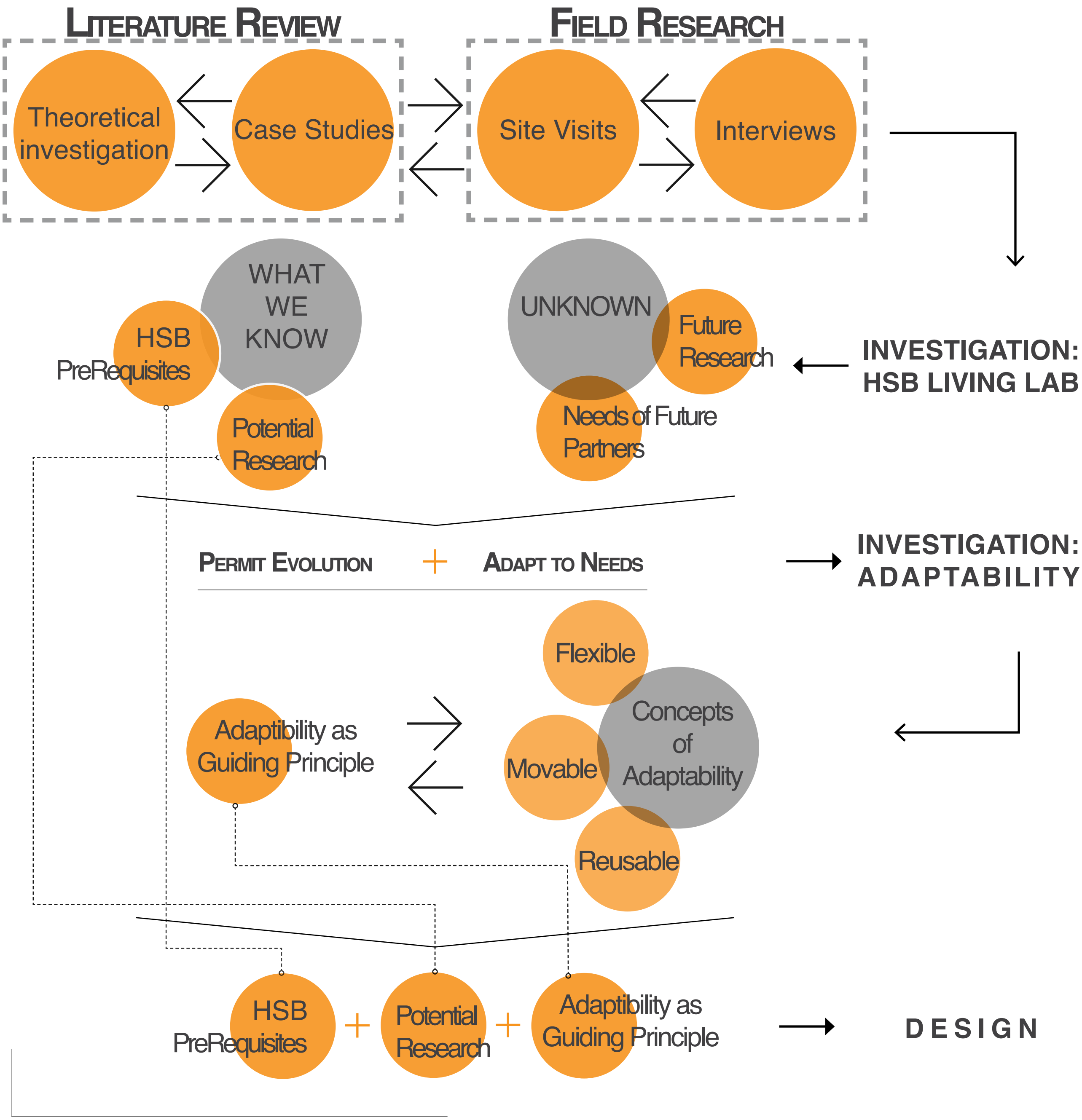


Figure 3.6 *Methodological Approach*

3.5 Exploring Adaptable Design

Adaptability in design is necessary for the HSB Living Lab considering the requirements of the stakeholders and the goal of creating innovation through co-creative prototyping and research as previously discussed.

The definition of adaptable can be simply stated as, the ability to change or be changed in order to suit new conditions.[36] However, depending on context adaptability can be used in many different applications. To narrow the scope to the concept of buildings and the architectural field, adaptability can be defined as the, "capacity of a building to accommodate effectively the evolving demands of its context, thus maximizing value through life."[37]

Adaptability in this sense becomes an important aspect for the HSB Living Lab as the demands of the living lab will be ever evolving with the needs of the inhabitants, research innovation and physical setting.
In their paper, Schmidt et al. identify six design strategies to achieve adaptability; available, scalable, flexible, refitable, moveable and reusable (see figure 3.7). Reusable and available were later deemed outside the scope of adaptability but could be used to achieve some added value for the HSB Living lab.

These strategies seem to have the potential to be effective in achieving the needs of the living lab when referenced to the known criteria.

Adaptability, has been a prominent part of the architectural and building discourse at least since world war II and can be argued, that it has been an innate aspect within the building environment from the beginning, as buildings by nature change function and occupancy. This is evident in the number and variety of adaptable scenarios, which have been used to test the limits of adaptability within housing some of which will be explored in the next sections to inform how these strategies can more practically be applied to the HSB Living Lab.

36 "Adaptable - Definition," Merriam-Webster, accessed October 22, 2013, http://www.merriam-webster.com/dictionary/adaptable.
37 Robert III Schmidt et al., "What Is the Meaning of Adaptability in the Building Industry?," in Proceedings of the CIB 16th International Conference on Open and Sustainable Building (Bilbao, Spain, 2010), 8.

FIGURE 3.7 *ADAPTABLE DESIGN STRATEGIES*

ADAPTED FROM Robert III Schmidt et al., "What Is the Meaning of Adaptability in the Building Industry?," in Proceedings of the CIB 16th International Conference on Open and Sustainable Building (Bilbao, Spain, 2010)

3.5.1 Movable & Scalable

The HSB Living Lab is to stay on Chalmers Campus for ten years. After this period, HSB plans to transport the lab in another location to continue renting the apartments. Behind this initiative, HSB wants to test transportable building systems that can be set up in different configurations on new site environments.

A common sight walking around any city are construction trailers or containers, usually stacked on top of one another. They are made and constructed to be transportable and adding more or slightly different modules allows for scalable solution to fit almost any situation. This concept has been used for housing in many variations. One that applies directly to student housing is the Space Box in the Netherlands (see case study below).

Case Study: SpaceBox

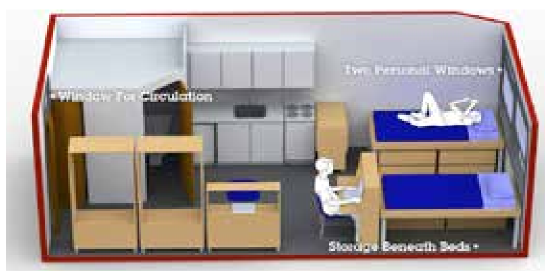
Constructed August 2004, (234 units) De Uithof Utrecht, student housing (nenygq.blogspot.com)

The units are completely factory prefabricated utilizing high performance materials, which decreases energy costs, as low as 1,8 kW per unit per day.

The Spacebox concept was develped in 2002 by Design Office De Vijf in collaboration with two housing institutes in Delft and Utrecht, Netherlands.

Designed as a 'plug and play' system the units sit on concrete pad foundations and can be stacked and moved quickly. In Eindhoven 84 units were stacked in 4 days. Utrecht's 234 units can be moved to another location in three weeks.

To date, roughly 1000 Spacebox units have been placed at several locations in The Netherlands.



SpaceBox interior view, studio for 2 students (danielplaya.com)

Source: "Spacebox® The Fast Affordable Flexible Innovative and Sustainable Housing Concept." Accessed November 14, 2013. http://www.spacebox.nl/index.cfm?lng=en.

3.5.2 Flexible & Refitable

"Incorporating Physical flexibility is consciously admitting to social flexibility and diversity and is one way to engage people in actively participating in exploring and reflecting on the way they live." [38]

Flexibility in this sense is extremely relevant as the purpose of the HSB Living Lab is co-creative innovation towards sustainable living. Flexibility can be applied to both internal and external changes and achieved by altering the physical fabric of a building by joining rooms, etc. [39] Flexibility and refitability are interdependent. Flexibility can allow for services and functions to be refitable over time making this a crucial aspect in relation to the research and experimentation that will take place within the building.

The experimental housing project in Kallebäck, located just outside the city of Gothenburg was one attempt at engaging users through flexibility. The design choice to include partitions that can be easily adjusted by the inhabitants allowing them to physically change their environment, engaged the users in taking an active role in creating and shaping their living spaces. Flexibility then could be used within the HSB Living Lab to engage users and facilitate co-creation as well as provide the ability to refit components, an important aspect to consider in order to meet the needs of the evolving research.

Case Study: Kallebäck Experimental Housing

Kallebäck housing development was built in 1960, located outside of Göteborg and consists of a concrete slab support structure with 18 detached housing units.

The design of the houses are made with a system of demountable partition walls, all fixed to the concrete floor plate. Two people are needed for changing partitions.

Constructed 1960, Kallebäck, Sweden(http://www.afewthoughts.co.uk)

A study was performed two years after completion and found that the majority of the occupants had chosen to buy into the project specifically for the possibility of changing things and therefore had an active commitment to flexible design. A second study, 11 years later confirmed that changes continued to be made by the inhabitants.

Source: Schneider, Tatjana. Flexible Housing. 1st ed.Amsterdam ; Boston: Architectural Press, an imprint of Elsevier, 2007.

38 Tatjana Schneider and Jeremy Till, "Flexible Housing: Opportunities and Limits," Architectural Research Quarterly 9, no. 02 (2005): 157–166, doi:10.1017/S1359135505000199.
39 Tatjana Schneider, Flexible Housing, 1st ed (Amsterdam ; Boston: Architectural Press, an imprint of Elsevier, 2007).

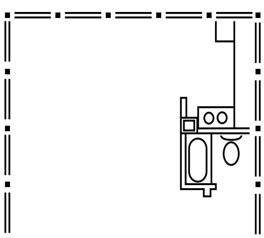
3.5.3 Available & Reusable

The strategies of availability and reusability may be outside the realm of adaptability but using these to guide material selection, could lead towards a more simple layered design. If materials are to be reused they must be easily separable where changing one layer does not disturb another layer. This can play an important role within the HSB Living Lab as many layers of the building may be changed with use and research. While at the same time using available, standard materials, can increase the reusability and replace-ability of the different layers over time potentially saving on costs for custom components. This can also lead to an evolution of the flexible and adaptable nature of the spaces and structure. Contrary to this idea a standardization of components can lead to obsolete adaptability.[40]

Case Study: Werfthaus

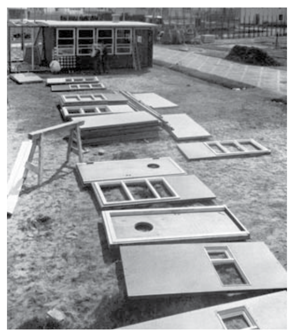
Otto Bartning's Werfthaus (afewthoughts.co.uk)

The thin steel frame was infilled with composite panels of copper alloyed steel and cork. There were four different types of panels that could be added over time to extend the house to a maximum of 60m2.



Werfthaus core unit plan (Adapted from Schneider, Tatjana, 2007)

Originally developed for the 1932 German competition, 'Das Wachsende Haus' (The growing house), Otto Bartning's Wertfhuas was one attempt to design a house where adaptability and extendability were central.



Otto Bartning's Werfthaus (afewthoughts.co.uk)

The protoytpe built for the Berlin Summer Show consisted of a 25m2 core which included, a bathroom, kitchen, and a combined 18m2 sleeping/living area

The interior walls were made of plywood and were fastened using bolted connections to allow for easy quick assembly and dissassembly

Source: Tatjana Schneider, Flexible Housing, 1st ed (Amsterdam ; Boston: Architectural Press, an imprint of Elsevier, 2007).

40 Tatjana Schneider, Flexible Housing, 1st ed (Amsterdam ; Boston: Architectural Press, an imprint of Elsevier, 2007).

"Adaptability forces design to become an ongoing social process between designer and user over time. The designer must focus on enabling adaptation to take place; as opposed to attempting to control experiences and anticipate the future." [41]

Schmidt et al.

41 Robert III Schmidt et al., "What Is the Meaning of Adaptability in the Building Industry?," in Proceedings of the CIB 16th International Conference on Open and Sustainable Building (Bilbao, Spain, 2010), 8.

4. Design for a Living Lab

According to the research and discussions that have been presented thus far, for an infrastructure to be classified as a living lab it must facilitate co-creative innovation by engaging stakeholders, partners and users. The partners (HSB and Chalmers) are willing, from a position of equality, to share their resources with external stakeholders and users and generate innovation from this collaboration. [42]

This co-creation should be centered around the active participation of the students for professional, educational, and life learning experiences. To invoke interaction and educational processes, the research should be visible within the building. The technical services and physical functioning of the building should be exposed providing a comprehension of the systems as well as easy access for physical modification, data control, and presentaton of the research.

The HSB Living Lab will explore and question future ways of living to shape our future habitat. In this purpose, the building should offer different living situations such as single flats, flat sharing, shared space and shared facilities. It is also an opportunity to compare these living situations in terms of life experiences, energy use, water consumption, waste production, and behavioral practices.

To allow for all these different research activities and possible changes to take place, the space has to be physically flexible. The technical services have to be accessible and easy to modify. The Living Lab is an experimental space that needs to continuously evolve. To permit this evolultion adaptable design strategies have been used in combination with the potential research projects and HSB prerequisites to inform the design.

The following chapter presents flexible design solutions for the HSB Living Lab. The aim was to maintain the co-creative functions of a living laboratory while meeting the needs of the stakeholders.

42 Nicholas Ind and Nick Coates, “The Meanings of Co-Creation,” European Business Review 25, no. 1 (January 4, 2013): 86–95, doi:10.1108/09555341311287754.

4.1 Living Unit

It appeared early in the design process that the concept of a living unit could be a viable solution to meet the demands of the HSB Living Lab. Many other solutions were discussed such as a plug-in architectural approach[43] or an Open Building[44] solution. However, the temporal nature of the HSB Living Lab on the Chalmers site was the main driver behind the choice of using a 'living unit' concept. Each of these solutions contained positive and negative aspects. However, not all of them seemed to allow for the material flexibility needed for the HSB Living Lab. The living unit option had the most potential to be reimagined and redesigned beyond the Spacebox idea (see case study page 44) to allow for flexibility using layered dissassociated components.

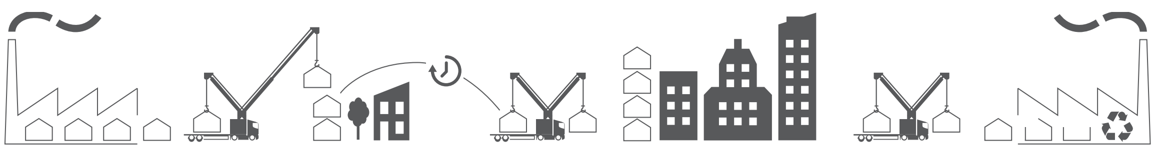
Movable and Scalable: The constructive system must allow the building to be moved and rebuilt somewhere else. In this context, the building has to be scalable in order to fit in different kinds of urban or rural situations. A single unit system permits multiple configurations by combining the units vertically and horizontally.

Enclosed Environment: The units are separated and isolated from one another. Each unit can be used by the researchers as an enclosed environment and collect data with little interference from other activities.

Prefabrication: The prefabrication in series can reduce the construction phase on site as well as the general cost of the building.

Transportation: The unit needs to fulfil the transportation regulation in order to facilitate the movable process and limit the cost. The dimension and shape of the unit has a large impact on the design.

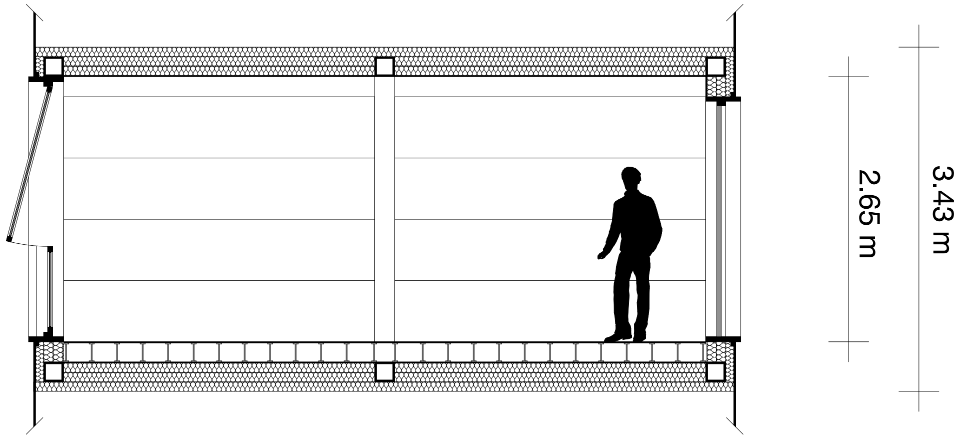
Reusable/ Recyclable: The future of the HSB Living Lab is not defined yet. So, the design should allow for change. At the moment the life of the building is limited to ten years, the period it will stay on calmers campus.



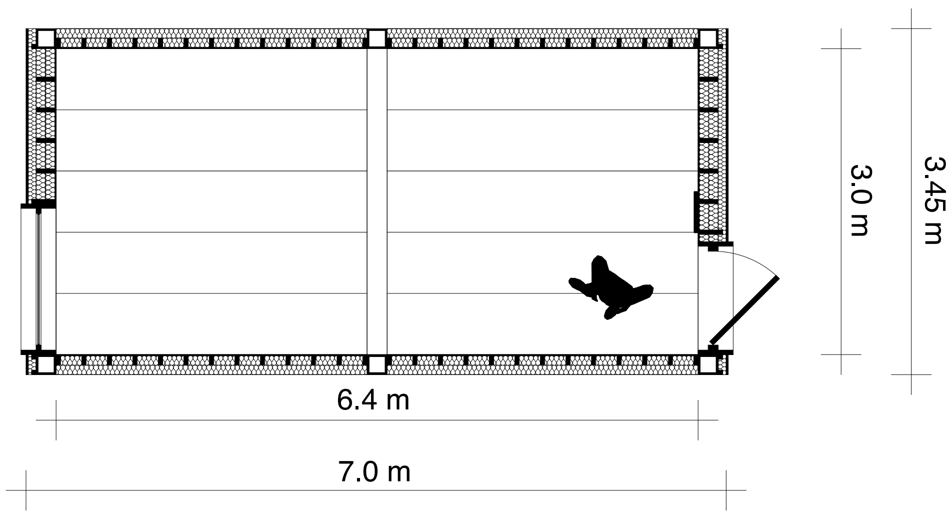
43 "21st Century Plug-in Housing," eVolo Architectural Magazine, January 3, 2012, http://www.evolo.us/architecture/21st-century-plug-in-housing-y-design-office/.
44 Stephen Kendall and Jonathan Teicher, Residential Open Buildings (London, GBR: Spon Press, 1999).

4.1.1 Living Unit Section

The Living Unit has been dimensioned to fit on a standard truck bed as well meet the space requirements of HSB (19m² interior). The Unit has been designed to provide qualities such as natural daylighting and ventilation. The high ceiling allows daylight to penetrate deep into the space.



4.1.2 Living Unit Plan



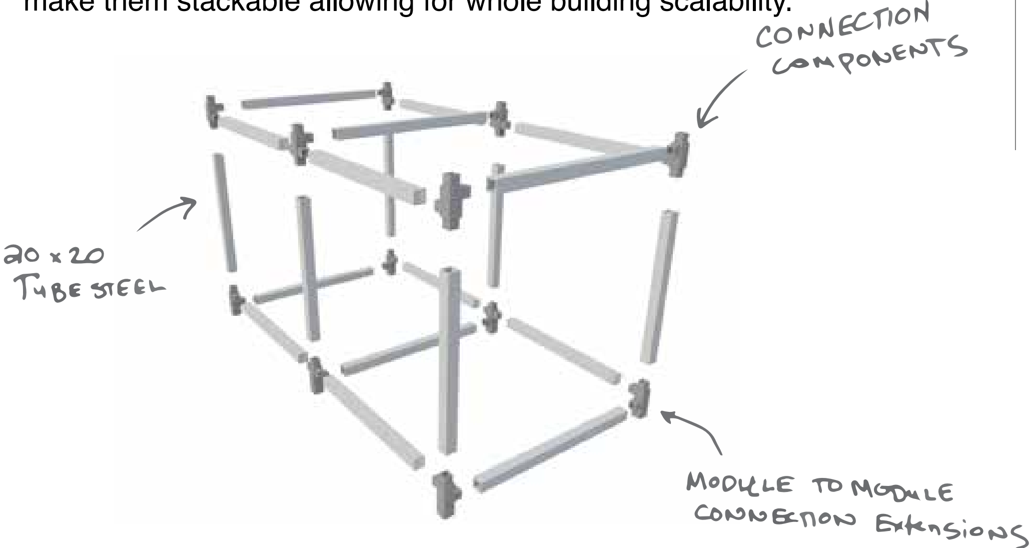
4.1.3 LIVING UNIT: LOAD-BEARING STRUCTURE

The material choice of the load bearing structure of the living unit was discussed in-depth. Tube steel was chosen over engineered wood for various reasons, including the assumption that steel allows for smaller dimensions at greater spans and is less prone to movement which could cause problems in the connection of the units over time. Steel however, presents other issues such as sound transmission and it's higher environmental impact.

Movable: The HSB Living Lab project has been planned to run to for 10 years therefore the building should be designed to be able to be rebuilt at another location.

Reusable: Steel can be fabricated in such a way that the materials can be separated and reused after the life of the project if necessary.

Scalable: Connection points on the top and bottom of the unit make them stackable allowing for whole building scalability.



Strategies

- FLEXIBLE
- SCALABLE
- REFITABLE
- REUSABLE
- AVAILABLE
- MOVABLE

Opportunity for Innovation

Prototyping and analysis of simple steel connections i.e bolting, pressure fit, cabletension, etc.

Transport: In a meeting with Anders Carlsson from A-hus, a company that specializes in prefabricated housing, the transportable load size limit was discussed. The unit design considers the need for transporation and needs to be under 3.5 meters in width. The structure was sized appropriately for transport with all components including exterior facade mounted during the prefabrication process. Connections can be used as lifting points for loading and assembly.

Dimensioning: The HSB prerequisite size requirement for interior space for each occupant is between 20 and 25 square meters. This requirement poses two main issues. The first being that with the proposed unit constructive system a unit of 25 square meters will need special permits to be transported. The second is the fact that smaller living spaces should be considered for purposes of experimentation associted with living practices and consumption. The proposed unit has approximately 19 square meters of interior space.

PreRequisites

20-30 OCCUPANTS

GROUND FLOOR COMMON AREAS

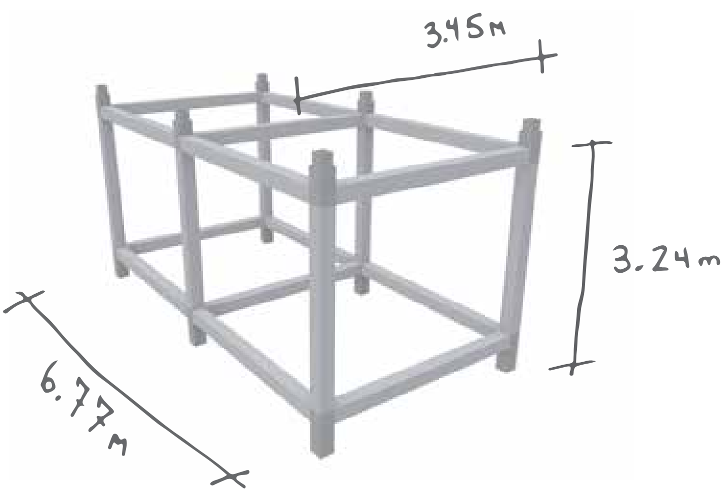
20-25M2 PER OCCUPANT

COMPACT BATHROOM

400M2 FOOTPRINT & 3 STORIES

COMMON KITCHEN

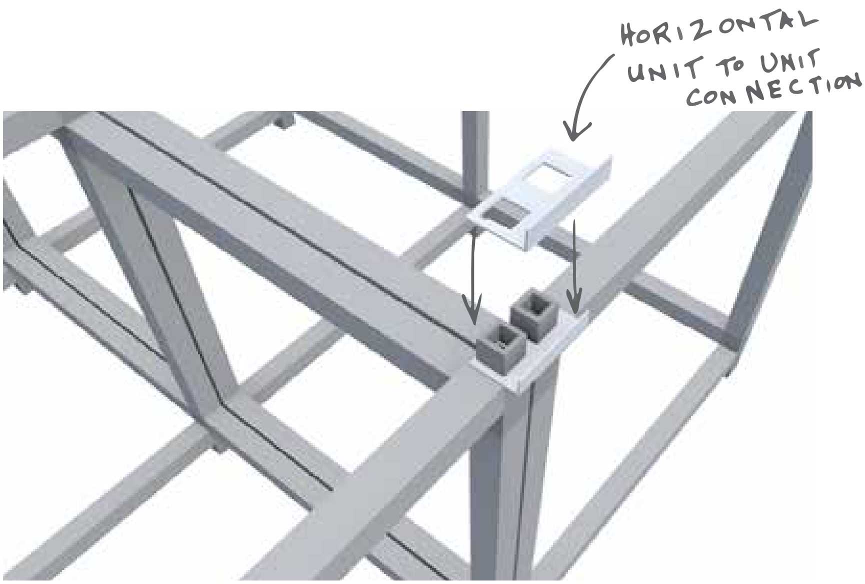
MOVABLE STRUCTURE



Opportunity for Innovation

Bracing system with no cross bracing in walls

Research: Different experiments must be tested, some of which are not known yet. The ability to have different stand alone/isolated units can help achieve the needs of controllable research and allow for future research without compromising on-going testing.



Opportunity for Innovation

Multifunctional connection plates that can also connect exterior walkways to load-bearing structure.

Case Study: B2 Skyscraper

Rendering of B2 Skyscraper (www.fastcoexist.com)

B2 is a 32-storey modular apartment building being constructed by Forest City Ratner in New York. The building will be made up of 42 to 88 square meter apartment units that will click and seal together to form the largest modular high-rise building in the world. The units are being produced in a factory in Brooklyn.

B2 is being constructed using a process called "group technology workcells" where multidisciplinary groups of tradesmen work on different parts of the same area of the building simultaneously. The system was implemented by the developer FCS Modular and its Swedish partner Skanska.

Units in Brooklyn Navy Yard (Photo: Joel Arbaje, www.fastcoexist.com)

Fitting units out and together (Photo: Joel Arbaje, www.fastcoexist.com)

"... a more radical innovation takes place in between the mods, when they are joined together by rubber sealant, like the connections between subway cars. The sealant goes on the façade in one of the final steps before the mod is trucked out. The apartments, meanwhile, require zero welding."

Source: "New York's Newest Skyscraper Is 32 Floors Of Prefab Apartments That Click Together." Co.Exist. Accessed November 30, 2013. http://www.fastcoexist.com/3020237/new-yorks-newest-skyscraper-is-32-floors-of-prefab-apartments-that-click-together.

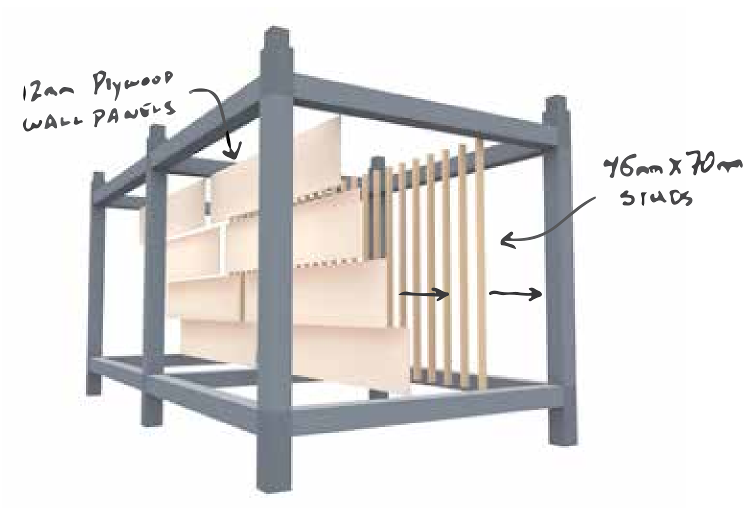
4.1.4 WALL INFILL & DEMOUNTABLE PANEL SYSTEM

The load-bearing structure allows for a non-load bearing infill wall system. This constrcutive system allows for horizontal flexibility between units, where multiple units can be linked to create new spaces and larger units by removing studs, plywood and insulation.

Flexible: A system of wall panels with non-load bearing studs and simple connections, allows for flexibility of the interior spaces that can be done potentially by users themselves.

Refitable: Incorporating a non-load bearing demountable wall system allows for future wall systems and materials to be tested without major distrubance to other components within the living unit.

Available: Using standard, available materials such as plywood can help to reduce initial costs while also ensuring that materials can be replaced easily.



Strategies

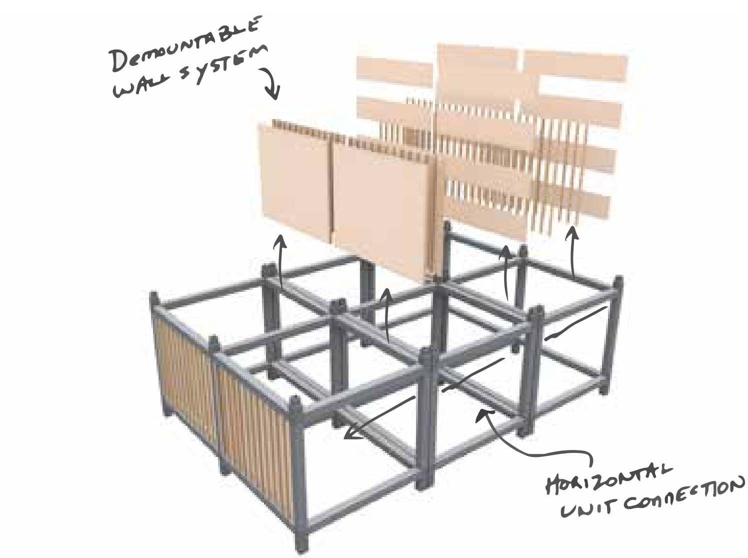
- FLEXIBLE
- SCALABLE
- REFITABLE
- REUSABLE
- AVAILABLE
- MOVABLE

Opportunity for Innovation

Multifunctional attachment of wall plywood to studs that can act at supports for shelving, etc.

Occupants: Wall system allows for horizontal connection of living units and reconfiguration of space leading to ability to adjust the number of occupants per square meter by redesigning space. This can be achieved by removing entire wall sections or just some studs and insulation through a layered wall construction where the components can be easily demounted. Simple connections and an easily demountable system allows for users to be active participants in the co-creation of their living spaces.

Living space: Allows for more simple increase or decrease in the size of living spaces as the removal of wall components do not disturb other materials or surfaces within the unit.

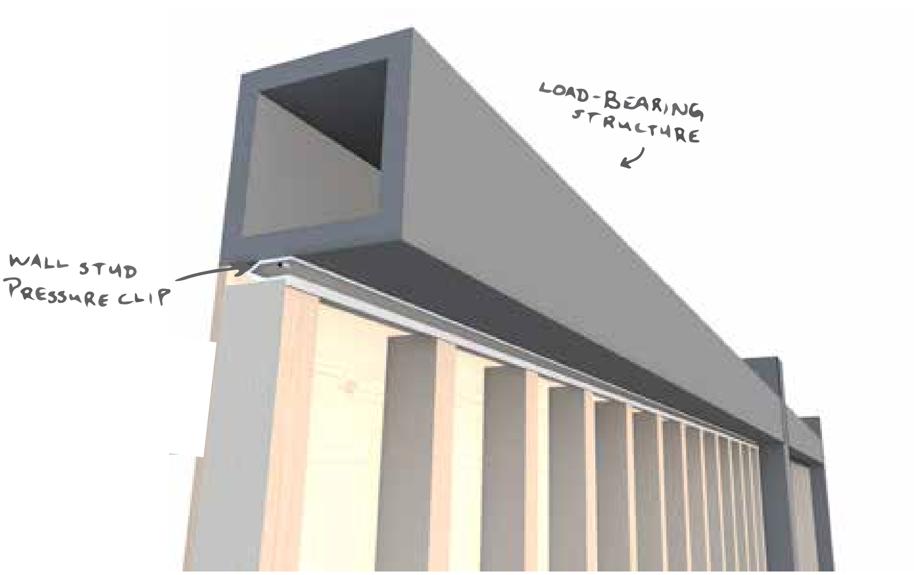


Opportunity for Innovation

Simple attachment of non-load bearing studs to structural frame, i.e. pressure fit.

Insulation: Demountable wall panels allow for different insulations to be replaced and tested without destruction of support structure or wall finish.

Design/Build/Live: Simple construction gives opportunity for students to be active partcipants in reshaping their living spaces. By using screws, clipping or pressure fit connections students with little or no construction experience are given the opportunity to deconstruct and construct infill walls most likely with some guidance. This can both engage students and inhabitants with research projects as well as provide hands on practical learning experiences.



Opportunity for Innovation

Sealing system between plywood panels, allowing wall panels to act as vapor barrier.

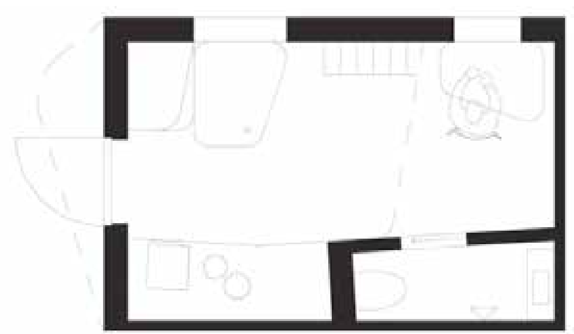
Case Study: Smart Student Unit


Interior Views of student unit (dezeen.com)

Swedish firm Tengbom in collaboration with students from Lund University have designed a ten square-metre wooden house for students. Using an efficient layout and crosslaminated timber has reduced both the rent and ecological impact for single student accomodation.

Exterior view of Smart Student Unit (dezeen.com)

The cross-laminated timber (CLT) components were sourced from Martinsons and mounted on site by Swedish building firm Ulestedt. The design aims to show the architectural and construction qualities of CLT.



Plan view of unit (dezeen.com)

"In 2014, 22 of the student units will be built and ready for students in Sweden to move into."

Source: "Smart Student Unit by Tengbom." Dezeen. Accessed November 30, 2013. http://www.dezeen.com/2013/09/29/smart-student-units-by-tengbom/.

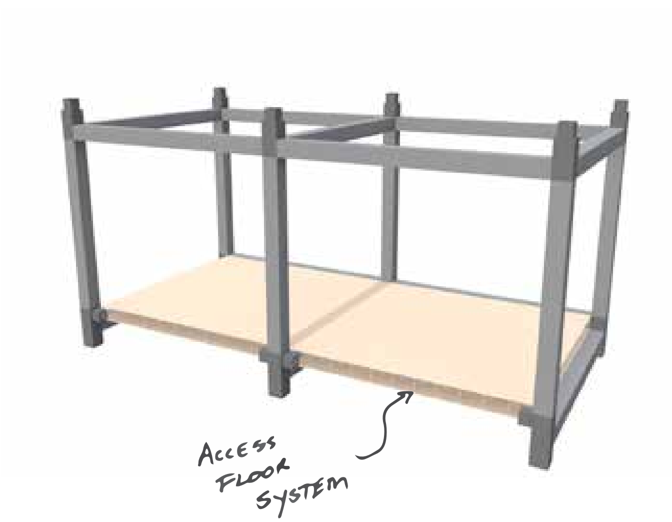
4.1.5 Access Floor For Building Services

An access floor will keep all services out of the walls allowing for units to be connected horizontally without major impact on service locations. Having access to all services within the unit is optimal to allow for the changing of systems over time. There is however the issue of sound that will need to be solved as the raised floor creates a void that can amplifyf sound from footsteps as well as mechanical systems located under the floor.

Flexible: Keeps all services out of walls to accommodate changes in unit connections and size. Allows for moving of services to accommodate changing use of space and needs of occupants.

Available: Utilizes available materials to lower cost compared to custom solutions.

Refitable: allows for changing of services and flooring materials to meet research needs.



Opportunity for Innovation

Floor panels made from plywood or other standard/available material

Strategies

FLEXIBLE

SCALABLE

REFITABLE

REUSABLE

AVAILABLE

MOVABLE

Services: An access floor creates a less invasive system for changing services, relocating bathrooms, kitchen, electrical outlets, etc. Within the Living lab all services should be located under the access floor.

PreRequisites

20-30 Occupants

Ground Floor Common Areas

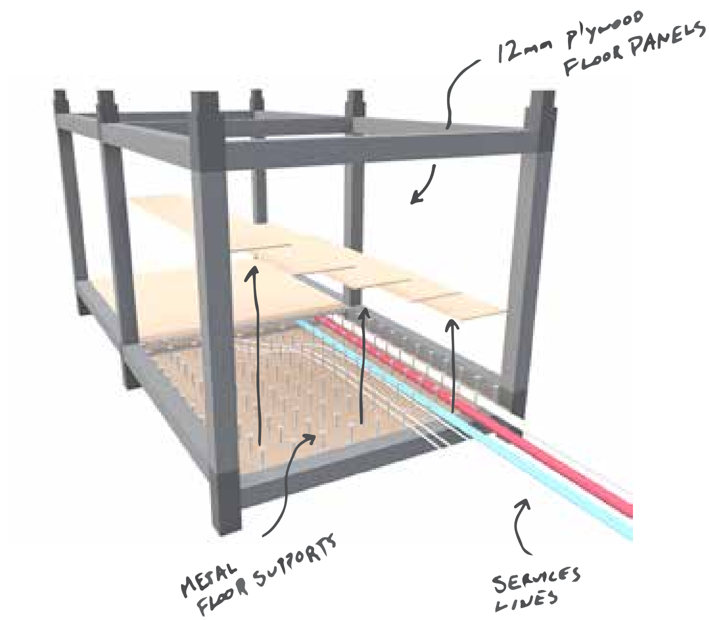
20-25m2 per occupant

Compact Bathroom

400m2 Footprint & 3 Stories

Common Kitchen

Movable structure



Opportunity for Innovation

Hydronic floor panel system where heating is integrated into the floor panels

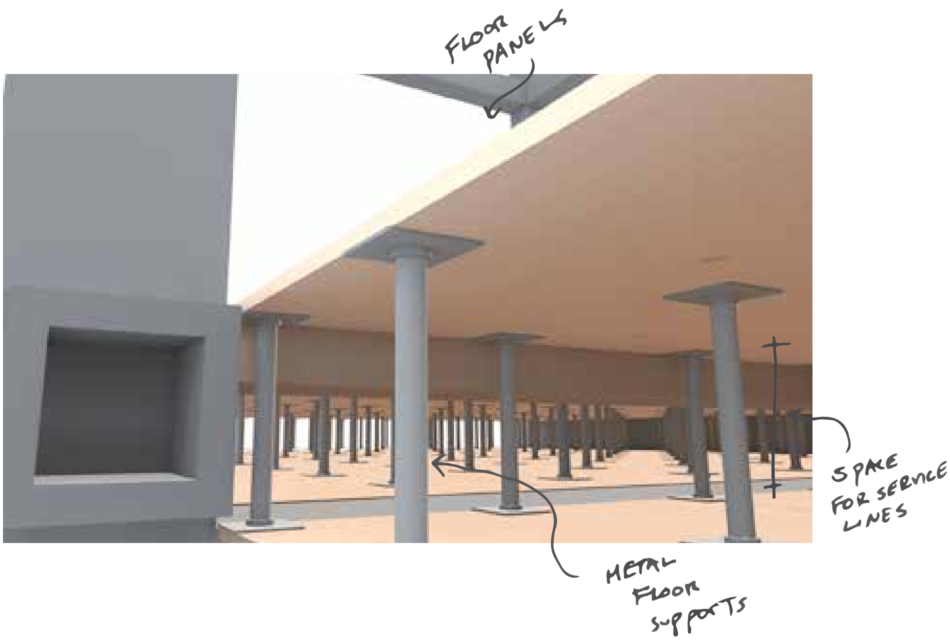
Water consumption: Allows for access to piping of individual water heating units for installation and changing of monitoring devices.

Systems Floor heating: Allows for a low temperature floor heating system to be installed, monitored and adjusted or replaced with a different heating system if needed.

Splash: Allows for installation and modification of prototype testing of splash technology and future replacement with other technologies.

Controlled ventilation: Allows for access, installation and replacement of different ventilation systems.

Zentigo: Utilizing underfloor space allows for installation, modification and replacement of different electrical systems.



Opportunity for Innovation

Acoustic solutions to dampen noise from systems under the floor

4.1.6 Interchangeable Facade

Movable & Scalable: Facade must have a modular design to allow for the structures to be connected and disconnected and moved easily.

Refitable: An interchangeable facade offers opportunities to test different materials.

Opportunity for Innovation

Simple clipping device for facade frame to be secured on horizontal rails

Strategies

FLEXIBLE

SCALABLE

REFITABLE

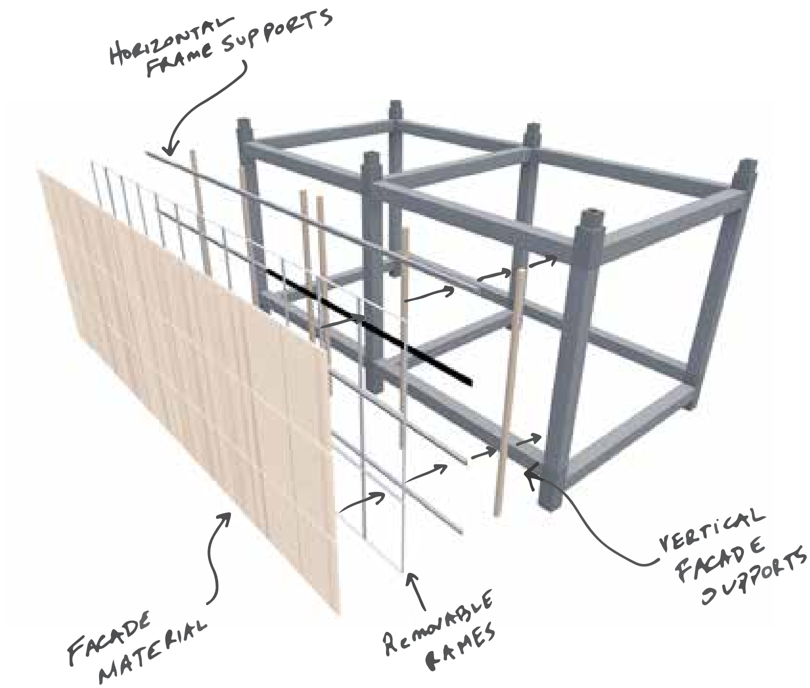
REUSABLE

AVAILABLE

MOVABLE

Movable Structure: Since the modules will be prefabricated there is a need for an Interchangeable facade to allow for facades on the units to be linked together after site assembly.

Facades at first did not seem to meet the criteria of user interaction or involvement that should be present in research for the living lab. However, after a field study trip to TUDelft (see appendix for summary) in the Netherlands where an explaination of the SusLab double-skin facade project was given, user involvement became evident with testing different facade technologies. This double-skin facade project, which is funded by the BTA Climate-Kic, will investigate if thermal comfort within a structure is improved by adding another facade over the existing. There is great interest in this as many older buildings have deteriorating facade and are extremely difficult and expensive to insulate from the inside.



Opportunity for Innovation

Attachment system for facade material to be mounted inside frames

Next Generation Insulation: This research project aims to test various materials' insulation properties when in contact with a habitated space. The first known material for testing is fiber reinforced concrete slabs. A facade made of demountable components can make such changing of materials less invasive. For this particular research a double frame is needd with insulation between to stop cold bridging. The concrete is then mounted into the frames. This will allow for isolated measurements of moisture and thermal transmittance through the concrete material.

Opportunity for Innovation

Demountable exterior wind barriers

Research

Central control ventilation

Vermi-composting

Shared multifunctional laundry space

Synergetic Peltiere kitchen system

Alternative personal heating

Small scale biogas generator

Next generation insulation

Reusable goods exchange

Design/Build/Live studio

Kitchen food-waste chute

Splash bathing technology

Inter-changeable facade

Low temperature floor heating system

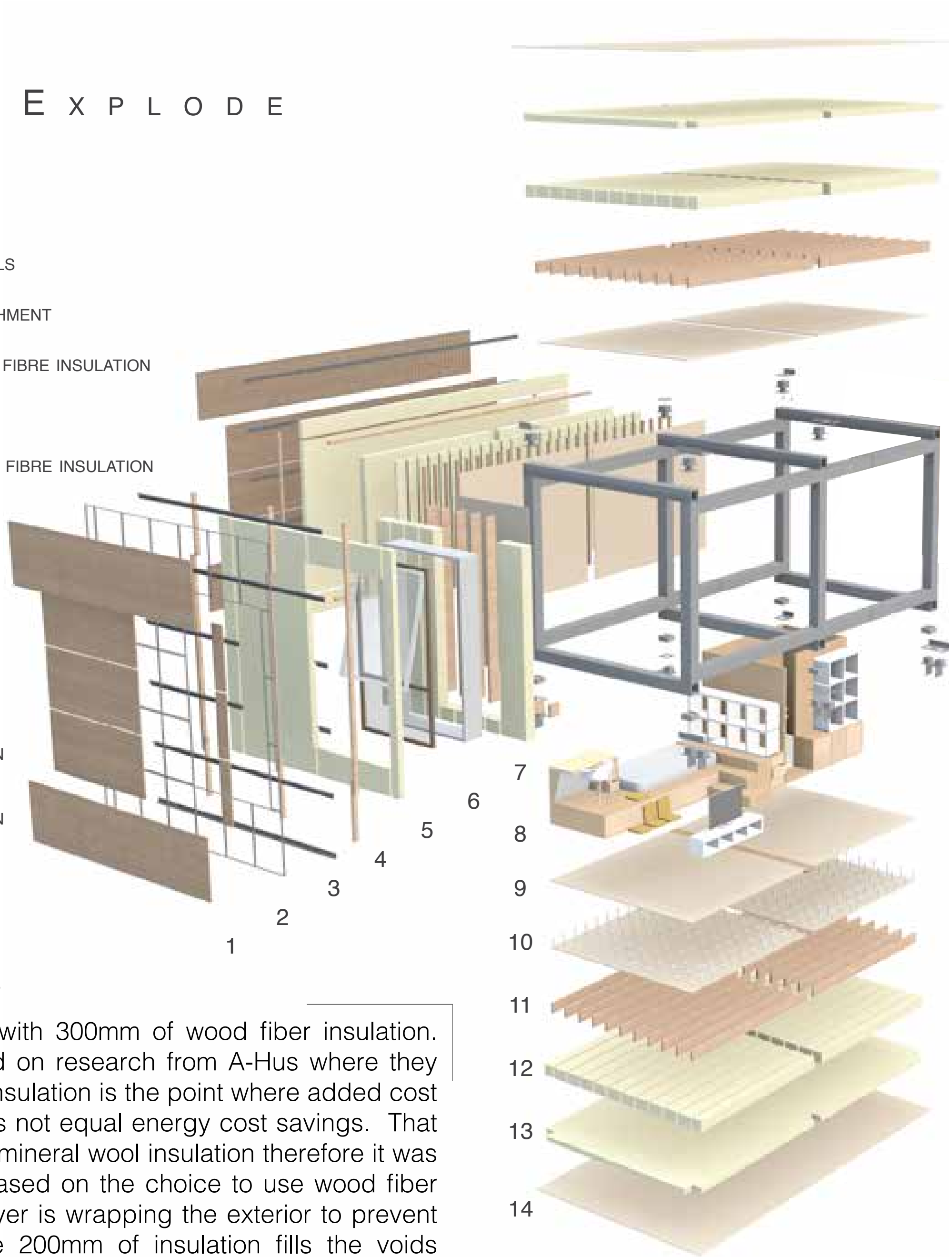
Phase-change light penetrating partitions

Zentigo DC power system

Visualisation of water consumption

4.1.7 Unit Explode

1. Wooden Facade
2. Facade frame
3. Horizontal facade rails
4. Vertical facade attachment
5. 100mm exterior wood fibre insulation
6. Window frame
7. 200mm Interior wood fibre insulation
8. Interior module
9. Raised floor panel
10. Raised floor spacer
11. Floor joist
12. 200mm Interior wood fibre insulation
13. 100mm exterior wood fibre insulation
14. Exterior Sheathing



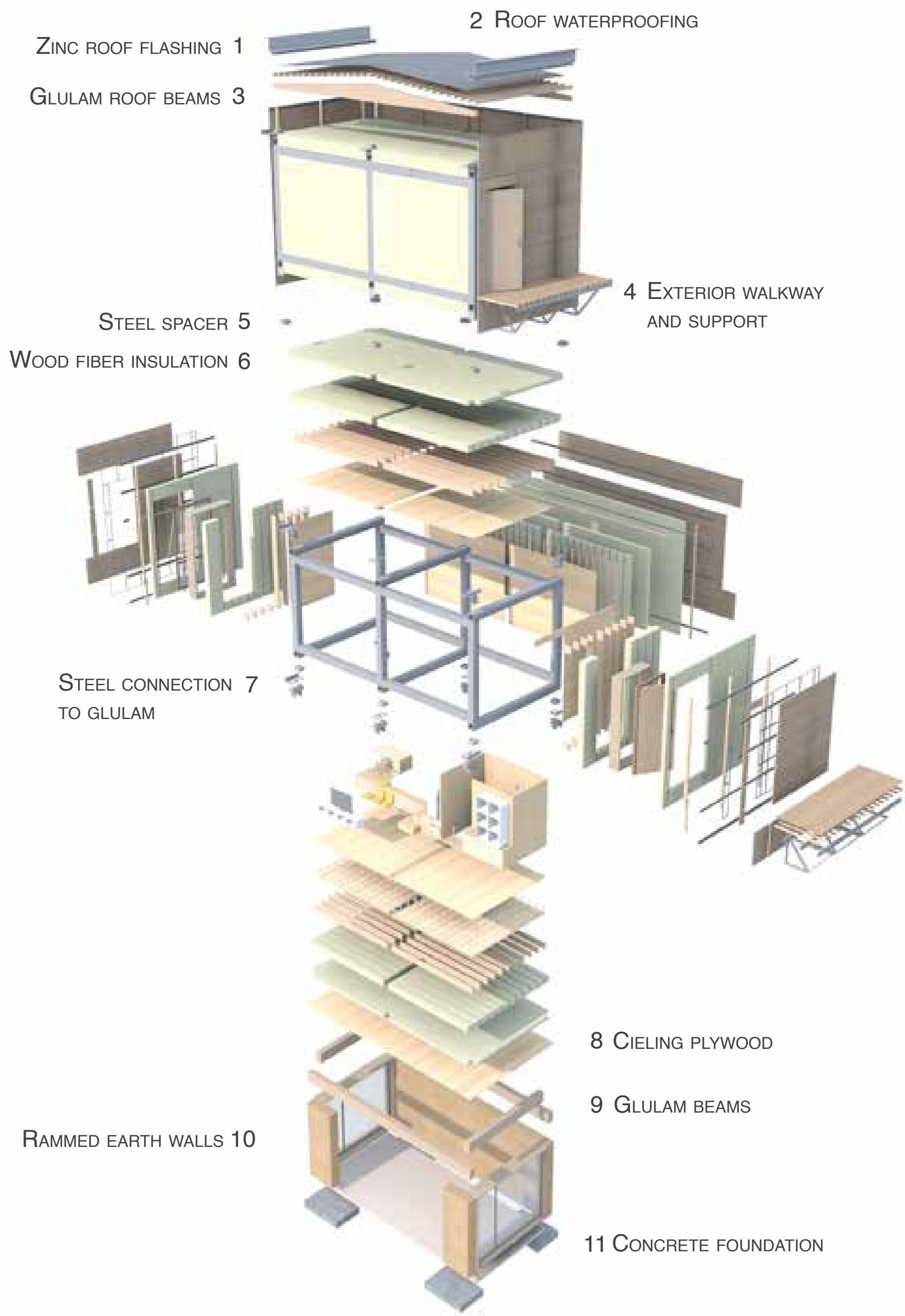
Thermal Performance

Each unit is insulated with 300mm of wood fiber insulation. This thickness is based on research from A-Hus where they have found 265mm of insulation is the point where added cost for more insulation does not equal energy cost savings. That analysis was based on mineral wool insulation therefore it was increased to 300mm based on the choice to use wood fiber insulation. A 100mm layer is wrapping the exterior to prevent thermal bridging, while 200mm of insulation fills the voids between the studs, rafters and joists. The tube steel structure is filled with blown cellulose to absorb acoustical vibrations and prevent thermal bridging. Due to time limitations no thermal performance analysis or LCA was done.

4.1.8 Three Floor Explode

Use of Earth

The ground floor is constructed of massive rammed earth walls that support the building structure. The intention was to show a clear delimitation between the ground floor and the rest of the building according to the program. The ground floor is supporting the active co-creation process by offering social interactive space open to all, while the two upper floors are private spaces for the inhabitants. The use of earth orginates from an interest in the material as well to give an expression of how the HSB Living Lab could be used for testing different building materials and constructive systems. It is as well a reflection around the future of the Living Lab after the ten years on the campus to imagine how this project can evolve. Perhaps by keeping a trace of the building on Chalmers' campus, by saving the ground floor and using it for different activities that can extend or promote the Living Lab experience.



4.1.9 INSIDE LIVING UNIT: PERSPECTIVE ONE

This perspective shows the large window facing west and an interpretation of what the interior furniture layout may be. It is not the intention to design the interior as this should be done collaboratively with the students through the Design/Build/Live Studio or other research projects.

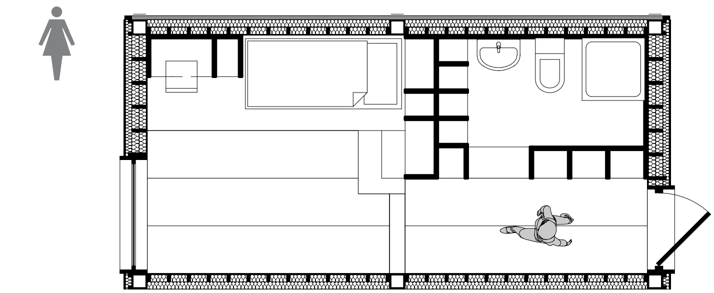
4.1.10 Inside Living Unit: Perspective Two

This perspective shows entry door facing East. Behind the shelving is a compact bathroom module, maybe including the proposed alternative washing system research project, Splash. The design of the unit modules are intended to allow for innovation and flexibility. This perspective aims to show a possible interior unit layout for one student.

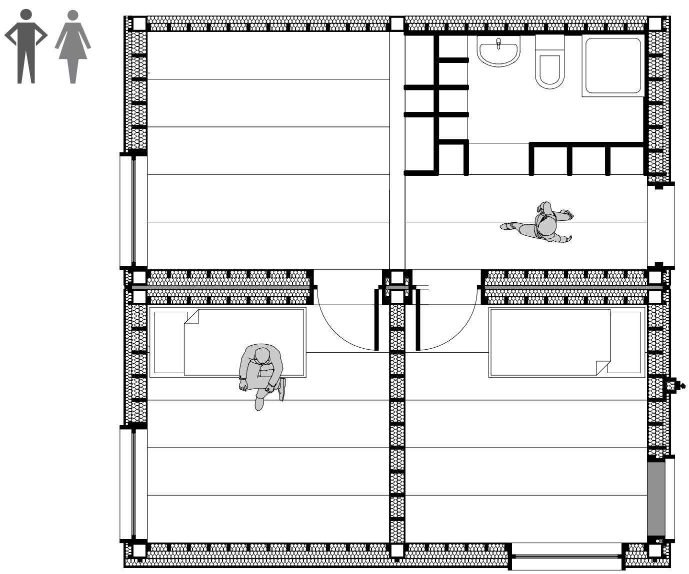
4.3 Living Unit: Configurations

The units enable many configuarions and layouts. The adaptable features allow for spaces to be fitted and reconfigured based on needs of inhabitants and research projects. The following are some examples of possible configurations and layouts.

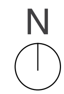
4.3.1 One Bedroom

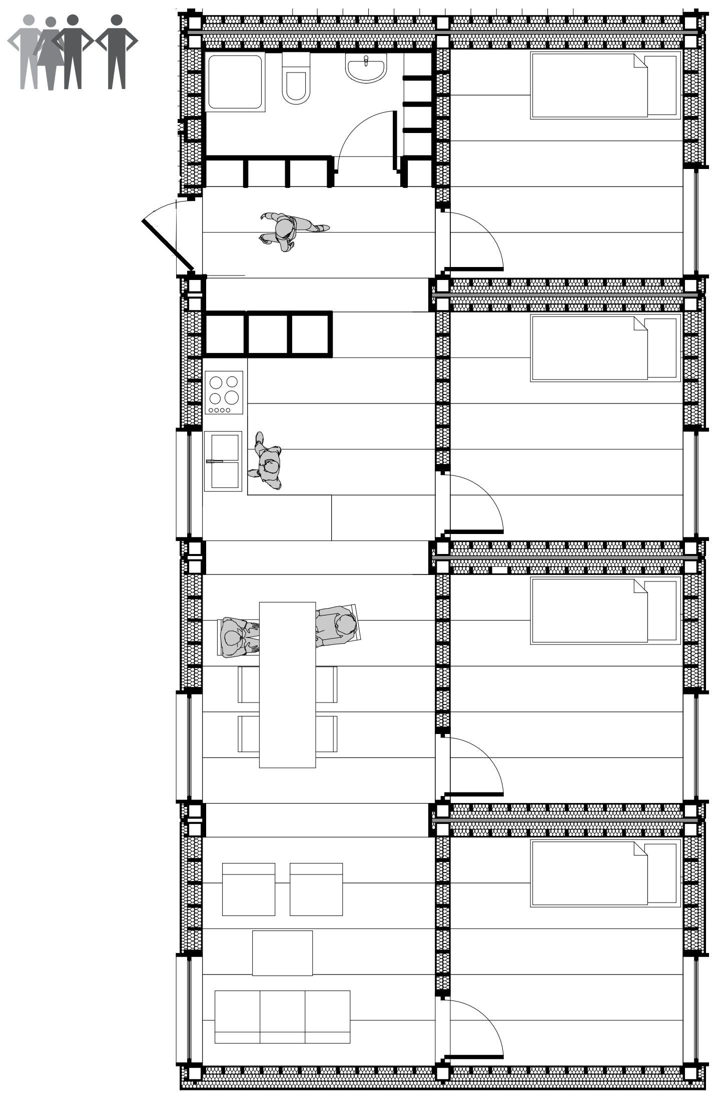


4.3.2 Two Bedroom



4.3.3 Four Bedroom



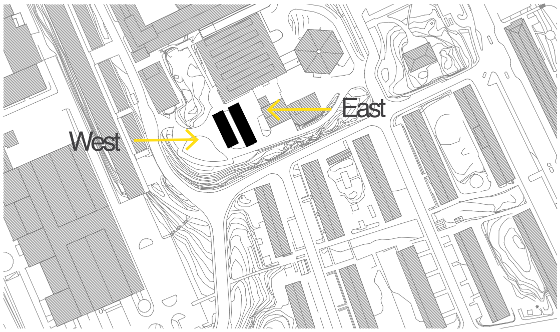


4.4 Site Plans

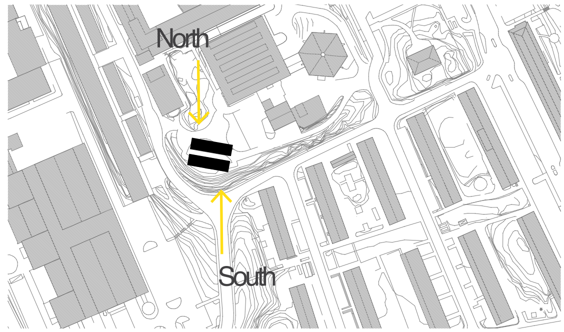
N

4.4.1 Site Analysis

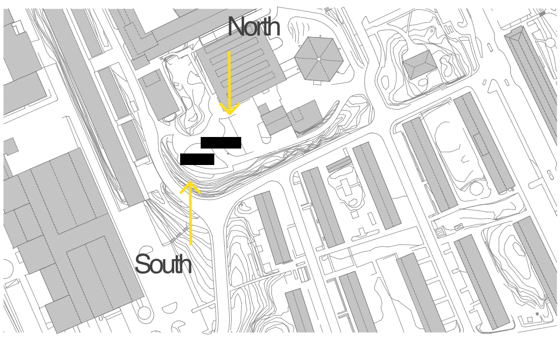
The site was chosen by Chalmers and is located at the south end of the Johanneberg campus. It consists of a parking lot and a park. The location of the surrounding buildings make it a difficult site to place a 400 square meter structure while maintaining the park space and allowing for access to the buildings and flow through the area. Different orientations were explored based on these limitations and the orientations of the living units within the HSB Living Lab.



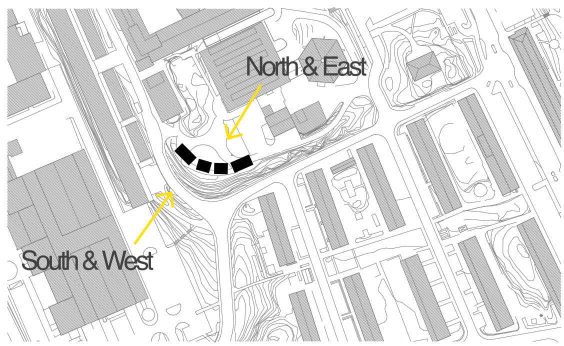
compact : flat mono oriented east & west:
less invasive: inequality between units:



compact: flat mono oriented north & south:
invasive: inequality between units:



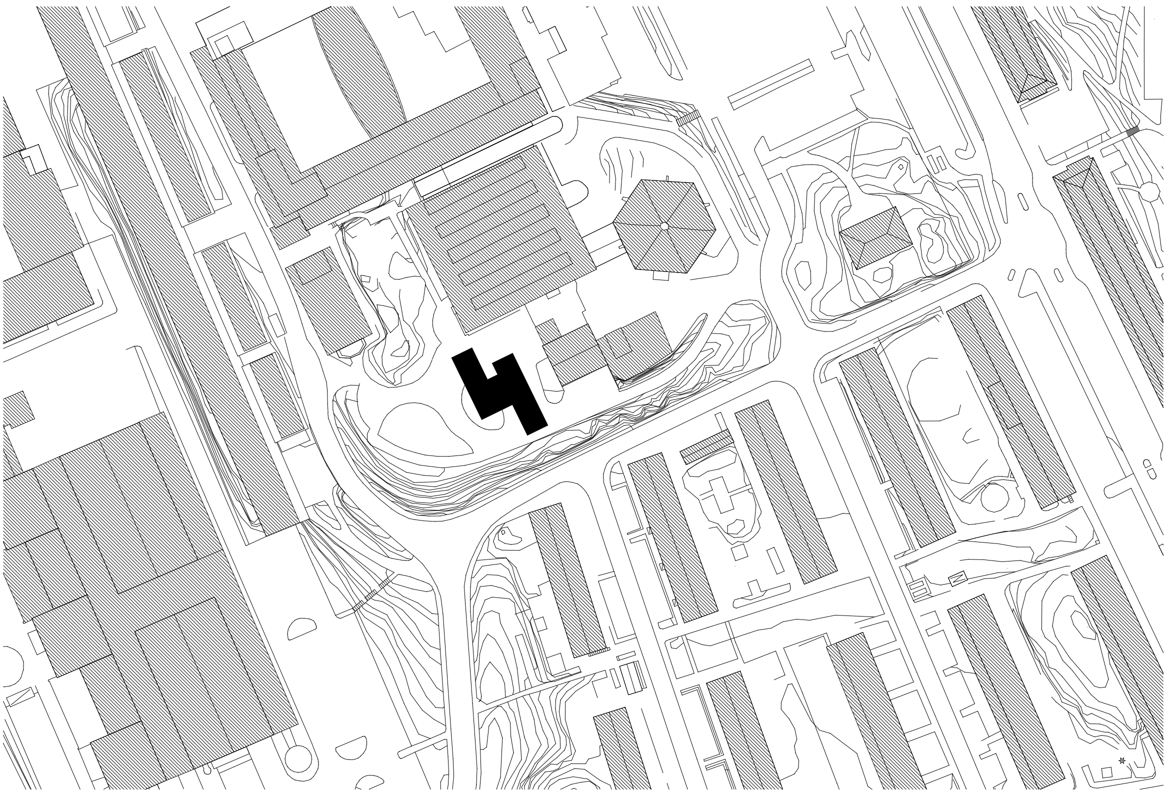
less compact : flat double oriented n & s :
invasive : equality between all units:



least compact: flat double oriented n & s.w:
invasive: equality between units:

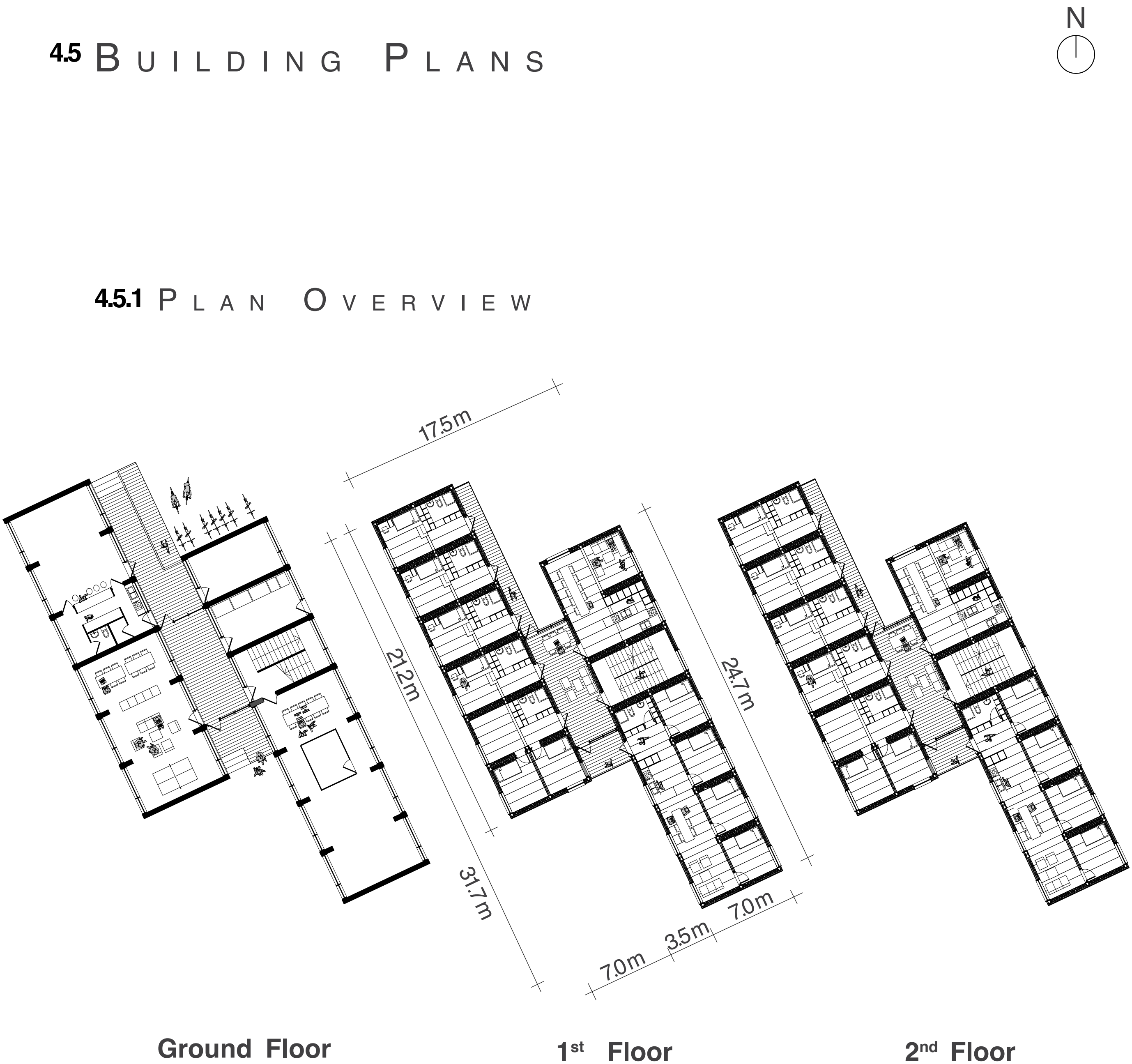
4.4.1 ORIENTATION

East-West orientation was chosen based on site limitations. This configuration and location allows for access around the building and appropriate orientation of the living units.



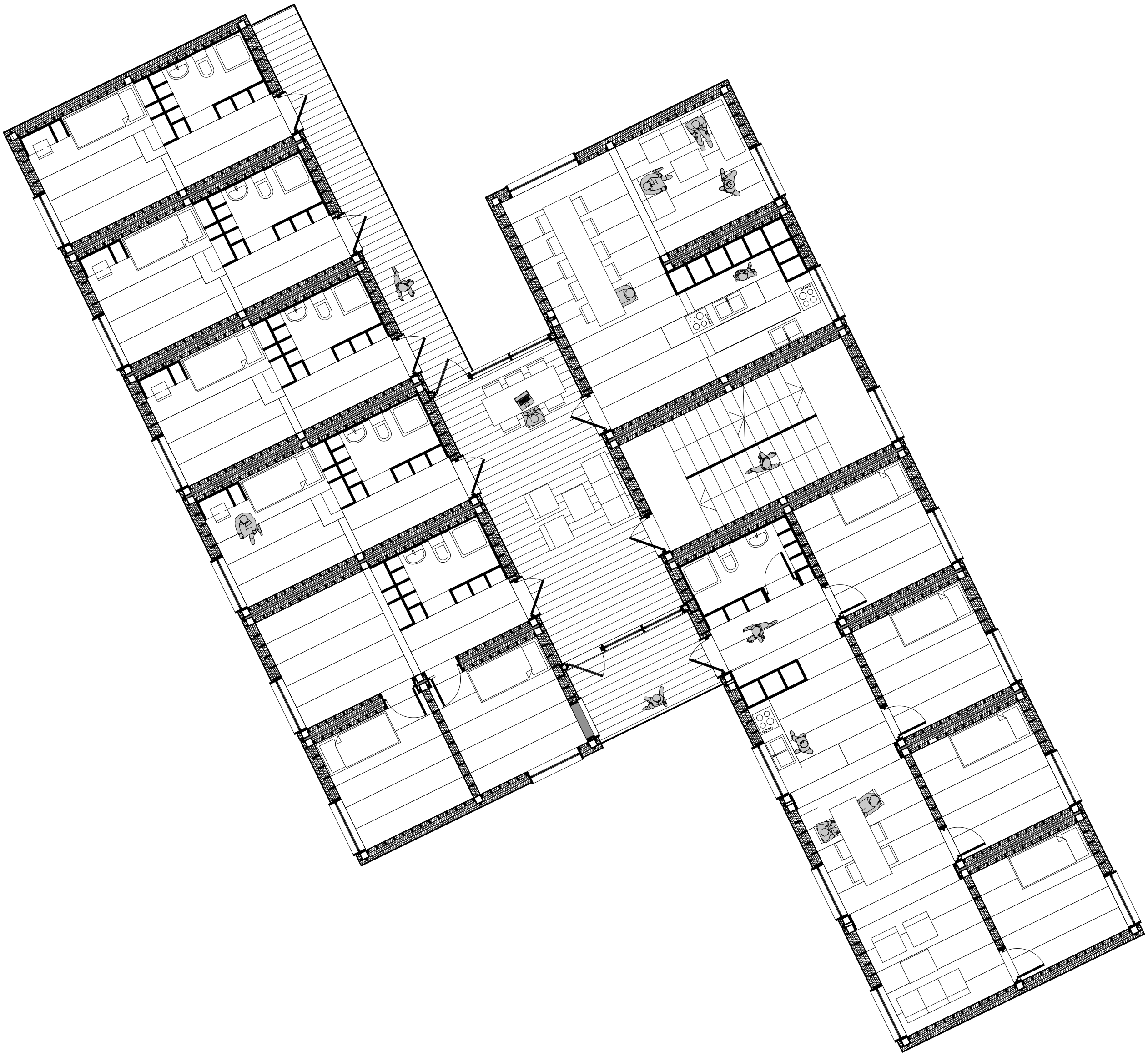
4.5 Building Plans

4.5.1 Plan Overview



4.5.2 Plan: 1st & 2nd Floor

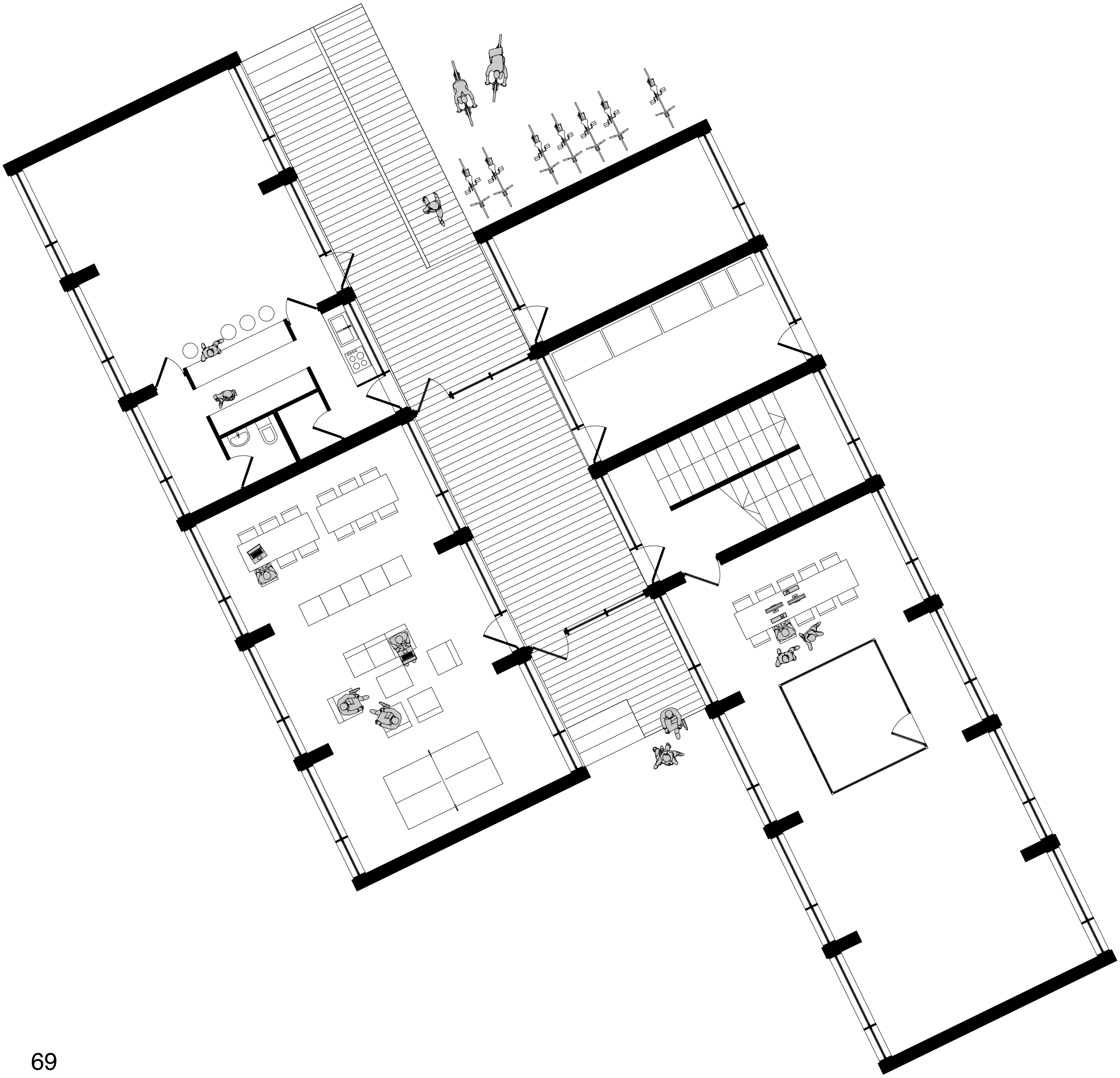
The general plan of the HSB Living Lab is constituted of single units arranged in two building blocks. The space in between the two unit rows is dedicated to the horizontal circulation as well as common areas for the building. The units can be physically connected to create different living situations such as shared flats. Some of the units are also used for common spaces and circulation.



4.5.5 Program: 1st & 2nd Floor

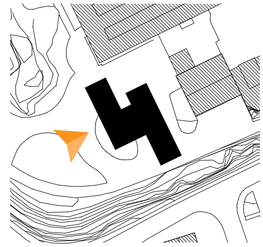
4.5.4 Plan: Ground Floor

The ground floor program aims to support the active co-creation and educational purpose of the Living Lab. The main building entrance is located in-between the two unit rows, an enclosed space open to everybody. The exhibition hall contains the mechanical and monitoring rooms. The shared multifunctional laundry space and reusable good exchange are added to the program as research features as well as social interactive spaces. The café is included to attract visitors and the campus community to the building.

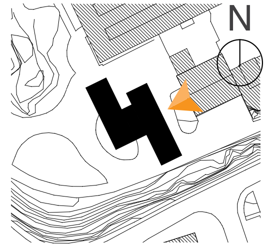


4.5.5 Program: Ground Floor

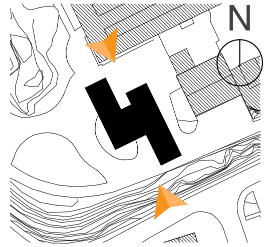
4.6 Building Elevations



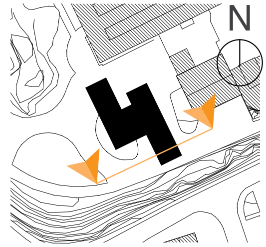
4.6.1 West Elevations



4.6.2 East Elevations

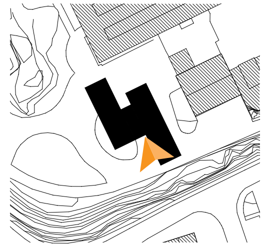


4.6.3 North & South Elevations



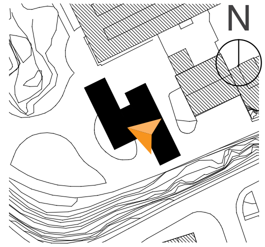
4.6.4 3 Floor Section

4.7 Building Perspectives



4.7.1 1st Floor Circulation and Common Space

This perspective shows the common spaces which also act as the main circulation between the two unit blocks. Also, the exposed service piping can be seen above the walkway.



4.7.2 Common Laundry

This perspective shows the ground floor multifunctional laundry space. The laundry machines are located behind the shelf/wall past the couches. The large windows look West onto the park and bring daylight into the room, highlighting the exposed earth walls and glulam beams.

5. Conclusion: general reflections

The HSB Living Lab is an initiative, which can be an example of a true collaboration across disciplines and fields. The co-creation processes, that have already begun between the different actors taking part in the planning, construction and management of the future Living Lab, are essential for this project to be a success in terms of innovation, education and trans-disciplinary work that will question and shape the world of tomorrow.

This report aims to be a catalyst towards the creation of the HSB Living Lab facility. However, this work is a static element within a quickly evolving project. The information and suggestions presented are based only on information available at the time of writing. This work should be used as an information resource and starting point for the partners and designers to progress the state of this project and bring the HSB Living Lab facility to realization.

5.1 Summary of Research

The literature review and research provided a foundational understanding of the living lab concept. The elements of co-creation and innovation are essential to a living lab and therefore should be at the core of the HSB Living Lab project.

It was interesting to see through the interview process the variety of responses and discussions, which showed the complexity of the project. The interviews and field studies brought a deeper understanding of the project and its decentralized nature. There have been efforts to coordinate all the fluid components of this project. However, to date, the goals of the researchers, and partners are not focused towards the goal of creating a world-class innovative living lab facility but instead seem to be diverted to more specific 'personal' project goals. The complexity of this project demands high levels of communication, coordination, and collaboration, which have not been established yet. Progress, in this respect, is being made but far too slowly to meet the deadline set by HSB for students to 'move-in' in 2015.

Understanding the needs of the partners in the form of the potential research and prerequisites formed the framework for the design proposals to answer the question of; How the HSB Living Lab can be designed to facilitate a flexible use of the building and support a co-creation process in research and innovation for sustainable living?

The proposed designs were informed by the inherent need of a living lab to foster co-creative innovation. However, this can only be fully realized by a true open collaboration among partners and users.

Adaptable design strategies were found to have the potential to facilitate this co-creation and innovation by allowing for flexibility of both systems and space within a built structure. By combining these strategies with the stakeholders' needs and consciously simplifying constructive systems the HSB Living Lab can be a successful tool in the research and innovation for sustainable living technology.

Throughout the research and exploration of designing for the HSB Living Lab a foundational knowledge base was formed and documented in this report. The design solutions proposed are just one interpretation of this collected information. The design was focused on supporting future innovation and has been conceptualized as a canvas for future co-creativity.

5.2 Recommendations: Moving Forward

The conceptual framework that has been laid out in this thesis for the HSB Living Lab is essential for the continued work towards realizing the HSB Living Lab project. If the physical structure is designed without incorporating co-creation, innovation, and adaptability, the built structure cannot and should not be classified as a living lab. Furthermore the co-creative nature should be an equal collaboration between the partners, stakeholders and most importantly the users.

There should be emphasis placed on setting up a curriculum to engage students throughout the life of the HSB Living Lab at Chalmers. The 'Design/Build/Live' research project should be initiated, as it can be a first attempt at co-creative prototyping for the living lab.

For the HSB Living Lab to be successful in researching, creating and disseminating sustainable living technologies and strategies, a clear management structure must be put into place before the final design of the building is completed. The

Under Construction:
HSB Living Lab 2015

designer, builder, partners and students should all be actively engaged in the design process from the start. As with any collaborative project communication is key, but even more so with a living lab as its aim is to promote an evolving equal collaboration, which will become ever more complex. Currently, there seems to be issues with communication and collaboration within the project. Therefore, setting guidelines for roles, procedures and research needs to be done quickly.

The final design of the HSB Living Lab must not only encourage co-creation, innovation, and participation but needs to be created in a working environment where these elements are driving the design process.


Five Years Later:
HSB Living Lab 2020

6. B i b l i o g r a p h y

"21st Century Plug-in Housing." *eVolo Architectural Magazine*, January 3, 2012. http://www.evolo.us/architecture/21st-century-plug-in-housing-y-design-office/.

Aaron Steven Wendel Greene. "Flux: Adaptable Architecture for a Dynamic Society." Masters' Thesis, Massachusetts Institute of Technology, 2004. http://dspace.mit.edu/bitstream/handle/1721.1/28323/55648189.pdf?sequence=1.

"About MIT Living Labs." Accessed December 27, 2013. http://livinglabs.mit.edu/index.php?option=com_content&view=article&id=51&Itemid=37.

"About Us I Open Living Labs." Accessed October 23, 2013. http://www.openlivinglabs.eu/aboutus.

"Adaptable - Definition and More from the Free Merriam-Webster Dictionary." *Merriam-Webster*. Accessed October 22, 2013. http://www.merriam-webster.com/dictionary/adaptable.

Afentoulidou, Galini, and Eva Pirri. "Student Lab: Experimental Sustainable Living." Masters' Thesis, Chalmers University of Technology, 2013.

Allwood, Julian M., Michael F. Ashby, Timothy G. Gutowski, and Ernst Worrell. "Material Efficiency: A White Paper." *Resources, Conservation and Recycling* 55, no. 3 (January 2011): 362–381. doi:10.1016/j.resconrec.2010.11.002.

Almirall, Esteve, Melissa Lee, and Jonathan Wareham. "Mapping Living Labs in the Landscape of Innovation Methodologies." *Technology Innovation Management Review* no. September 2012: Living Labs (2012). http://www.timreview.ca/article/603.

Altaş, Nur Esin, and Ahsen Özsoy. "Spatial Adaptability and Flexibility as Parameters of User Satisfaction for Quality Housing." *Building and Environment* 33, no. 5 (September 1998): 315–323. doi:10.1016/S0360-1323(97)00050-4.

"Alvar Aalto MUSEUM." Accessed November 21, 2013. http://www.alvaraalto.fi/experimentalhouse.htm.

Anna Ståhlbröst, and Marita Holst. "The Living Lab Methodology Handbook." Unpublished Manuscript, 2012.

"ArchDaily - AD Classics: Eames House / Charles and Ray Eames." *ArchDaily*. Accessed September 23, 2013. http://www.archdaily.com/66302/ad-classics-eames-house-charles-and-ray-eames/.

Bannova, Olga, and Pernilla Hagbert. "Mapping Human Factors For Sustainable Design and Living." Unpublished Manuscript, 2013.

Beadle, Katy, Alistair Gibb, Simon Austin, Almudena Fuster, and Peter Madden. *Adaptable Futures: Sustainable Aspects of Adaptable Buildings*. ARCOM, 2008. http://www.arcom.ac.uk/-docs/proceedings/ar2008-1125-1134_Beadle_et_al.pdf.

Bergvall-Kareborn, BHMSA, M. Hoist, and A. Stahlbrost. "Concept Design with a Living Lab Approach." *In System Sciences, 2009. HICSS'09. 42nd Hawaii International Conference on,* 1–10, 2009. http://ieeexplore.ieee.org/xpls/abs_all.jsp?arnumber=4755508.

Bröchner, Jan. "Innovation in Construction." *In The Handbook of Innovation and Services: A Multi-Disciplinary Perspective*, by F. Gallouj and F. Djellal, 744–763. Edward Elgar Publishing, 2010.

"Chalmers Teknologkonsulter AB." *Chalmers Teknologkonsulter AB*. Accessed December 30, 2013. http://ctk.se/.

Chesbrough, Henry William, Wim Vanhaverbeke, and Joel West. *Open Innovation*: *Researching a New Paradigm*. Oxford: Oxford University Press, 2006.

"Climate-KIC : The EU's Main Climate Innovation Initiative." Accessed December 27, 2013. http://www.climate-kic.org/.

Cotgrave, Alison J., and Noora Kokkarinen. "Developing a Model Promoting Sustainability Literacy through Construction Curriculum Design." *Structural Survey 28*, no. 4 (August 30, 2010): 266–280. doi:10.1108/02630801011070975.

Cunningham, Paul. "Supporting the Evolution of Sustainable Living Labs and Living Labs Networks in Africa," n.d. http://www.ist-africa.org/home/files/Supporting_the_Evolution_of_Sustainable_Living_Labs_and_Living_Labs_Networks_in_Africa.pdf.

Cuperus, Ype. "An Introduction to Open Building." In *Proceedings of the 9th Annual Conference of the International Group for Lean Construction*, 2001. http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.202.7917&rep=rep1&type=pdf.

Davies, Colin. *Key Houses of the Twentieth Century: Plans, Sections and Elevations*. London: Laurence King, 2006.

"Definition Laboratory." Accessed October 4, 2013. http://www.merriam-webster.com/dictionary/laboratory.

Dhar, Tapan Kumar, Md Sk Maruf Hossain, and Khan Rubayet Rahaman. "How Does Flexible Design Promote Resource Efficiency for Housing? A Study of Khulna, Bangladesh." *Smart and Sustainable Built Environment* 2, no. 2 (September 13, 2013): 140–157. doi:10.1108/SASBE-10-2012-0051.

"Eames House History : Eames Foundation." Accessed September 23, 2013. http://www.eamesfoundation.org/eames-house-history/.

Elliott, Monica. "ADAPTABLE Architecture." *Industrial Engineer* 37, no. 9 (September 2005): 28–33.

European Commission, and Directorate-General for Energy and Transport. *2020 Vision: Saving Our Energy*. Luxembourg: Office for Official Publications of the European Communities, 2007.

European Network of Living Labs (ENoLL). "City as a Living Lab Esteve Almirall." Technology, August 20, 2012. http://www.slideshare.net/openlivinglabs/the-citi-as-a-lab-ea.

European Union, European Commission, and Directorate-General for the Information Society and Media. *Living Labs for User-Driven Open Innovation: An Overview of the Living Labs Methodology, Activities and Achievements January 2009*. Luxembourg: EUR-OP, 2008.

Field, Christopher B, and Intergovernmental Panel on Climate Change. *Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation: Special Report of the Intergovernmental Panel on Climate Change*. Cambridge: Cambridge University Press, 2012.

"Flexible Housing." Accessed September 13, 2013. http://www.afewthoughts.co.uk/flexiblehousing/index.php.

Flood, Joe. "Urban and Housing Indicators." *Urban Studies* 34, no. 10 (October 1, 1997): 1635–1665. doi:10.1080/0042098975385.

Foyer Notre Dame Des Sans Abris, La Maison de Rodolphe, Lyon, 2012. http://www.youtube.com/watch?v=_RyT59O7f_0&feature=youtube_gdata_player.

Friedman, Avi. *The Adaptable House: Designing Homes for Change*. New York: McGraw-Hill, 2002.

"Futuristic Vertical City Holds Plug-In Hexagonal Housing Units I Inhabitat - Sustainable Design Innovation, Eco Architecture, Green Building," August 18, 2010. http://inhabitat.com/plug-your-hexagonal-house-into-this-vertical-city/.

Gambatese, John A., and Matthew Hallowell. "Enabling and Measuring Innovation in the Construction Industry." *Construction Management & Economics* 29, no. 6 (June 2011): 553–567. doi:10.1080/01446193.2011.570357.

Grundrissatlas Wohnungsbau: *Floor Plan Atlas Housing*. Basel ; Boston: Birkhäuser, 1994.

Guimarães Marcos. "Bioclimatism and Space Use in Alvar Aalto's Summer House." Polytechnic University of Catalunya, Barcelona, Spain, 2007.

Hertzberger, Herman. *Lessons for Students in Architecture*. Rotterdam: 010 Publishers, 2005.

"Homes for Tomorrow." Accessed November 4, 2013. http://www.chalmers.se/en/areas-of-advance/builtenvironment/research/strategic-research-project/Pages/homes-for-tomorrow.aspx.

"Homes for Tomorrow - H42." Accessed December 28, 2013. http://www.homesfortomorrow.se/.

"House_n The PlaceLab." Accessed November 19, 2013. http://architecture.mit.edu/house_n/placelab.html.

Howieson, Jill. "ADR for a Built Environment Interdiscipline: Curriculum and Practical Applications." *International Journal of Law in the Built Environment* 3, no. 1 (April 19, 2011): 11–23. doi:10.1108/17561451111122589.

"Hustillverkare: A-Hus." Accessed January 2, 2014. http://www.a-hus.se/om-a-hus.

"In English / Fakta / Om HSB / HSB - Där Möjligheterna Bor." Accessed October 22, 2013. http://www.hsb.se/omhsb/fakta/in-english.

Ind, Nicholas, and Nick Coates. "The Meanings of Co-Creation." *European Business Review* 25, no. 1 (January 4, 2013): 86–95. doi:10.1108/09555341311287754.

"Innovative Modular Design Relies on Steel to Help Troubled Teens." Accessed October 9, 2013. http://www.livingsteel.org/case-study/innovative-modular-design-relies-steel-help-troubled-teens.

IPPC Working Group 1. "30 September 2013 WORKING GROUP I CONTRIBUTION TO THE IPCC FIFTH ASSESSMENT REPORT CLIMATE CHANGE 2013: THE PHYSICAL SCIENCE BASIS," September 30, 2013. http://www.climatechange2013.org/images/uploads/WGIAR5_WGI-12Doc2b_FinalDraft_Chapter01.pdf.

Jelena Nikolic. "Multifamily Open Building: Application of 'Open Building' Approach in Design and Construction Process of Multifamily Housing." Masters' Thesis, Universidad Politécnica de Catalunya, 2011. http://mastersuniversitaris.upc.edu/tecnologiaarquitectura/tesis/2011/Nikolic.pdf.

Kale, S., and D. Arditi. "Innovation Diffusion Modeling in the Construction Industry." *Journal of Construction Engineering and Management* 136, no. 3 (2010): 329–340. doi:10.1061/(ASCE)CO.1943-7862.0000134.

Kendall, Stephen, and Jonathan Teicher. *Residential Open Buildings*. London, GBR: Spon Press, 1999. http://site.ebrary.com/lib/chalmers/docDetail.action?docID=10054143.

Kielion, Lucas J. “Adaptability in Architecture.” Accessed October 21, 2013. http://digitalcommons.unl.edu/archthesis/72/.

Kozo Kadowaki, and Seiichi Fukao. “Relationships and Casual Structure among Building Design in Multi-Unit Residential Building.” Unpublished Manuscript, n.d.

Kronenburg, Robert. “A Moveable Strategy.” *The Architects’ Journal* (July 2008): 44–45.

Kuijer, Lenneke, and Annelise de Jong. “A Practice Oriented Approach to User Centered Sustainable Design.” In *Ecodesign 2009 Conference*. Saporo, 2009. http://studiolab.ide.tudelft.nl/studiolab/kuijer/files/2011/12/EcoDesign2009_Kuijer_copyright-JSME.pdf.

Leminen, Seppo, Mika Westerlund, and Anna-Greta Nyström. “Living Labs as Open-Innovation Networks.” *Technology Innovation Management Review* no. September 2012: Living Labs (2012). http://timreview.ca/article/602.

Liedtke, Christa, Maria Jolanta Welfens, Holger Rohn, and Julia Nordmann. “LIVING LAB: User-Driven Innovation for Sustainability.” *International Journal of Sustainability in Higher Education* 13, no. 2 (2012): 106–118. doi:http://dx.doi.org/10.1108/14676371211211809.

“Living Lab.” *Wikipedia, the Free Encyclopedia*, April 19, 2013. http://en.wikipedia.org/w/index.php?title=Living_lab&oldid=542739125.

“Lotus Living Laboratory: Green Dorm.” Accessed December 27, 2013. http://www.stanford.edu/group/greendorm/greendorm.html.

“Magic Bus Staff Dormitory, Karjat - Architecture BRIO, Mumbai / India.” Accessed September 18, 2013. http://architecturebrio.com/projects/magic-bus-staff-dormitory-23#.UjnCdD9YW1k.

Martijn Pater. “Co-Creation’s 5 Guiding Principles,” April 2009. http://www.thunderfactory.com/pdfs/Co%20creation%20princples%2011-09.pdf.

Matsuhashi, Noriko, Lenneke Kuijer, and Annelise de Jong. “A Culture-Inspired Approach to Gaining Insights for Designing Sustainable Practices.” In *EcoDesign 2009 Conference.* Saporo, 2009. http://repository.tudelft.nl/assets/uuid:4a53a95a-165b-4c8f-9803-f39fab87cf71/EcoDesign2009_Matsuhashi_copyright_JSME.pdf.

McPhee, Chris, Mika Westerlund, and Seppo Leminen. “Editorial: Living Labs.” *Technology Innovation Management Review* no. September 2012: Living Labs (2012): 3–5.

Morrison, Greg. “Flagship Proposal BTA-Business Plan 2014.” Unpublished Manuscript, 2013.

———. “Infrastructure Proposal: The Sustainable Living Lab.” Unpublished Manuscript, 2013.

Mulder, Ingrid. “Living Labbing the Rotterdam Way: Co-Creation as an Enabler for Urban Innovation.” *Technology Innovation Management Review* no. September 2012: Living Labs (2012): 39–43.

Nam, C. H., and C. B. Tatum. “Major Characteristics of Constructed Products and Resulting Limitations of Construction Technology.” *Construction Management and Economics* 6, no. 2 (June 1988): 133–147. doi:10.1080/01446198800000012.

National Research Council (U.S.). *Laboratory Design, Construction, and Renovation: Participants, Process, and Product.* Washington, D.C: National Academy Press, 2000.

“New York’s Newest Skyscraper Is 32 Floors Of Prefab Apartments That Click Together.” *Co.Exist.* Accessed November 30, 2013. http://www.fastcoexist.com/3020237/new-yorks-newest-skyscraper-is-32-floors-of-prefab-apartments-that-click-together.

Oliveira, A., E. Fradinho, and R. Caires. “From a Successful Regional Information Society Strategy to an Advanced Living Lab in Mobile Technologies and Services.” 83a–83a. IEEE, 2006. doi:10.1109/HICSS.2006.189.

“Open Building Concepts.” Accessed September 18, 2013. http://www.open-building.org/ob/concepts.html.

“Open Innovation.” *Wikipedia, the Free Encyclopedia*, September 8, 2013. http://en.wikipedia.org/w/index.php?title=Open_innovation&oldid=568527582.

“Open Living Labs: The First Step towards a New Innovation System.” Accessed December 27, 2013. http://www.openlivinglabs.eu/.

“OPEN Prototype Home - Building the Future.” Accessed October 1, 2013. http://www.madeforone.com/features/20050916_Open_Prototype_home.html.

“Patrick Seguin Restores Jean Prouvé’s Maison Des Jours Meilleurs | Architecture.” Accessed September 23, 2013. http://www.wallpaper.com/video/architecture/patrick-seguin-restores-jean-prouvs-maison-des-jours-meilleurs/1653927328001.

Plattner, Hasso, Christoph Meinel, and Larry Leifer. *Design Thinking Research: Studying Co-Creation in Practice*. Springer, 2012.

“Plug-in Architecture Loses an Icon.” *ArchiTakes*, August 21, 2009. http://www.architakes.com/?p=1441.

“Plug-in Skyscraper for Suburbian Homes.” *Evolo*, June 21, 2010. http://www.evolo.us/architecture/plug-in-skyscraper-for-suburbian-homes/.

“Prefab Architecture : A Guide to Modular Design and Construction.” Accessed September 16, 2013. http://site.ebrary.com/lib/chalmers/docDetail.action?docID=10442691.

Raban, Jonathan. *Soft City*. London: Picador, 2008.

Rahkonen, Timo. “Driving Growth through Collaborative Innovation-Case Living Lab” (2012).

Reimer, Maria Hellström, Kes McCormick, Elisabet Nilsson, and Nicholas Arsenault. “Advancing Sustainable Urban Transformation through Living Labs: Looking to the Öresund Region” (2012).

“Research Laboratory: Whole Building Design Guide,” May 26, 2010. http://www.wbdg.org/design/research_lab.php.

Schaffers, Hans, and Petra Turkama. “Living Labs for Cross-Border Systemic Innovation.” *Technology Innovation Management Review* no. September 2012: Living Labs (2012). http://www.timreview.ca/article/605.

Schmidt, Robert III, Toru Eguchi, Simon Austin, and Alistair Gibb. “What Is the Meaning of Adaptability in the Building Industry?” In *Proceedings of the CIB 16th International Conference on Open and Sustainable Building*. Bilbao, Spain, 2010.

Schmidt, Robert III, Syed Mohyuddin, Simon Austin, and Alistair Gibb. “Using DSM to Redefine Buildings for Adaptability.” In *10th International Design Structure Matrix Conference*. Stockholm, Sweden, 11-12 November 2008.

Schmidt, Robert III, Toru Eguchi, and Simon Austin. “Lessons from Japan: A Look at Century Housing System.” Accessed November 4, 2013. http://adaptablefutures.com/wp-content/uploads/2011/11/Schmidt-et-al.-2010a.pdf.

Schneider, Tatjana. *Flexible Housing*. 1st ed. Amsterdam ; Boston: Architectural Press, an imprint of Elsevier, 2007.

Schneider, Tatjana, and Jeremy Till. “Flexible Housing: Opportunities and Limits.” *Architectural Research Quarterly 9*, no. 02 (2005): 157–166. doi:10.1017/S1359135505000199.

Schuurman, Dimitri, and Lieven De Marez. “Structuring User Involvement in Panel-Based Living Labs.” *Technology Innovation Management Review* no. September 2012: Living Labs (2012).

Slaughter, E. “Builders as Sources of Construction Innovation.” *Journal of Construction Engineering and Management* 119, no. 3 (1993): 532–549. doi:10.1061/(ASCE)0733-9364(1993)119:3(532).

“Smart Student Unit by Tengbom.” *Dezeen*. Accessed November 30, 2013. http://www.dezeen.com/2013/09/29/smart-student-units-by-tengbom/.

“Spacebox® The Fast Affordable Flexible Innovative and Sustainable Housing Concept.” Accessed November 14, 2013. http://www.spacebox.nl/index.cfm?lng=en.

"Spiral Staircase Shapes Tokyo Home." *Dwell*. Accessed October 3, 2013. http://www.dwell.com/house-tours/article/spiral-staircase-shapes-tokyo-home.

Stanescu, Aurelian Mihai, Ioan Dumitrache, Corneliu Burileanu, Nicolae Vasiliu, Mihnea Alexandru Moisescu, and Ioan Stefan Sacala. "ARCHE3S: First Living Lab Enabler in Romania Aiming at Cross Domain Synergy-Based Approach to Sustain SMEs," 2012. http://ami-communities.eu/pub/bscw.cgi/d494373/79_Arches_stanescu_poster.pdf.

"Suslab: HSB Living Lab." *Suslab.eu*. Accessed September 18, 2013. http://suslab.eu/partners/chalmers-th/hsb-living-lab/.

"Suslab: Methodology." Accessed October 23, 2013. http://suslab.eu/about/methodology/.

"Suslab: Suslab." Accessed October 18, 2013. http://suslab.eu/home/.

"Swedish Sutainable Building," n.d. http://www.formas.se/PageFiles/5460/Formas_SB11_brochure.pdf.

"UN-HABITAT: Strengthened Human Settlements Finance Systems." Accessed September 25, 2013. http://www.unhabitat.org/content.asp?cid=7970&catid=578&typeid=24&subMenuId=0.

"Updates from the Fronteer: CO-CREATION'S 5 GUIDING PRINCIPLES Or.... What Is Successful Co-Creation Made Of?" Accessed October 10, 2013. http://fronteerstrategy.blogspot.se/2009/04/co-creations-5-guiding-principles-or.html.

"Walter Segal Construction Method: Selfbuild Central." Accessed September 13, 2013. http://www.selfbuild-central.co.uk/construction/main-structure/post-and-beam/.

"What We Do I Johanneberg Science Park." Accessed November 4, 2013. http://www.johannebergsciencepark.com/en/what-we-do.

Winsor, John. Spark: *Be More Innovative through Co-Creation*. Chicago: Dearborn Trade Pub, 2006.

7. Appendix

7.1 Research Project Spreadsheet

7.2 Summary of Interviews

The following are brief summaries of the interviews performed for this thesis. However, not all interviews are included as some were more informal meetings.

Research Investigation/Interview

1. Description of Research

- Numerical modeling of coupled heat, air and moisture transport in buildings and components.

2. Interest in living Lab?

- Testing new building envelope materials.
- Experiment

3. What experimentation will be performed?

- New exterior wall systems (thinner wall)
- Thinner Insulation materials (Vacuum panel, Aerogel), active materials (phase change materials), new concretes (textile reinforced concrete)

4. How is your research relevant to the Living Lab design?

- Needs to have exchangeable parts of walls to test different materials over the years.
- At least three wall sections between 2 and 4 m2
- In contact with outdoor, direct sun and rain exposure
- Instrumentation for experimentation measurement will be inside the wall.

5. Will The Living Lab help make your research more effective and how?

- There is a need for experimental evaluation of novel walls and materials before they come to market.
- Experiments will give more credibility to theoretical investigations (numerical simulations) on novel wall elements.

7. What are the possible challenges for you working in a Living Lab setting?

- A project work which would involve students in the design and construction of HSB Living Lab is currently not a part of the course syllabus at the Department of Civil and Environmental Engineering.

8. What form should Living Lab take?

- The experimentaion should be visible so the inhabitants can understand better and give feed back on the reserach.

9. Do you think it will encourage true cooperation between departments and partners?

- Good oportunity to try to make the departments work together.

10. In one word what is the Living Lab for you?

- Field testing

Angela Sasic Kalagasidis

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Research Division:
Building Technology

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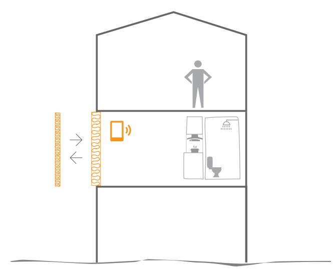
Date of Interview:
2013 / 09 / 30



Next Generation Wall Insulation

Research Investigation/Interview

1. Description of Research

- Developing sociale practical in design
- Understand how people behave in their daily life attitude.

2. Interest in living Lab?

- Prototyping, developing and testing the «splash» shower.
- (shower system that encourages less water consumption by influence our comportment).

3. What experimentation will be performed?

- Using the splash shawor system in a daylife contexte

4. How is your research relevant to the Living Lab design?

- Design a space that allow the shower prototype to be integrated into the bathroom.
- Optimal situation:
- Three to five shawers, used by one and several students
- For multicultural issues, having students from different origines.

5. Will The Living Lab help make your research more effective and how?

- Collect Data

6. How will you involve the inhabitants?

- Extremely active, using the shower and give the feedback by interview or diary.

7. What are the possible challenges for you working in a Living Lab setting?

- Collecting the different data (water flow,behavior)
- Collaboration with the other

8. What form should Living Lab take?

- Flexible

9. Do you think it will encourage true cooperation between departments and partners?

- N/A

10. In one word what is the Living Lab for you?

- Sustainable Living

Annelise De Jong

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Delft University of Technology

Research Division:
Industrial Design Engineering

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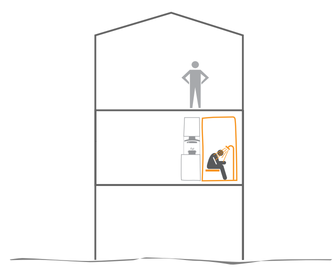
Date of Interview:
2013 / 10 / 15



Splash, New Bathing technology

Research Investigation/Interview

1. Description of Research

- Calculation models for coupled heat, moisture and air transfers inside the building envelope and thermal insulation materials.

2. Interest in living Lab?

- Having a real situation where people are monitoring their own environment.
- Test systems for the market
- Reinforce collaboration between the departments

3. What experimentation will be performed?

- Testing new wall insulation components
- Low temperature floor heating systems In concrete slab or light-weight systems, in real-life use, and monitored.
- Light Tubes
- Smart building components (light penetrating walls)
- Moisture and ventilation research in attics

4. How is your research relevant to the Living Lab design?

- Flexible exterior wall
- Best case: six independent units which can be controlled individually and monitored
- One monitoring room for all the data
- Keep design flexible and open to new possibilities

5. Will The Living Lab help make your research more effective and how?

- Testing new systems
- Will help considerably to integrate the new products into the market

6. How will you involve the inhabitants?

- Use interactive features
- Show the experimentation
- The inhabitants should be students who are interested in the project.

7. What are the possible challenges for you working in a Living Lab setting?

- Make it a real life experience

8. What form should Living Lab take?

- Should be attractive and different

9. Do you think it will encourage true cooperation between departments and partners?

- Yes! ,there is a need of real project where people can work together without real projects collaboration is difficult.

10. In one word what is the Living Lab for you?

- Cutting edge future technology

Carl Eric Hagentoft

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Research Division:
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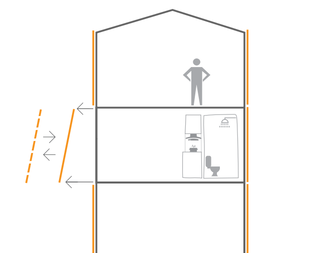
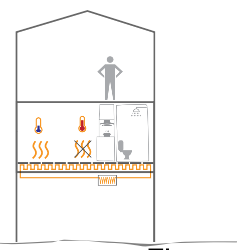
carl-eric.hagentoft@chalmers.se

Date of Interview:
2013 / 10 /03



Interchangeable Facade



Low Temperature Floor Heating System

Research Investigation/Interview

1. Description of Research

- Mikael is doing his PhD through the Formas funded project Homes for tomorrow (H42), in which he is responsible for issues concerning water and sanitation. He is currently working on a pilot study of Swedish homes' 'water sensitivity'.

2. Interest in living Lab?

- Shared living
- Interactions between inhabitants
- Laundry room: as a double/triple function space. (Social/ common room for the inhabitants).
- No direct interest for his current work but interesting for future challenges.

3. What experimentation will be performed?

- Social experiments
- How people live together, and share the space, the common resources.

4. How is your research relevant to the Living Lab design?

- The common area should be flexible and be used for different functions.

5. Will The Living Lab help make your research more effective and how?

- No professional use of the Living Lab for his current work as his PHd research timeline does not match with the Living Lab.

6. How will you involve the inhabitants?

- Oral interaction, collecting their feed back about sharing the space.
- Involved researcher living inside the Living Lab (Master student or phd)

7. What are the possible challenges for you working in a Living Lab setting?

- The living lab is not giving a good representation of the average society.
- Create a flexible space that can adapt with the times

8. What form should Living Lab take?

- A large common area in the ground floor where research and inhabitants can coexist
- Two floors of living units/habitation above

9. Do you think it will encourage true cooperation between departments and partners?

- Maybe

10. In one word what is the Living Lab for you?

- Students

Mikael Mangold

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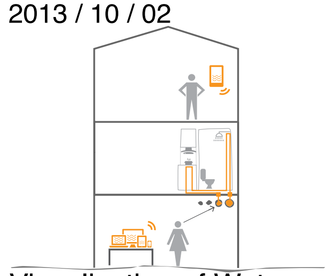
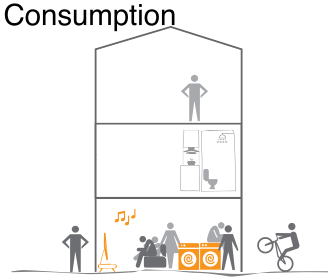
Date of Interview:
2013 / 10 / 02



Visualisation of Water Consumption



Laundry Room, Shared Multifonctional Space

Research Investigation/Interview

1. Description of Research

•Conceptualisation of sustainable home.

2. Interest in living Lab?

•Use it as a meta case study, to investigate researchers views on sustainable housing.

3. What experimentation will be performed?

•Laundry room: Interactive system for the laundry and Integration to other functions.

4. How is your research relevant to the Living Lab design?

•Living unit as pratical application for testing ideas and design generated by studio coures (at least 2 units on the first floor).

5. Will The Living Lab help make your research more effective and how?

•Not directly, my fied of research is partly in an other area, although related to how students perceive their living environments and for example shared spaces

•But really interested in how it could be a tool for study how the researchers perceived the sustainable home.

6. How will you involve the inhabitants?

•Extremly active participation + Feed back

7. What are the possible challenges for you working in a Living Lab setting?

•The living lab is not giving a good representation of the average society.

8. What form should Living Lab take?

•Testing facility.

•Not conventional student housing.

9. Do you think it will encourage true cooperation between departments and partners?

•It has already.

10. In one word what is the Living Lab for you?

•Radical Change

Pernilla Hagbert

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Architecture

Research Division:
Design for Sustainable Development

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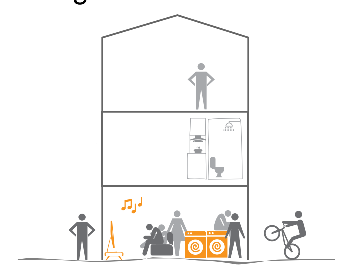
Date of Interview:
2013 / 10 / 10

Design/Built live studio



Laundry room, Shared multifonctional space

Research Investigation/Interview

1. Description of Research

- Alternative personal heating- Sara Renström: PhD Student
- District heating- Gunnar Nilsson: Civil Engineer at Göteborg Energi

2. Interest in living Lab?

- Make people undestand how the district heating systems work.
- Prototype products for localized heating experiences

3. What experimentation will be performed?

- Connect the HSB Living Lab to the Chalmers district heating system
- Application: Drying & Washing machine + Kitchen + heating system (air by heat transfer, hot water)
- Potentially: Test of small eating mobile devises conected to the district heating
- Best connect all the units

4. How is your research relevant to the Living Lab design?

- Install a central subsation (around $4m^2$+ Service) to connect the building to the district heating system.
- Each unit has a small subsation (around 30x60x60cm) with heat exchanger which can be used for; hydronic floor heating or forced air heating systems
- Units need to be monitored to collect all the data

5. Will The Living Lab help make your research more effective and how?

- Essentiel for testing and prototyping
- Show the flexibility of district heating systems

6. How will you involve the inhabitants?

- Feed back by interview
- Show the application of district heating through prototypes and visualisation

7. What are the possible challenges for you working in a Living Lab setting?

- The living lab is not giving a good representation of the average society.

8. What form should Living Lab take?

- Laboratory

9. Do you think it will encourage true cooperation between departments and partners?

- it has already started

10. In one word what is the Living Lab for you?

- Laboratory

Sara Renström

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Product and Production Development

Research Division:
Design & Human Factors

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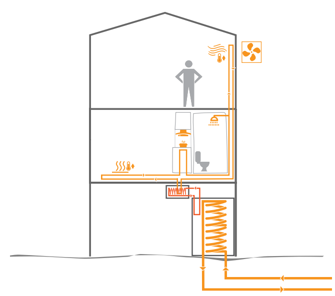
sara.renstrom@chalmers.se

Date of Interview:
2013/10/14 & 2013/11/27

Other Interviewee:

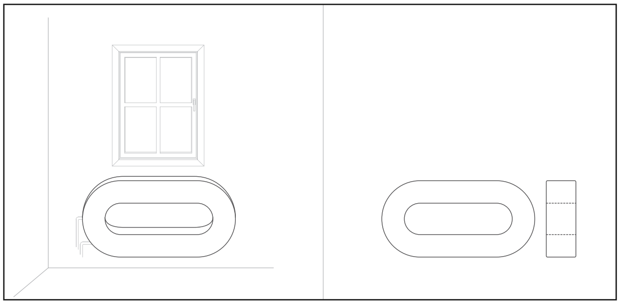
Gunnar Nilsson
Göteborg Energi
Gunnar.Nilsson@goteborgenergi.se



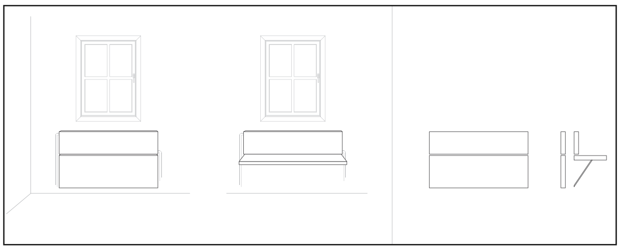
Alternative Personal Heating (Distric Heating)

Sara's Preliminary Project Ideas

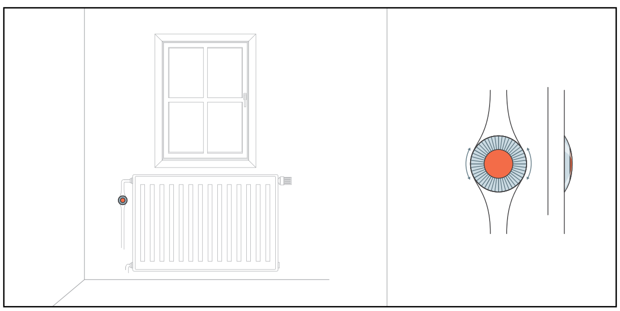
SENSING THE RADIATORS



Small heating mobile devices connected to the District Heating System

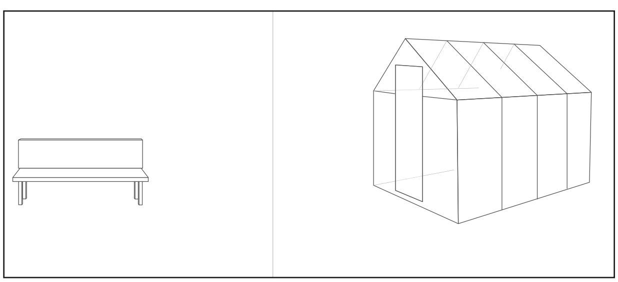


Radiator bench



System understanding through feedback

GATHER AROUND THE SYSTEM



Using waste heat from district heating in other applications such as outdoor heated benches or greenhouses

Research Investigation/Interview

1. *Description of Research*
   - CIT is the commercial link between academia and industry.
   - Within the project group they are involved in electric, electronic, acoustic, and magnetic projects.
2. *Interest in living Lab?*
   - Testing devices for direct current (DC) electricity consumption (ZENTIGO) in a daily life context
   - Create and test new products working with DC power
3. *What experimentation will be performed?*
   - Using DC voltage (ZENTIGO)
   - Testing a synergetic Kitchen (PELTIERE system)
4. *How is your research relevant to the Living Lab design?*
   - Would like to test/prototype in five units
5. *Will The Living Lab help make your research more effective and how?*
   - Test the products to have them quickly become market ready.
6. *How will you involve the inhabitants?*
   - Extremely active. Engineering students will be developing new products for DC voltage.
7. *What are the possible challenges for you working in a Living Lab setting?*
   - Provide the products working with DC voltage
8. *What form should Living Lab take?*
9. *Do you think it will encourage true cooperation between departments and partners?*
   - Yes
10. *In one word what is the Living Lab for you?*
    - Playground

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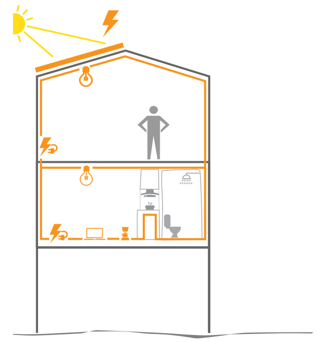
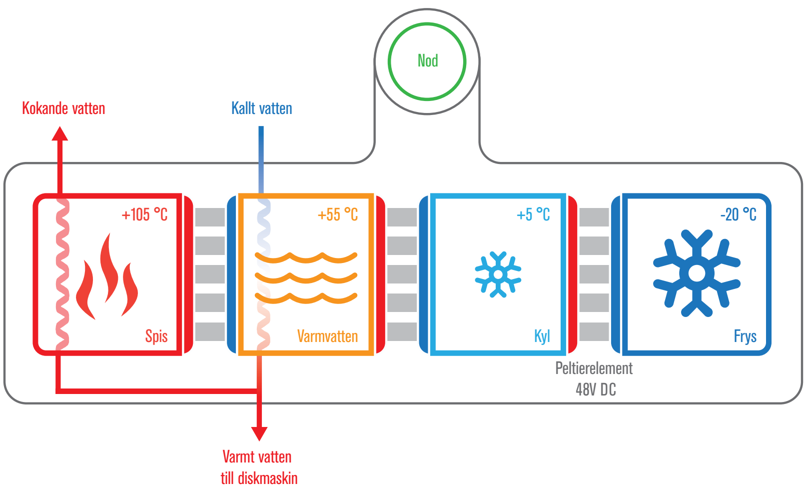
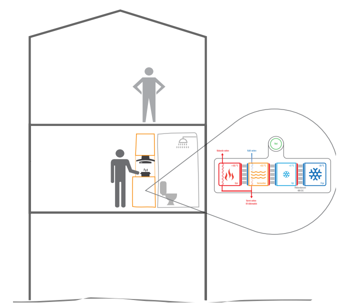
Date of Interview:

2013 / 10 / 14



Zentigo DC Power System





Synergetic Peltiere
Kitchen System

Research Investigation/Interview

1. Description of Research

- Isabel is a Chilean industrial designer and PhD student focusing her research in closing the material loop in society by improving Municipal Solid Waste handling using design and participation.
- Ulrike Rahe is professor at Chalmers and involved in the following projects: LifeLab, More by Less and Meeting Future Demands.

2. Interest in living Lab?

- Testing new products in a real life context
- Evaluate how people can adapt to a new system and compered them

3. What experimentation will be performed?

- Evaluate how people can adapt at a new system, how they used it in a daily life.

4. How is your research relevant to the Living Lab design?

- The design have to be flexible for future tests
- Anticipate uses that we did not know yet

5. Will The Living Lab help make your research more effective and how?

- Real life context

6. How will you involve the inhabitants?

- Oral interaction, collecting their feed back.

7. What are the possible challenges for you working in a Living Lab setting?

- The interaction between the user and the research.
-

8. What form should Living Lab take?

- Landmark
- Open the project to an international architectural competition.

9. Do you think it will encourage true cooperation between departments and partners?

- Yes

10. In one word what is the Living Lab for you?

- Extraordinary place for research

Ulrike Rahe

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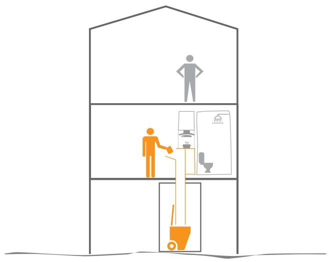
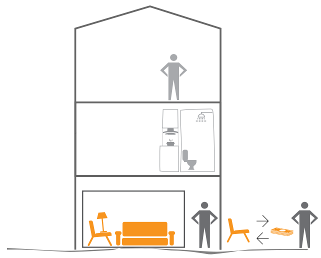
Research Division:
Design & Human Factors

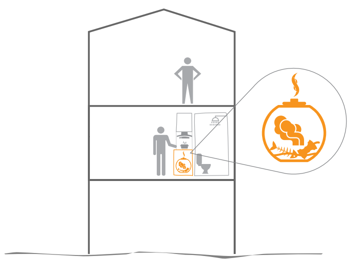
Date of Interview:
2013 / 09 / 30



Kitchen Food Waste Chute



Reusable Goods Exchange



Small Scale Biogas Generator

Vermicomposting

Research Investigation/Interview

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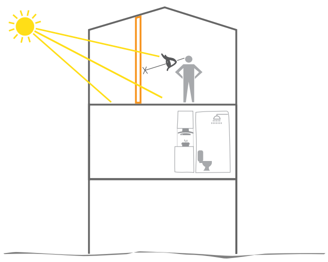
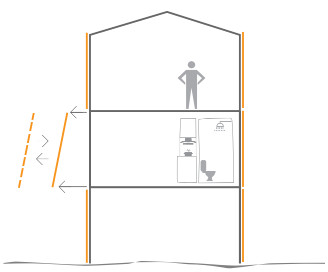
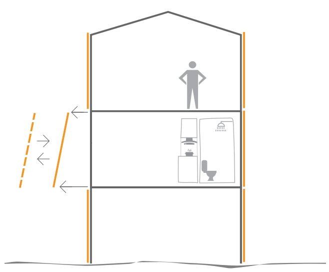


Phase change light penetration partition



Interchangeable Facade



Interchangeable Facade

Design/Build/Live Studio

L a r r y   T o u p s

NASA Johnson Space Center
New Initiatives Office

Adjunct Professor at Chalmers
Architecture Department

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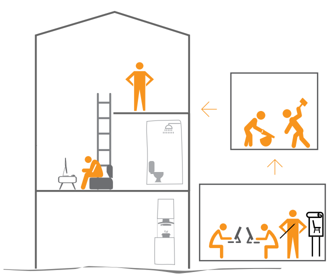
larry.toups@chalmers.se

Resource allocation



Design/Build/Live Studio

7.2 TUDelft Field Study

Delft suslab meeting Nov. 18th 2013

Attendees:

David Keyson
Sacha Silvester
Jeroen van der Aa
Natalia Romero
Marc den Hoogh
Tasos Ioannou
Willemijn van Harinxma
Martin Havranek(left to work on the toolkits)

Concept house Discussion

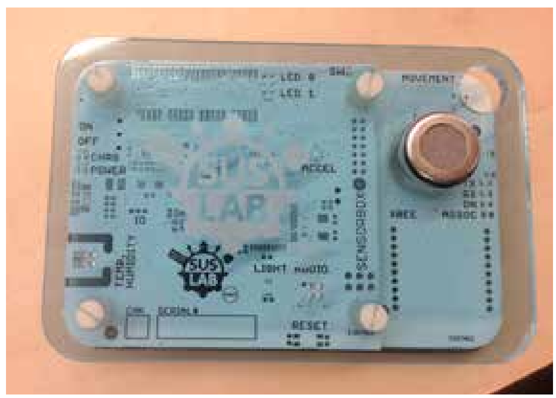
-was started as prototype to test energy neutral apartment block

E-quarium Discussion

- Uses empathetic interface
- First test will include 25 households in Sweden, England, Netherlands and Switzerland??
- Currently dealing with data collection issues and roll out of equipment
- Some issues with smart metering, regulations on how much information can be shared and shown(living labs can educate government also)
- City and energy companies need to be brought in early to discuss issues

Industrial Design Building Courtyard

Industrial Design Building Hall Lounge



E-quarium Sensor

General Discussion

Choosing research and funding:

- Only research that generates new knowledge
- Intergrate design review, is it innovative?
- Only a demonstration is not interesting
- Need selection process for HSB Living Lab

BTA Flagship:
- Builds on existing suslab structure
- But will be similar to suslab activities planned for 2014
- Plans to expand from housing to office space in Spain and ETH

Living Lab progression:
1. Enoll- defined what to do
2. Suslab- actively did it
3. BTA- will take those things into industry and beyond

- Facades are important in BTA with second skin research-goal is to reduce energy only through use of facades

TUDelft Student Housing

TUDelft SpaceBox Student Housing

Meeting with Dr. Sacha Silvester, Associate Professor of Industrial Design at TU Delft

What is the difference between knowledge generated in living lab vs. existing infrastructures?

- This is a challenge to explain
- Longitudinal research and interactions
- Focus should be set on innovations that affect people within a living lab, like comfort
- Behavioral dependency of innovations is becoming more important especially for energy nuetral housing where is is essential to have 'expected' behavior by inhabitants in order to meet energy goals.

How does behavior affect home efficiency?

- It is difficult to design for this
- Intitial thoughts on behavior turned out to be based on the quality of construction. The better quality the less unexpected behavior affected energy performance
- It is essential to test a house before it is inhabitated to get base line and understand 'quailty'
- Behavior is always different from what architects design for, this means flexibility must be incorporated into design
- Designers must identify different lifestyles and design products to fit those lifestyles

Examples: passive house for old people who enjoy warmer more constant temperatures. Need to understand demographics, who enjoys fresh air and

Normal day in Rotterdam

Rotterdam Apartments

RDM Innovation Dock

wants to open windows. Design must consider this.
- So what do we do when people want warm and fresh??
- In apartments blocks there is usually not much insulation between apartments, my work has found that there is large transfer between apartments both vertically and horizontally. An individual unit should be able to control comforts. But this adds cost.
- Check out Frawnhofer- a plug and play living lab in Germany researching hospital interiors
- There is a need to measure quality of life for inhabitnants..but how?

How should research be chosen for the Living Lab?

-There needs to be a steering group to adjust research within living lab
-The more ready the product the more you can learn from it
- but how ready is ready?
-Research should use all potential of living lab

Flexibility Discussion

-Open building movement
-What is the value of flexibility? This research has not been done, there needs to be iterative feedback in design concepts surrounding flexibility over long term the HSB living lab is great opportunity to develop methodology and spearhead this research

Living wall prototyping: RDM Innovation Dock

Inside RDM Innovation Dock

Concept Village CHIBB House under construction

Meeting with Mick Eekout, Chair of Product Development at TU Delft

Concept house discussion

-Started 8 years ago as a challenge to develop industrialized housing
-First years was investigation into housing typology and the market
-There were 10 partners for financing which formed a prototyping consortium. Each partner was challenged to innovate in at least one aspect of the building.
-The goal was to produce a prototype for commercial construction
-During the process we looked at:
1.industrialized houses vs. customization
2.energy neutral
3.low ecological footprint
4.multistory housing
- The project aimed to select, integrate, coordinate, and optimize building components and installations
-The needs feedback with various families living there, but currently not happening

Concept House Prototype One

Concept House Prototype One: Kitchen

Concept House Prototype One:Energy Display Interface

Concept House Prototype One: Living Room

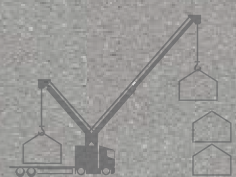
STUDENT HOUSING

INNOVATION

EDUCATION

EXPERIMENT

CO-CREATION



This thesis aims to provide a collection of materials for use as a resource to catalyse the creation and design of the HSB Living Lab.

The HSB living lab is an on-going project for the creation of a 'living laboratory' that will take the form of student-housing and be built in the coming year on the Johanneberg campus of Chalmers University of Technology in Gothenburg, Sweden.

This thesis contributes to the general reflection around the HSB Living Lab by proposing both concrete design solutions and laying out a framework for design. The specific needs of the stakeholders have shaped the methodology and approach to design, resulting in adaptable design solutions for the HSB Living Lab infrastructure.