smart living lab

SMART LIVING LAB

2016 ANNUAL REPORT

a research and development
center for the built environment
of the future

Haute école d'ingénierie et d'architecture Fribourg
Hochschule für Technik und Architektur Freiburg

UNI FR
UNIVERSITÉ DE FRIBOURG
UNIVERSITÄT FREIBURG

EPFL
ÉCOLE POLYTECHNIQUE
FÉDÉRALE DE LAUSANNE

SMART LIVING LAB

- 2016 ANNUAL REPORT -

Table des matières

Foreword

At the smart living lab,

researchers design and imagine reality through distinct, yet complementary prisms. The reason the Ecole polytechnique fédérale de Lausanne, the School for Architecture and Engineering in Fribourg, and the University of Fribourg set up such an audacious academic alliance is their shared conviction that interdisciplinarity is essential to rethinking the world we live in.

At the smart living lab,

and across its many inter-institutional research projects, one common thread emerges: human beings – their environment – their wellbeing. Through the power of collective intelligence, reflecting on this fundamental theme brings about new perspectives: What if future occupants of a building were actively involved in its design phase? What if technological solutions never took precedence over the comfort of a building's occupants, but instead helped them manage their surroundings, control their power consumption, or control their buildings? And what if everybody became prosumers, small-scale producers and consumers of their own energy? And if all of this energy was produced within a small community of prosumers, then shared and stored, and excess energy were sold? And if everyone could choose the greenest energy sources and consume power from the grid or energy produced in the very buildings they inhabit? And if the buildings' structures and systems were reused over centuries to save natural resources? And if construction became a truly local endeavor, using human and material resources from within a 50 km radius?

At the smart living lab,

new transdisciplinary methods are being put into practice, and closely scrutinized, such as BIM (digital modeling of buildings). The comfort of users and their energy consumption behavior are tested full-scale in a living lab that researchers can manipulate according to the environmental objectives set for 2050.

The smart living lab is a research and development center that gives human beings and their wellbeing center stage in research projects that share the common goal of directing us towards a more sustainable world..

Olivier Curty and Andreas Mortensen

THE SMART LIVING LAB OPENS ITS DOORS DURING THE SMART LIVING DAYS IN 2016

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smart living lab at a glance

The smart living lab is a center for research and development dedicated to the built environment of the future, from both a technical and a societal perspective. It conducts interdisciplinary and interinstitutional projects. Its goal is to imagine and design living spaces, while focusing on users' well-being and the environment.

It combines the expertise of the Ecole Polytechnique Fédérale de Lausanne (EPFL), the School of engineering and architecture of Fribourg (HEIA-FR / HES-SO) and the University of Fribourg (UNIFR) in the areas of sustainable architecture, technology and materials, comfort, as well as law and social sciences.

STATE: 31.12.2016

Staff	**60 (versus 48 in 2015)**
EPFL	19 persons
HEIA-FR	28 persons
UNIFR	13 persons
Research groups	**8**
Occupied surface	**798m^2**
Workstations	**60**
Ongoing projects	**51 (half of them interinstitutional)**
Publications in 2016	**75**

smart living lab's partners

Encompassing over 300 labs and research groups on its campus, the Ecole Polytechnique Fédérale de Lausanne (EPFL) is among the most productive and innovative research institutions worldwide.

ÉCOLE POLYTECHNIQUE
FÉDÉRALE DE LAUSANNE

Ranked in the top three on a European level and globally in the top twenty according to several scientific rankings, EPFL has attracted some of the best researchers in their field.

In 2016, EPFL pursued its recruitment efforts for Fribourg with a proposal to the ETH Board for a nomination in building engineering systems and by launching a new recruitment in the field of indoor environmental quality and building control systems.

Four chairs and a guest professor chair from the EPFL will focus their research on the following subjects:

- Structure, construction and material sciences within the built environment.
- Energy systems at the building and neighborhood scales.
- Building's users behavior, health and comfort.

Located in the heart of a bilingual region, culturally rich and ideally situated, the mission of the School of Engineering and Architecture (HEIA- FR) is to train future engineers and architects holding a bachelor or a master from universities of applied sciences.

Haute école d'ingénierie et d'architecture Fribourg
Hochschule für Technik und Architektur Freiburg

This state-of-the-art school offers university level training based on professional practice. Recognized by society and the local economy for its many applied research activities, the school contributes to the innovation and the technical and scientific outreach of the canton of Fribourg.

For the HEIA-FR, the smart living lab represents the opportunity to develop an interdisciplinary team of architects and engineers who will work on the smart integration of state-of-the-art processes and technologies into the transformation of the living space, taking into account their use, cultural values, and in particular issues related to the following aspects:

- Systemic modelling at a neighborhood and building scale.
- Adaptation – flexibility – interactivity.
- Performance measurement and improvement.

Founded in 1889, the University of Fribourg (UNIFR), is the only bilingual university in Switzerland and has a strong international tradition. It operates as a cutting-edge scientific and teaching center with a strong human-centered approach that covers a wide range of disciplines from all five faculties.

UNIVERSITÉ DE FRIBOURG
UNIVERSITÄT FREIBURG

Nearly 10,000 Bachelor, Master and PhD students benefit from its excellent infrastructure and its many educational opportunities.

At the UNIFR, three research groups will conduct research that will bring knowledge to the smart living lab in the following areas:

- Economic and sociological impacts in the field of energy turnaround.
- Human-building interaction.
- Construction law and regulations.

It is worth mentioning that the smart living lab project is the first of its kind in Switzerland. It brings together the knowledge of several institutions in a single location at the heart of a city and of the State of Fribourg that supports the development. The project offers a unique infrastructure for rapid transfer of key skills to the construction industry.

ETAT DE FRIBOURG
STAAT FREIBURG

For the State of Fribourg, whose construction industry is a major pillar, the presence of a center of national and international outreach reinforces its economic fabric by offering multiple new competitive advantages.

smart living lab's internal organization

Terms of reference were cosigned in 2016 by the State of Fribourg, EPFL, the HEIA-FR, and UNIFR to validate the missions of the smart living lab, its general organization across all parties involved, in particular the three schools, as well as its internal organization, financial contributions, and finally, the vision for the next steps.

Status on January 1, 2017

Steering committee

State of Fribourg

Olivier Curty
State councilor,
Minister of Economic Affairs

Jean-Pierre Siggen
State councilor,
Minister of Public Education, Culture and Sport

Jean-Luc Mossier
Director of Fribourg development agency

Ecole polytechnique fédérale de Lausanne (EPFL)

Andreas Mortensen
Vice President for Research

Etienne Marclay
Vice President for Human Resources and Infrastructures

Marc Gruber
Vice President for Innovation

Marilyne Andersen
Dean of the school of architecture, civil and environmental engineering ENAC

School of engineering and architecture of Fribourg (HEIA-FR)

Jean-Nicolas Aebischer
Director

University of Fribourg (UNIFR)

Astrid Epiney
Rector

Operational committee

State of Fribourg

Jean-Luc Mossier
Director of Fribourg development agency

Ecole polytechnique fédérale de Lausanne (EPFL)

Corentin Fivet
Professor of Architecture and Design of Structures

School of engineering and architecture of Fribourg (HEIA-FR)

Jean-Philippe Bacher
Head of technology transfer and ENERGY Institute

University of Fribourg (UNIFR)

Stephanie Teufel
Professor and Director international institute of management in technology (iimt)

Coordinator

Anne-Claude Cosandey
Head of operations of EPFL Fribourg

Scientific Commission

EPFL

Marilyne Andersen
Dean ENAC faculty,
Committee Chair

Anne-Claude Cosandey
Head of operations of EPFL Fribourg

Thomas Jusselme
Project manager of research for the Building 2050 project

Paolo Tombesi
Professor of Construction and Architecture

Corentin Fivet
Professor of Architecture and Design of Structures

HEIA-FR

Jean-Philippe Bacher
Head of technology transfer and ENERGY Institute

Florinel Radu
Head of the TRANSFORM Institute

UNIFR

Stephanie Teufel
Professor and Director international institute of management in technology (iimt)

Denis Lalanne
Professor Human-Computer Interaction chair (Human-IST)

Martin Beyeler
Professor in construction law

smart living lab's location: Blue Hall, blueFACTORY

The Blue Hall of the blueFACTORY site, located in the innovation quarter in Fribourg, is home to the collaborators of the smart living lab. The teams of the smart living lab will temporarily work in the Blue Hall, while awaiting the completion of the definitive smart living lab building. The smart living lab researchers have 60 workplaces at their disposal in the Blue Hall as well as a workshop for construction and experimentation, which enables the production of prototypes, building components (facades, roofs, structures) and even entire buildings. In the future, the smart living lab will have its own building that will host its research and technology transfer activities on sustainable architecture: the smart living building.

THE BLUE HALL OF THE BLUEFACTORY SITE

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smart living lab's research activities

Research groups per institution

The smart living lab brings together the following research groups:

EPFL

Building 2050 research group

This research group works on defining a novel approach to conceive the innovative smart living building. An ambitious and trail-blazing project, the smart living building will help put into practice the energy and environmental goals set for 2050. It will house the research activities of the smart living lab as of 2020

Structural Xploration Lab

This lab was created in 2016. Its goals is to support the transition of the construction industry towards a more circular economy. The research team places the focus on the geometry of the structural solution, its interactive shaping and its practical implementation.

Laboratory of Construction and Architecture

Founded in 2016, this lab seeks to analyze construction processes and identify successes and failures, and their origins. A second fundamental question is to understand construction processes that encourage innovation.

HEIA-FR

TRANSFORM Institute

TRANSFORM seeks to achieve a dynamic balance between the human factor, inhabited environment and technical progress on the one hand and an optimum use of resources and methods on the other, in order to meet the challenges facing architecture today.

ENERGY Institute

ENERGY supports the development of sustainable energy supply and energy management in our society. The Institute works actively to transfer knowledge and technology to key industrial sectors: construction, energy generation and distribution, production (energy consumers).

UNIFR

international institute of management in technology

The international institute of management in technology (iimt) is a leading competence center for Information and Communication Technology (ICT) and Utility Management, offering executive training programs and research. The chairs' research team is active in the fields of Energy Systems Management, Innovations and Technology Management, Information Security Management and Project Management.

Human-IST research center

The Human-IST (Human Centered Interaction Science and Technology) research center is dedicated to research and training in Human-Computer Interaction combining expertise in computer science, psychology and sociology.

Institute for Swiss and international construction law

The Institute for Swiss and international construction law is dedicated to research, training and ongoing education in all fields regarding construction law, public markets law and real estate law.

Researchers and collaborators hired in 2016

EPFL

Jan Brütting
PhD

Sofia Colabella
scientist

Dominique Corday
administrative assistant

Vanda Costa Grisel
scientist

Corentin Fivet
professor

Claude-Alain Jacot
technical employee

Cédric Liardet
scientist

Paolo Tombesi
professor

Riccardo Vannucci
scientist

HEIA-FR

Lauriane Bererd
collaborator

Martin Boesiger
collaborator

Layal Bou Antoun
collaborator

Harold Brülhard
collaborator

Jérôme Kaempf
professor

Gabriel Magnin
collaborator

Charles Riedo
technical employee

Joëlle Rudaz
collaborator

Damien Vionnet
collaborator

UNIFR

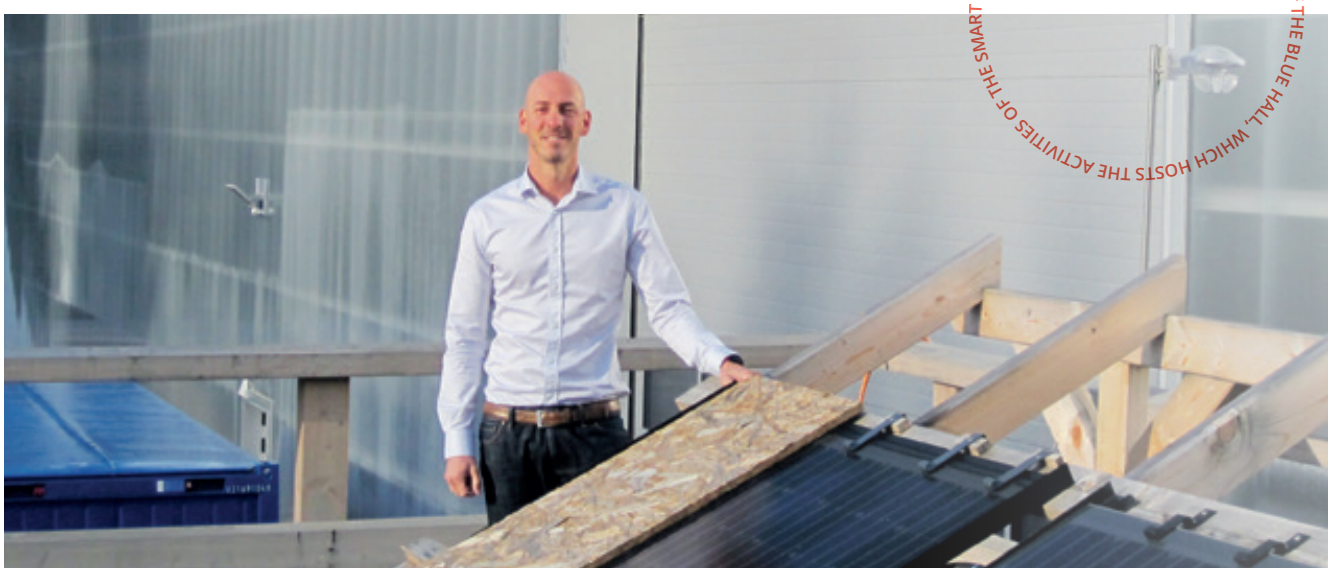
Michaël Papinutto
PhD

Number of people per research group linked to the smart living lab

IN TOTAL	60 PERSONS
From EPFL	**19 persons**
EPFL Fribourg administration	4 persons
Building 2050 research group	9 persons
Structural Xploration Lab	4 persons
Laboratory of Construction and Architecture	2 persons
From HEIA-FR	**28 persons**
TRANSFORM Institute	19 persons
ENERGY Institute	9 persons
From UNIFR	**13 persons**
international institute of management in technology	5 persons
Institute for Swiss and international construction law	3 persons
Human-IST research center	5 persons

Professors recruited in 2016

HEIA-FR appointed a professor in the ENERGY Institute: Jérôme Kaempf.



Interview with Jérôme Kaempf, new professor at the smart living lab

You have just arrived at the smart living lab, which HEIA-FR is partner with. What are your initial impressions?

My first impressions of the smart living lab have been rather positive: the Blue Hall has plenty of meeting areas for the three partners HEIA-FR, EPFL and UNIFR. There's a cafeteria, an impressive interior space and joint seminar rooms. The premises seem to have been designed with interaction in mind. My first day was a very pleasant experience, which helped me to quickly find where I'll be working and orient myself within the ENERGY box.

How did you become interested in your field of research?

When I was a kid, we had a rather unreliable home heating system, which was one of the first air/water heat pump systems built in Nordic countries. It was supposed to heat our house without any problem no matter how cold it got in winter. Well, that turned out to be a joke since we frequently had to light a fire in the chimney on cold days. Back in those days, energy efficiency pioneers often had to give up comfort as a reward for their good intentions.

Nowadays, preserving comfort is an essential consideration in efforts to promote energy conservation. I have always kept this multiple-objective aspect in mind in my research on how to optimize the energy efficiency of buildings.

What are the main themes that you will focus on over the next few years?

Over the next few years, my research will primarily be focused on finding ways to optimize the performance of buildings in the future. Swiss industry has a particularly firm grasp of building renovation techniques, which are also supported by efficient state incentives. However, new challenges have emerged for passive buildings: how to cope with considerable energy demand fluctuations, how to achieve self-generation from renewable energy sources and how to store this energy to serve the needs of a single building or a building complex. These challenges can be broken down into three main categories: building energy optimization for interior air conditioning systems; renewable energy conversion systems; and preservation of user comfort (both thermal and visual).

Research directions

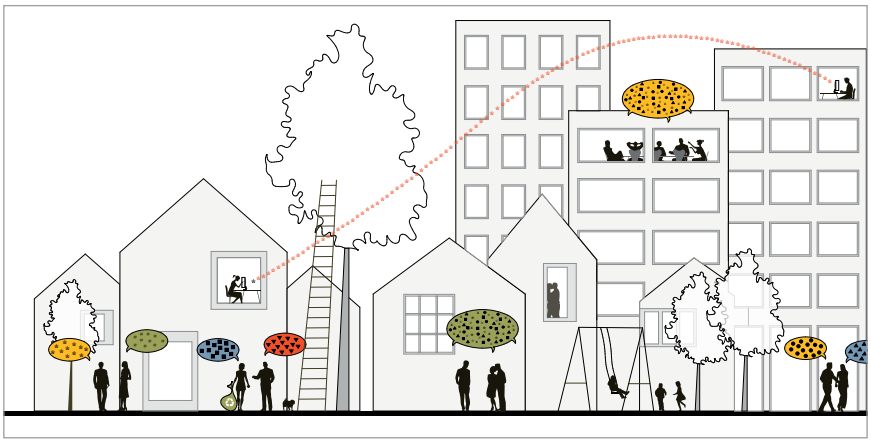
Different research groups contribute to bringing significant input on technical, societal and economical challenges that the development of the built environment faces in the following fields:

Comfort and perceptions:

the influence of buildings on users' comfort and health, especially thermal, visual and acoustic comfort, as well as air quality.

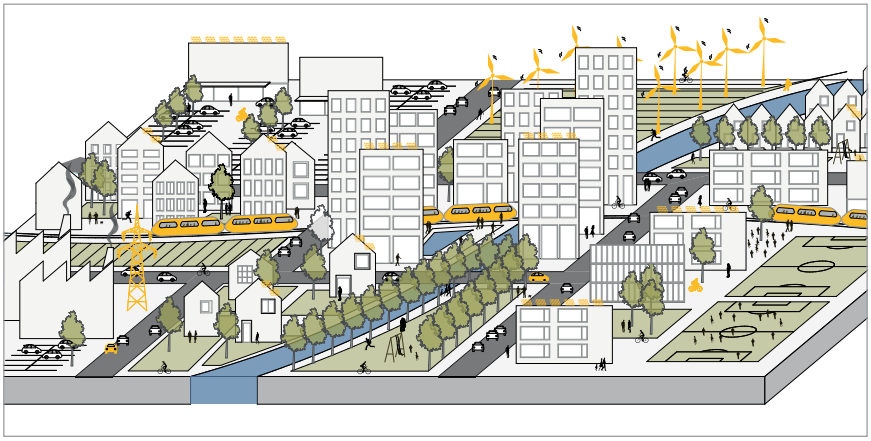
Interactions and behaviors:

understanding the factors that influence users' behaviors and their social interactions.

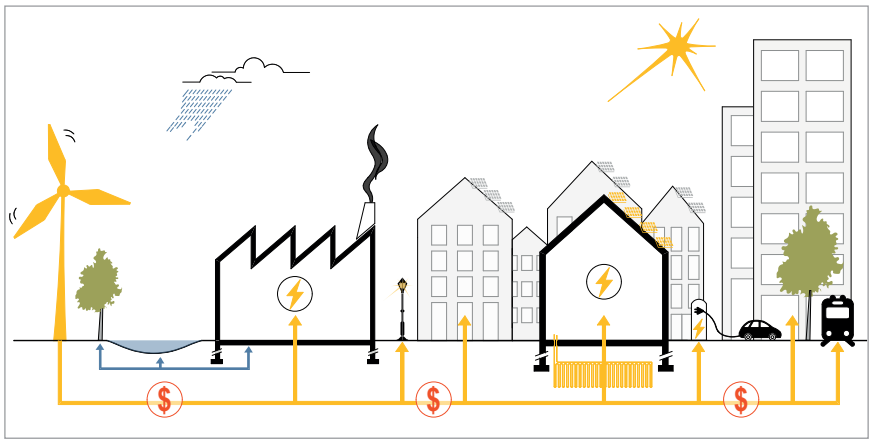


Adaptability of buildings and neighborhoods :

design methods and processes ensuring the capability of the building and of the neighborhood to adapt to the changing needs of users and to environmental fluctuations.

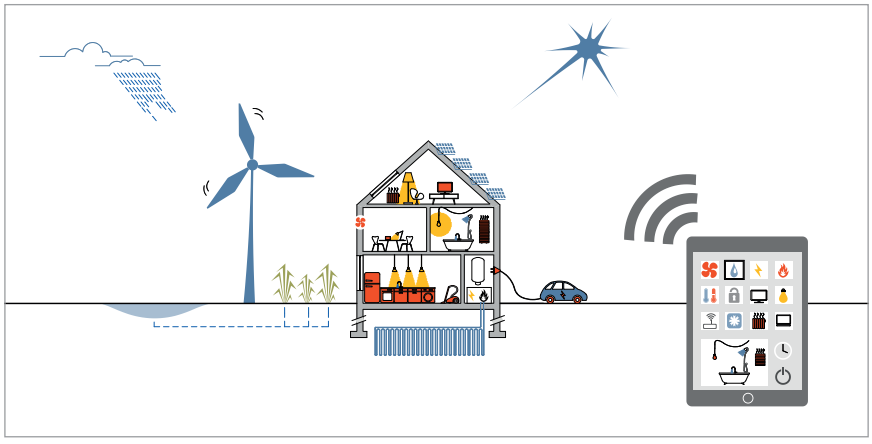


TO FIND OUT MORE: WWW.SMARTLIVINGLAB.CH



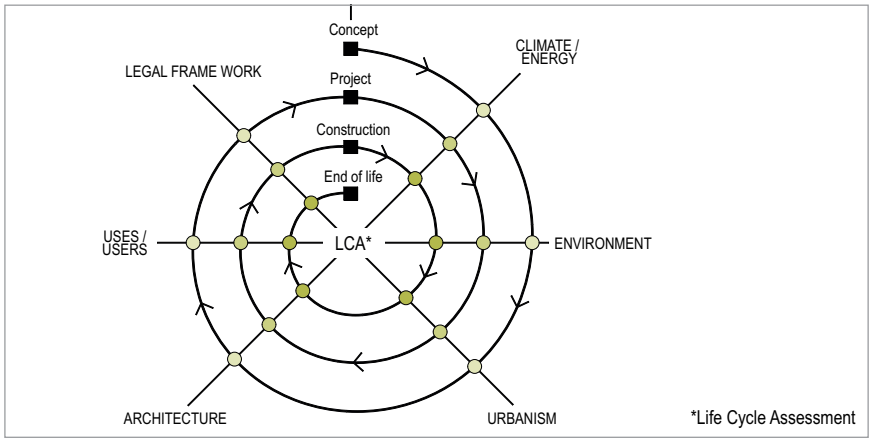
Energy networks and economics:

technical management of interactions between the consumption and the production of decentralized (building) and centralized (neighborhood) energy production. New relative economic models, prosumer concept (consumer-producer).



Active systems and controls:

new technologies in heating, ventilation and lighting integrated to the building. Control and automation methods which account for changing needs and climatic fluctuations.



Integrated design and construction process:

consideration of climatic and environmental issues during design and construction. Consideration of regulatory and legal processes.

9 flagship projects

smart living building

THOMAS JUSSELME, DIRECTOR OF THE SMART LIVING RESEARCH PROGRAM, PRESENTING RESULTS

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Project title	Smart Living Research Program
Starting date	2014
End date	2016
Director	Thomas Jusselme
Supervision	Marilyne Andersen, Emmanuel Rey
Research groups involved	Building 2050, Institut TRANSFORM, Institut ENERGY, Human-IST, EPFL ECAL LAB, CRAterre laboratory at ENSAG, EPFL LIPID, EPFL LAST, EPFL LASUR
Researchers involved	Thomas Jusselme, Arianna Brambilla, Endrit Hoxha, Stefano Cozza, Amélie Poncéty, Vanda Costa Grisel, Cédric Liardet, Didier Vuarnoz, Michelle Jiang
Private companies involved	Estia SA, Atelier Oï, JPF, Terrabloc
Reference publications on the project	http://building2050.epfl.ch/publications-awards

Since the beginning of 2016, the blueFACTORY site in Fribourg has hosted the smart living lab, which will see the construction of its own building in 2020. Awaiting the final building, research teams have their offices in the blueFACTORY's Blue Hall.

The vanguard building that is currently being designed by the researchers will be called the smart living building and will be sustainable and constantly evolving. Comprising laboratories, classrooms, and offices for about one hundred researchers, it will also host experimental accommodations designed to monitor the comfort of their occupants in real-time.

In the context of multifunctionality, the building itself will become an object of study in the quest for solutions to reduce power consumption and the associated greenhouse gas emissions.

A building in line with Switzerland's environmental objectives

The Swiss Federal Council has affirmed its commitment to moving towards a 2000-watt society by 2150, with an intermediary objective of 3500 watts by 2050. To help the smart living building meet this objective, an interdisciplinary research program has been set up, funded by the Canton of Fribourg and EPFL. Headed by the Building 2050 research group, about thirty researchers from EPFL, the HEIA-FR, and UNIFR will be involved in the passionate mission of designing a model building for the future.

Focusing on questions related to energy, comfort, and architectural quality, the researchers have identified their main axes of inquiry:

1. The user, for whom the building is designed
2. The building's envelope
3. In situ energy production and transformation
4. Energy storage
5. The link with mobility

The smart living building, a true center of excellence integrated into the heart of the city and sensitive to societal developments, will give researchers a 30-year head start in experimenting with tomorrow's lifestyle.

An international workshop in Gruyères

Concrete actions are being carried out to ensure that preliminary research results effectively find their way into the conception and construction of the smart living building. The research group is going out of its way to confront the results of its investigations with on-the-ground reality. To do so, they are organizing events that stimulate personal meetings and debates with building experts. On October 5 and 6, a palette of international experts from academia and private industry met with about twenty members of the smart living lab in Gruyères on the topic of research that will lead to the construction of the smart living building.

The main objective of the workshop was to validate and consolidate the outcome of the preceding 18 months of work through the input of the international scientific community, before transitioning to the operational phase in 2017.

Analysis of research

The multidisciplinary teams of experts zeroed in on the Building 2050 research axes, namely:

- A methodology to provide design assistance, while managing a limited carbon and energy budget
- A investigation into perceived comfort in various façade composition scenarios (thermal inertia, lighting, ventilation)
- The optimization of the ratio between available green energy and a building's energy demand
- A limit on the amount of material to be used to set up the workplaces
- The establishment of a decision-making process for this type of experimental project

Recommendations for the future of the program

The experts insisted on the importance of placing the user at the center of all decisions pertaining to the building, while providing a simple decision-making process. Rather than increasing the density of office spaces, they recommended specializing spaces according to the types of activities they would host. Accommodations in the smart living building will let researchers carry out innovative research insofar that they are flexible and adaptable, and their resident population will depend on the types of experiments that will be carried out.

Overall, the experts commended the originality and the comprehensiveness of the research and helped cast a light on other complementary axes of research.

These research efforts, enhanced by the outcome of the 2015, 2016, and soon the 2017 workshops and that bring together professionals and international experts in the construction sector, will define the specifications for the future designers of the smart living building. In 2017, the project will enter its operational phase, which will involve further defining the project specifications and launching the call for tenders. The building is expected to be completed in 2020.

Minimizing the ecological footprint of building energy systems

SOLAR INSTALLATIONS OF THE BLUE HALL

© Alain Herzog

Project title	Carbon correlation
Starting date	2015
End date	2016
Director	Didier Vuarnoz
Research groups involved	Building 2050, Human-IST, ENERGY Institut
Researchers involved	Didier Vuarnoz, Thomas Jusselme, Stefano Cozza, Gabriel Magnin, Thibaut Schafer, Philippe Couty, Elena-Lavinia Niederhauser, Jean-Philippe Bacher, Agnes Lisowska, Julien Nembrini, Denis Lalanne
Reference publications on the project	"Studying the dynamic relationship between energy supply carbon content and building energy demand" Vuarnoz, D., Jusselme, T., Cozza, S., Rey, E., Andersen, M., 2016., in: Plea 2016. Los Angeles. "Temporal variation in the environmental impact assessment of the Swiss grid" Vuarnoz, D., Jusselme, T. In press. 2017. "Carbon based energy strategy for buildings" Vuarnoz, D., Cozza, S., Jusselme, T., Magnin, G., Schafer, T., Couty, P., Niederhauser, E.L., Bacher, J.-P. In prep. 2017. "Exploring the Potential Impacts of Shifting Energy Consumption in Work Environments" Nembrini, J., Lisowska Masson, A., Vuarnoz, D., Lalanne, D., In prep. 2017. "Development and validation of an intelligent algorithm for synchronizing the low-environmental-impact electricity supply with the building's electricity consumption" Niederhäuser, E.L.,Magnin, G., Schafer, T., Vuarnoz, D. In prep. 2017.

The environmental consequences of striking balance between a building's energy demand and the ecological footprint of potential energy sources remain poorly investigated.

Using a new tool, the capacity of a building's energy installations and their operation can now be optimized. The tool also provides information into the greenest energy sources for each solution considered

In Switzerland, and elsewhere, energy demand fluctuates from hour to hour and from season to season. Consumption typically peaks in the winter and in the evening hours when the heating and domestic appliances run simultaneously. Demand tends to be lower during the summer, as production, in particular solar production, peaks. The mismatch between production and consumption is problematic, in particular because energy storage still comes with an environmental cost.

A tool to design more powerful energy systems

As part of the project, Didier Vuarnoz, a scientist in the EPFL Building 2050 research group at the smart living lab, investigated how renewable energy production and storage could be integrated in the context of a building to reduce its environmental footprint.

Under his leadership, a group of researchers set up a versatile simulation tool that allows them to evaluate the performance of a building's energy systems based on multiple criteria (carbon emissions, autonomy, minimizing losses through storage, etc.). Using the tool, a variety of technological designs to produce or store energy can be compared quickly and the best variants selected.

Modeling the scenarios required determining fundamental aspects that had to be considered:

- The characteristics of the building itself
- The users and their behavior in the building
- The users' potential to shift their energy consumption away from demand peaks to smooth energy consumption
- Environmental impacts of traditional energy sources
- Environmental impacts of renewable energy and its storage

From predicting a building's needs to optimizing its operation

A case study was defined to test the method: the smart living building, the future research and development center that will host the smart living lab's staff and researchers. Based on a survey of 1600 academic researchers and staff members (who thus represent the building's future users), the needs of this population were identified. Using these results, the energy consumption of the building and its future occupants were simulated over the course of an entire year, hour by hour, taking into account the specific environmental and climatic conditions that characterize the blueFACTORY site, where the building will be built.

"Thanks to this approach, predictions will help us optimize the design of the smart living building's energy infrastructure," explains Didier Vuarnoz.

Once the building is in use, the team plans to inform its users about the carbon footprint associated with their behavior and show at what time of the day consumed energy has the lowest environmental impact. The idea is to consume better by directly sourcing renewable energy produced by the building when enough is available. "By effectively informing the users, we could reduce greenhouse gas emissions associated to their consumption without reducing their comfort," he says.

Quantifying the carbon footprint of available power

Buildings can draw energy from a range of sources. It can come from the grid (approx. 1/3 nuclear power, 1/3 hydroelectricity, 1/3 imports, and some renewable energy), or from on-site production (for example from solar panels on the building) with the possibility of storage. Not all of these sources have the same environmental impact. The team therefore determined the carbon footprint of all types of energy sources available to the smart living lab, including those from the traditional grid. It was the first time that the hourly environmental impact of the Swiss grid had been computed. "This will let us take advantage of the dynamic potential of temporal variations on the quality of available energy to reduce the impact of buildings on our environment."

An outstanding tool to calculate the environmental impact of energy

Once the team was able to quantify the volume of energy produced and consumed, as well as its environmental impact, the custom designed tool provided real time information on the preferred energy sources to minimize a building's environmental impact. Different variants of a building's energy system designs could be rapidly assessed and compared. "Our tool provides unprecedented decision-making support, but stops short of proposing the ultimate strategy. Constructing or renewing a building required taking into account environmental and energetic criteria, but there is more to it than that. Other aspects also have to be considered, such as financial constraints, aesthetic considerations, and political preferences," Vuarnoz concludes.

Applying the circular economy to the construction sector?

Project title	Applying the circular economy to the construction sector
Starting date	2016
End date	In progress
Director	Corentin Fivet
Research groups involved	Structural Xploration Lab
Researchers involved	Corentin Fivet, Sofia Colabella, Endrit Hoxha, Jan Brütting, Valeria Didonna et futurs collaborateurs
Reference publications on the project	http://sxl.epfl.ch/pub

Proportionally, the construction of new buildings will soon pollute more than their operation. Moreover, the potential to recycle a building's "waste" material post-demolition is still underexploited. So what if a building's structures and systems were designed to be reused several times over centuries?

The past decade has seen efforts directed primarily at reducing the operational energy consumption of buildings (heating, lighting, etc.). In the near future, construction and demolition will comparatively account for more carbon emissions. Waste products from these two phases abound, because buildings are not designed to be recycled. Even if anything can be recycled in theory, it always comes at an economic and ecological cost. Furthermore, recycling often leads to a loss in quality in terms of material properties, potentially disqualifying recycled construction materials from being reused for their initial use. Recycling is not a miracle solution.

Opposing the linear economy

The prevailing model in the construction industry (based on the predominant linear economic model of production-consumption-disposal) strongly contributes to depleting natural resources. "To make concrete, you need sand. Today, we have to scrape the seabed 200 meters underwater, destroying any existing flora and fauna in the process, because we have used up available sand resources. Desert sand is too smooth to be used in construction because of wind erosion," explains Corentin Fivet, EPFL professor and director of the Structural Xploration Lab based at the smart living lab. That is why it has become urgent to look for other models that, essentially, increase the lifetime of extracted raw material and of the components produced with it. The circular economy stands in opposition to the linear consumption economy. "The idea is to close the loop for materials according to the principle of 'nothing is lost, nothing is created, everything is transformed or transferred.' Reducing the amount of material used, repairing, reusing, recycling, and returning to nature, are principles that can be applied in that order of priority: repairing consumes less energy than reusing, which consumes less than recycling, and so on..."

Multiple lives for a building's structures and systems

Understanding how to design a building's support structure (walls, slabs, columns, flooring, roofs, foundations) in a way that makes them reusable over several generations of buildings is one of the goals of the Structural Xploration Lab. Using locally sourced materials to reduce transportation costs and associated carbon emissions is also part of the philosophy. A building's lifespan is typically around 100 years, so reusing elements over multiple centuries would involve adopting a very long-term perspective – nothing short of a paradigm change.

To look that far into the future, the team developed tools to evaluate the potential of materials from demolished buildings to be reused.

"Considering the Swiss building stock, we have no idea what percentage of materials or components could be reused post-demolition. Being able to reuse demolished heritage to build new buildings is one of the scenarios that we will have to investigate," says Fivet.

It isn't enough to reuse structural systems only, he explains, instead, all the integrated systems from the old buildings (plumbing, insulation, air and waterproofing, and a building's finishes) should be reused, and that despite having to disassemble and reassemble them.

Circular economy or restitution to nature

As things stand, the researchers still have to find out whether the circular model (reusing elements over centuries) could be successfully applied to the construction industry, or whether elements should simply be returned to nature once a building is demolished. "How can we measure reuse? What technologies would promote reuse? These are questions we expect to address over the coming years," concludes Fivet.

Deconstructing construction: understanding successes and failures

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Project title	Digital fabrication technologies: Analyzing patterns of adoption and innovative transformations in architectural design and practice
Starting date	2015
End date	2017
Director	Paolo Tombesi et Bharat Dave
Research groups involved	Laboratory of Construction and Architecture , Australian Research Council
Researchers involved	Paolo Tombesi and Bharat Dave
Reference publications on the project	https://youtu.be/nt04PH_ePvw

Once they are completed, do construction projects live up to their promises? Which factors explain why certain buildings succeed and others fail? And are their specific configurations that make it more likely for innovations to materialize?

In the construction industry, it is far from common practice to critically examine the production process of buildings. Why? It takes such a multitude of actors to build a building that dysfunctions get drowned out by the complexity of the project.

"Construction is one of those complex social disciplines in which no one is ever at fault. As an activity based largely on experimentation, errors are an integral component of the construction process," says Paolo Tombesi, EPFL professor and director of the Laboratory of Construction and Architecture based at the smart living lab.

Analyzing the production of buildings

Paolo Tombesi dedicated his long career to analyzing construction processes. To do so, he focuses on real and often internationally popular architectural projects, frequently traveling on site to visit them. Armed with his camera, he combs the buildings from their basements to their attics to capture both their strong points and their flaws. Sometimes he follows the projects before their completion, regularly going on-site and visiting the suppliers to study their means of production. Tombesi also analyses all the documents that he can get his hands on, including project specifications and blueprints. Using a method he developed himself, he focuses on the many actors involved and on their interactions.

Role dynamics

Rather than simply assigning actors to their fields of expertise and the services that they provide, Tombesi focuses on their actual roles in the project. What is their sphere of influence? What interests are they guided by? What specific knowhow can they offer? More broadly, what role do the actually play in the project? By attributing roles (drivers, facilitators, challengers) to each person involved in several case studies and analyzing them serially, Tombesi was able to identify configurations that might explain a project's success. "If there is one constant that stands out in architectural projects that meet their objectives, it is that the people behind the design had both the knowhow and the power to adapt the industry's behavior according to the specific needs of the project," he explains.

Fostering innovation

In 2016, Paolo Tombesi carried out a comparative assessment of three buildings built using digital fabrication methods (advanced modeling, 3D printing, laser cutting, automated assembly of prefabricated elements, etc.). Analyzing construction methods, it became apparent that digital fabrication was particularly useful when the shop drawer took onto himself the risk and the responsibility of both creating only the digital files and handling the entire digital coordination, starting with the architects all the way to the production facilities. In these cases, the shop drawer became the driving force of the project; if the project succeeded, his business would stand out in the market. His obvious economic interest would push him to shoulder not only the role of the project's driving force, but also all of the other key roles required for the project to take shape. While analyzing his case studies, Tombesi observed that certain social configurations tend to foster innovation such as digital fabrication, while others slow it down, curtail it, or extinguish it altogether. He established a correlation between the distribution of power among the actors and whether or not innovations materialize. "Innovation can be realized if they clearly benefit those who have the power to act," he concludes.

Comfort vs. home automation? Involve the future tenants!

INDOOR VIEW OF THE SOLAR INSTALLATIONS AT THE ENERGY INSTITUTE

© Alain Herzog

Project title	THE4BEES - Transnational Holistic Ecosystem 4 Better Energy Efficiency through Social innovation
Starting date	2016
End date	2018
Director	Jean-Philippe Bacher
Research groups involved	ENERGY Institute + participants in co-creation workshops
Researchers involved	Jean-Philippe Bacher, Damien Vionnet, Harold Brülhart, Martin Boesinger
Private companies involved	Lutz Architectes, Climate Services, Cluster énergie & bâtiment

Differences in power consumption of individuals occupying the same building can be astonishingly large, as can the power consumption of distinct buildings. Who is to blame for these differences, the buildings or their occupants?

Is more energy consumed by a building's tenants or by the building itself? A European project with Swiss participation is focusing on a building's users, encouraging them to rethink their behavior to save energy. The THE4BEES project comprises seven European pilot sites. The Blue Hall – currently occupied by the smart living lab – is one such experimental venue. Currently, one of the strategies exploited to curb energy consumption involves automating buildings. The Blue Hall is no exception. However, it has generally been found that, when deprived of the ability to control the lights or open windows, users find strategies to overcome the ensuing lack of comfort, sometimes in ways that are actually worse than if they had been allowed to control the temperature or the blinds. What if the users had their say before the building was built?

An unprecedented collaborative process

To understand the habits and needs of building occupants, the THE4BEES project adopted a participatory approach: surveying the users of an existing or future building.

"Given that the smart living lab will soon build its own building, and that the staff and researchers have for the most part already been hired, this original situation – having united most of the users of a future building before its construction – was an opportunity we had to seize," says Jean-Philippe Bacher, professor at the HEIA-FR and director of the ENERGY Institute that is involved in the smart living lab.

As the head of the Swiss component of the project, he brought together several members of the smart living lab to discuss potential improvements to the current temporary facility (the Blue Hall pilot site) and to the future smart living building. Involving a building's future users in the earliest design phases has many advantages. "People can present their needs, reflect on their consumption habits, and express their wishes for the future building. Because of their first-hand experience as users, they are also a precious source of very concrete knowledge on good or bad architectural practice.

Developing custom designed tools

To the researchers, the participatory approach provides a way to understand why users sometimes consume too much energy (e.g.: no natural ventilation, leading to a constantly open window with the heating on full blast), but also to reflect on ways to control consumption as a group. In addition, digital technology provides real-time information on the consumption of each individual user. "As many studies have shown, seeing ones power consumption in real-time only has a very short term beneficial impact. That's why we decided to ask users to help us come up with tools that would incentivize them to optimize their consumption," says Bacher. Lights, colors, sounds, and forms of human-machine interaction are being investigated to find constructive ways to sound the alarm. Gauges, meters, comparators, challenges, and team competitions are also planned. Another advantage of the participatory approach is that the tools are conceived by their future users, increasing the likelihood of their acceptance. And "the users that designed them will also adopt them better from a technological perspective, because technology is often intimidating," says Bacher. Once the tools are conceived, they will be developed and then tested by the users. Following the test phase, they will be improved and then validated. Next, the impact of the digital tools on behavior will be measured and evaluated. The results from the pilot sites will be compared among themselves, making the resulting data a valuable resource to guide public policy. "A poorly designed building leads to overconsumption of energy, and that despite it's users' best intentions, especially if their wellbeing is at stake. Even though the project is still far from completion – it will go on until December 2018 – we are convinced that technology should not come at the behest of the users' comfort. Instead, it should help them control their environment and their energy consumption," concludes Bacher.

Architectural quality and collaborative production of buildings

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Project title	Architectural quality and production processes for the construction sector
Starting date	2015
End date	2016
Director	Florinel Radu
Research groups involved	TRANSFORM Institute
Researchers involved	Chantal Dräyer, François Esquivié, Yingying Jiang

Architectural quality is a multifaceted principle that focuses on the user throughout a building's design process. Adopting this perspective opens new avenues for building production processes.

Achieving architectural quality is equivalent to prioritizing a building's future users. It's a concept that comprises multiple facets, including questions pertaining to construction, techniques, energy, and the environment. In other words, everything that relates to the building as a physical object and its performance (insulation, passive strategies, ventilation, etc.). The functional dimension – indoor and outdoor circulation, the organization and role of each space, and the personalization of each room according to its future occupants, the size of the team and the technical installations – is also fundamental. The building's integration into the urban fabric in the context of a specific climate also needs to be considered. Financial constraints related to the building's construction and its maintenance are additional crucial parameters. And finally, there is the aesthetic dimension (everything that is visible and creates an atmosphere in the building, from the lights to the materials used).

"All of these dimensions are interdependent and often contradictory. It is precisely here that we have to make a smart compromise," explains Florinel Radu, professor at HEIA-FR and director of the TRANSFORM Institute involved in the smart living lab.

Putting the users first

Most if not all aspects comprised in the concept of architectural quality impact a building's users. The term is rife with subjectivity, as it involves the users' perceptions, their systems of values, and their personal sensitivities. To respect the wellbeing of the majority of users and identify the tolerable margins of acceptance of the rest, Radu's team made an inventory of the various actors, their interests, and their constraints regarding a building project, in this specific case, the smart living lab and its future smart living building. This first step was crucial for the development of the process what would lead to the smart compromise between the many actors and all of the issues involved in producing a first-class building in terms of its architectural quality. "The project's objective is to adopt an ideal process (formulating objectives, managing time, identifying methods, tools, actors, and resources), from the conception to the final construction of the smart living building, followed by its operational phase," says Radu.

Designing an ideal collaborative process

It quickly became apparent that the main issue in producing a building that respects a maximum number of interests and constraints is the communication and collaboration between the actors at all levels. In a classic case, a building project is submitted to an architectural competition. The specifications are determined ahead of time, and the competing teams all work independently without sharing information on the competition. Radu's team came up with a new process. The specifications used to initiate it could be iterative. The participating teams and the future users could thereby suggest improvements. Furthermore, the teams involved would no longer be true competitors, but would instead find themselves working together. Several opportunities would be planned to meet and openly assess the evolution of the project prior to the final decision. Throughout the competition, the researchers of the smart living lab will be available to interact with the teams. The selected project will be the fruit of the collective intelligence of all involved. It's a huge process of co-construction. Our demands for the smart living lab are high. To meet them, we also have to innovate in terms of our working methods!" he concludes.

The impact of future consumer-producers on the electricity grid

PROFESSOR STEPHANIE TEUFEL DURING HER PRESENTATION AT THE SMART LIVING TALKS

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Project title	Handling the Crowd: An Explorative Study on the Implications of Prosumer-Consumer Communities on the Value Creation in the future Electricity Network
Starting date	2014
End date	ongoing
Director	Stephanie Teufel
Research groups involved	iimt
Researchers involved	Mario Gstrein, Stephanie Teufel
Reference publications on the project	Handling the Crowd: An Explorative Study on the Implications of Prosumer-Consumer Communities on the Value Creation in the future Electricity Network

In the near future, many more people will produce their own energy, for example using solar panels, and become "prosumers." Excess energy will either be stored, shared, or sold. So what will the future energy market look like?

"Handling the Crowd: An Explorative Study on the Implications of Prosumer-Consumer Communities on the Value Creation in the Future Electricity Network" is the title of Mario Gstrein's PhD thesis. His research investigates tangible trajectories: what would happen if all power were produced locally and renewably? What if people in a neighborhood joined forces to produce, store, and share energy within their community? At the very least, this would involve setting up new micro-grids and decentralizing production on-site. Decentralization is an increasingly popular trend with several benefits in terms of cost, but also for the environment, as, for example, transportation distances are reduced. It is a trend that could also make it into the energy sector.

Consuming energy produce on-site

What would happen if everyone was able to partially or completely cover their energy needs?

"This study takes the perspective of the prosumer (a contraction of producers and consumers). Its novelty is to put the collectivity, or the crowd, in the center and to prove that this could be entirely feasible," says Stephanie Teufel, Gstrein's thesis supervisor, who is a professor at UNIFR and directs the international institute of management in technology, a partner of the smart living lab.

To address this challenge in his thesis, Gstrein adopted a multidisciplinary approach. Using a web survey, he studied a range of social aspects, such as the desire to belong to a group of energy producers, or common decision-making schemes related to saving or sharing energy. He also focused on economic aspects, such as the price of electricity produced at home, and calculated the production potential using a simulation of a collective in a real neighborhood.

A form of autonomy that will redefine classic distribution networks

His findings showed that people are becoming increasingly interested in investing in infrastructure and are waking up to the idea of becoming prosumers. Also, producing energy as part of a collective is tempting, as long as the collective is large enough to preserve each individual's anonymity. And, with sufficient size, say that of an apartment building or a suburban area, a collective could significantly reduce its dependence on power utilities, influence the production chain, and be self-sufficient during transition periods (outside of peak demand). To create the conditions required for achieving full autonomy, the collectivity has to increase its production and storage capacity and have access to less volatile forms of energy, to the extent that it is financially able to do so. In such a situation, power utilities could become the rescue solution, acting as an insurance that sells its electricity when shortages occur.

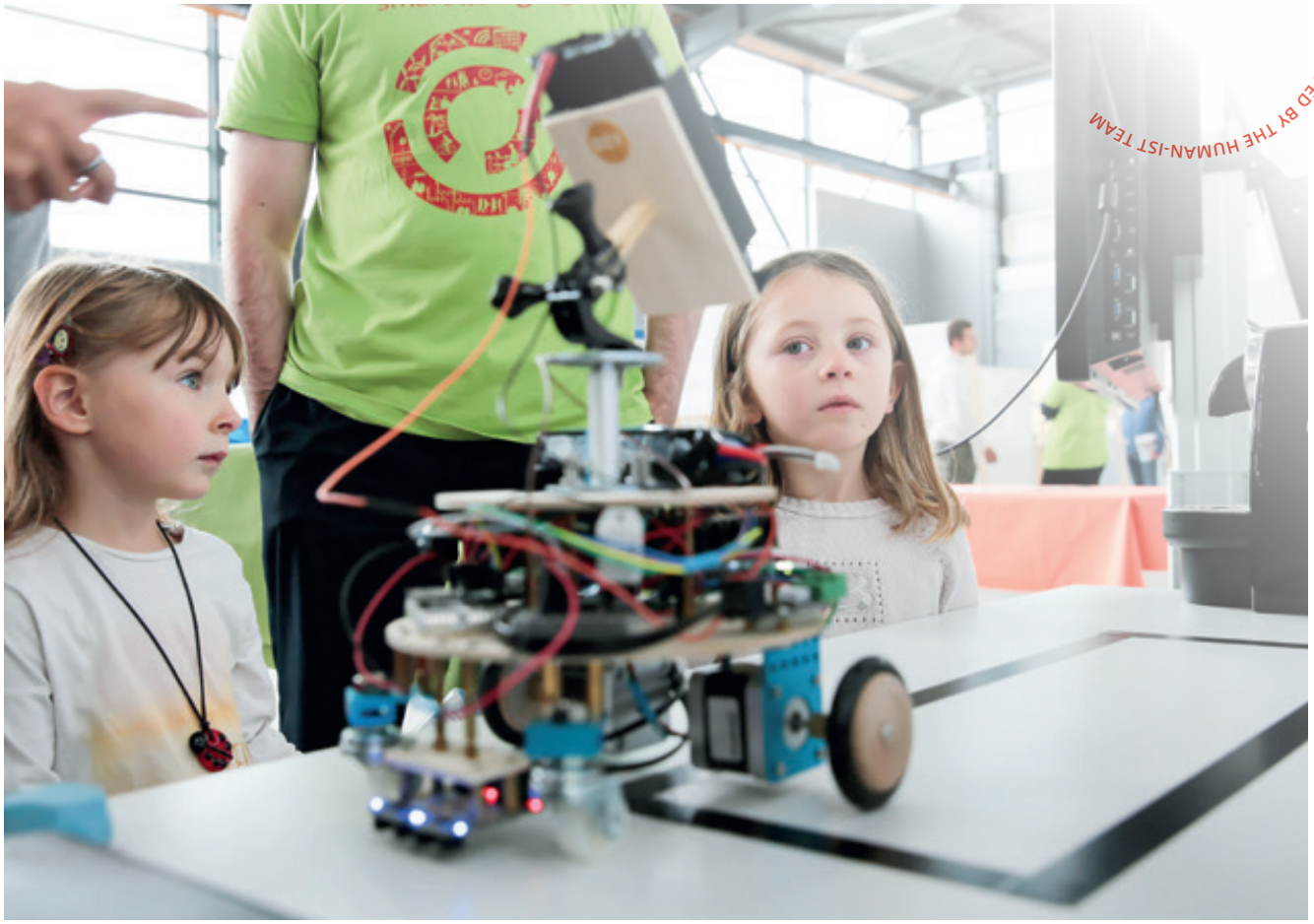
Sharing energy and values

"Sharing behaviors, decision making patters or trust and commitments, are decisive for creating and maintaining crowd structures," writes Marco Gstrein. His research shows that, for the principle of sharing to be viable, a collective has to establish moral codes that are respected by all. This requires attributing the same value to one's own energy as to that of the other members of the collective. Transparency is fundamental to fostering cooperation. Running a simulation on an existing neighborhood, Mario Gstrein also discovered that the number of interactions peaks when the production-consumption ratio is equal, in other words, when more options are available (sharing / storing / selling).

Additionally, there are two groups of prosumers that influence the dynamics on the power grid: adaptive and non-adaptive prosumers. Non-adaptive prosumers are risk averse and only share their stored energy when the sun is out. The adaptive group takes risks when weather forecasts predict nice weather. The success of a collectivity depends on its overall capacity to manage storage and interactions among its members. "Knowing just how much energy can be produced, stored, shared, or sold will drive us towards a paradigm shift. Energy takes on a whole new value, both in terms of its price as in terms of each individual's personal implication. Energy consumption will also be optimized. Giving people the responsibility of producing their own energy may be one of the best ways to make them aware of the stakes!" concludes Stephanie Teufel.

Towards a better understanding of human-building interactions

VISITORS INTRIGUED BY A TECHNOLOGY DEVELOPED BY THE HUMAN-IST TEAM



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Project title	The Comfort Box / User Experience Study I
Starting date	2016
End date	2016
Director	Denis Lalanne
Research groups involved	Human-IST
Researchers involved	Himanshu Verma, Hamed Alavi, Denis Lalanne
Reference publications on the project	Himanshu Verma, Hamed Alavi, Denis Lalanne. "Studying Space Use: Bringing HCI Tools to Architectural Projects". Proceedings of ACM CHI Conference on Human Factors in Computing Systems, with Honorable Mention award (top 5% paper).

How exactly are buildings used? How do their users perceive their own comfort? How do their bodies respond to environmental changes? And how can we enhance the dialogue between humans and buildings?

As part of the smart living lab, the Human Centered Interaction Science and Technology research center (Human-IST) is seeking to get a better grasp on how humans interact with their buildings. This knowledge paves the way for the development of technologies that aim to improve the comfort and efficiency of their use while preserving their energy performance.

"We are developing interactive tools that will help us understand the needs of a building's occupants, increase their comfort, and improve the energy efficiency of the building," explains Denis Lalanne, professor at UNIFR and director of the Human-IST research center.

To study comfort, researchers at Human-IST hypothesized that people do not notice small, gradual changes to their comfort. To test their hypothesis, they developed tools to measure human and environmental comfort. One of them, the "Comfort Box," has since been patented. This box, explains Hamed Alavi, one of its inventors, monitors air quality (carbon dioxide), temperature, humidity, brightness, and noise, and displays them on a screen as well as using a circle of LEDs that change color to indicate whether the conditions are good or out of bounds. The tool not only presents this information to nearby occupants, it also communicates with the building, which can then adjust certain parameters to improve its occupants' comfort.

Customizing the atmosphere

Using buttons, users can share their preferences with the Comfort Box. It too can initiate the dialogue by putting questions to the users when conditions that influence comfort change drastically. Predictions and personalized adjustments of the environment become possible using machine learning. The next experiment will involve comparing three different types of comfort: one measured from the environment, another as it is perceived subjectively by the building occupants, and finally, one that is determined using physiological values measured on their bodies (heart rate, sweating, skin temperature). "The idea is to better understand the relationship between these three different types of comfort to predict a building occupant's discomfort," says Denis Lalanne.

Inferring user-profiles based on displacements

In 2016, the Human-IST research center also set up an experiment for which 22 volunteers wore smart bracelets for two weeks. Sensors in the bracelets communicated with antennas located in 12 of the smart living lab's rooms, allowing the researchers to track the volunteers' movements throughout their workday. "To correctly interpret the data, we used visualization and data mining techniques." In their next experiment, the researchers plan to track environmental comfort data as well and compare them to the participants' displacements. "This new experiment will let us observe the activity of the occupants and how they relate to the comfort of the rooms," explains Denis Lalanne. Using a first set of modeled results, the researchers identified three types of occupants:

- Messengers, who regularly go and interact with their colleagues in person and are also often visited by them. They tend to spend a lot of time behind their desks, but also interact with nearby offices.
- Collaborators, who lack a fixed routine, travel frequently, and are often absent from their offices. They have many meetings in the meeting rooms and spend little time in the cafeteria.
- Workers, who are focused on specific research activities. They tend to be more sedentary and spend more time in the cafeteria than the other types, but rarely leave their offices.

In the next test phase, micro-interactions will be monitored using infrared sensors that can resolve movements down the centimeter. Two rooms in particular will be observed: a noisy shared workspace and a quite one reserved for reading and individual work. The many objectives of the experiment, which will be carried out in collaboration with the EPFL Building 2050 research team and that of the LASUR, as well as with the Atelier Oï, include achieving a better understanding of the spatial needs of a building's users, densifying a building's use, and increasing the level of collaboration. "With this new, more precise analysis, we will be able to better consider the needs of the smart living lab members and propose innovative, comfortable, and energy efficient spaces," concludes Denis Lalanne.

Legal issues related to Building Information Modeling (BIM)

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Project title	Legal Aspects of Building Information Modeling
Starting date	2016
End date	ongoing
Director	Martin Beyeler
Research groups involved	Institute for Construction Law
Researchers involved	Martin Beyeler
Reference publications on the project	Beyeler, Martin, Rechtsfragen zu BIM in 19 Thesen, in: Jusletter 12. Dezember 2016 (www.jusletter.ch)

Using software, any building can be modeled, from its walls to its doorknobs. The prospect of bringing together all of this information, at an unprecedented level of detail, raises a slew of legal questions.

BIM (Building Information Modeling) is a new computational technology to model any existing or future building using extremely detailed and comprehensive information. Today, BIM software cannot only be used to create a virtual 3D representation of a building and all its properties, but also to present the juxtaposition of its many layers (foundations, walls, plumbing, electric circuits, etc.) and isolated components (from the roof to individual nails). But the possibility of reporting an abundance of information, of interacting and working within a single platform, also entails new issues involving a range of legal fields. The Institute for Swiss and International Construction Law at the University of Fribourg has made it its goal to identify these issues and provide initial solutions.

Uniting all existing information

In Switzerland, more and more architects are using the BIM methodology. While it was initially developed for the automotive industry to simulate future cars or machines, it has been applied in the United States to design, simulate, and test buildings, from the construction site to their demolition, including the operational phase. The methodology comes with many advantages: "It may come as a surprise, but there are still many inconsistencies that only become apparent when construction is well underway! This is due to the fact that designing and planning a building requires a large number of specialists, which makes it difficult to comprehensively coordinate the various contributions using traditional tools. As a result, there are often a number of persistent incompatibilities that can potentially become expensive later on," explains Martin Beyeler, a professor at the smart living lab and at the Institute for Construction Law. By bringing together all of the information pertaining to a project to model and by analyzing it for incoherencies or incompatibilities, BIM offers more integrated, and consequently, more reliable planning. Additionally, detailed simulations of digital models make it relatively simple to explore any range of variants of a building and test other strategies or components. "Optimize before you build" is the mantra of this new methodology that provides a means of making better-informed, more responsible, sustainable, efficient, and cost-effective decisions ahead of time, with a significant potential energetic and environmental impact.

Spotlight on legal issues

The BIM method paves the way for new practices and processes that legal experts have to anticipate to provide answers to problems and disputes related to its use. The digitalization of a construction process has repercussions on contract law.

"The contractual fabric of a construction project is a labyrinth of bilateral contracts. But, to a certain extent, BIM relies on uniform processes. Moreover, certain tasks traditionally assigned to specific participants disappear; others change due the use of computerization; others are newly created, such as the task of integrating all of the information on a common virtual platform. These changes will likely have consequences on the attribution of responsibilities and on the question of financial compensation," explains Martin Beyeler.

Who has what rights on the information united in the BIM models? Which types of information are to remain confidential, and how can they be protected from thieves or hackers? And what can be done to keep innovations from being plagiarized or stolen?

Requesting building permits with BIM?

For the time being, construction law requires submitting blueprints (or computer models) in 2D to request a building permit. "Submitting a building permit request using a BIM model could considerably speed up the procedures. The BIM model makes it easier to verify the conformity of the project while also making its evaluation more precise. As a result, requests could be processed more quickly," explains Martin Beyeler. We are not there yet; the laws still need to be adapted, which will require not only addressing issues related to form and content, but also those related to the public inquiry and data protection, "because when you compare them with plans printed on paper, digital models can contain much more information and can easily be copied and misappropriated."

The state is also concerned

Martin Beyeler has found that, like private actors, the state is entitled to use BIM for its projects (and during the tender process). Under the principle of non-discrimination, the state must not, however, impose a specific software solution without a compelling reason, as this would put those accustomed to working with different software at a disadvantage. A similar risk of discrimination could arise when construction work is put out to tender using a BIM model with certain elements already in place corresponding to specific products. This, concludes Martin Beyeler, would be against public procurement law.

Development and participation in national and international projects

Solar Decathlon

The Solar Decathlon is a student-driven contest, in which student teams design and build a high-performance and fully functional house that uses the sun as its sole energy source.

In 2017, students from the EPFL, the HEIA-FR, the Geneva School of Art and Design (HEAD / HES-SO) and the UNIFR will fly to Denver (United States) where their construction will be exhibited and operate as a regular, pleasant-to-live-in place before returning to Fribourg.

This challenge is closely related to the question of the protection of the landscape and agricultural land, thanks to the rational management of land (LAT) which requires new solutions to suburban land densification. In this context, the project will facilitate the transfer to the main suburban conditions (houses, multiple home housing, industry) and initiate transformation processes. Its role will be to instigate a local and collective dynamic by proposing new shared spaces and services, as well as other approaches to consumption and mobility.

www.solardecathlon2017.ch

Collaboration with the NEST (Empa)

At the "NEST-Next Evolution in Sustainable Building Technologies" research platform, at EMPA in Dübendorf, scientific innovations can be tested at full-scale to accelerate the process of launching products and innovative concepts in the building sector on the market.

In the SolAce unit, EPFL and HEIA-FR researchers are working with architects from Lutz Associés on light. The façade of the unit will be outfitted with technologies to improve its energy efficiency and comfort. In addition to producing energy using photovoltaic and photothermal cells, the researchers are focusing on improving interior comfort by controlling the influx of natural daylight and using other active façade elements. The unit will host living and work space for two people.

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STUDENTS IN THE SOLAR DECATHLON PROJECT DURING THE SMART LIVING TALKS

smart living lab's promotional activities

Events 2016

The smart living lab organized the following events in 2016:

07.10.2016	**Opening of the smart living days**
07.10.2016	**smart living talks** The talks covered the future building that smart living lab intends to build for its activities, inspiring examples of sustainable architecture and complex projects based on a winning participative and interdisciplinary methodology. The "crowd energy" concept, i.e. giving individual households the possibility of generating their own energy and exchanging or reselling it, was also discussed.
08.10.2016	**smart living lab Open Day** Smart living lab researchers set up demos for the general public, including watt meters to measure power consumption of household appliances, suggestions on how building occupants can reduce their carbon footprints. There was even a water fountain-based simulation of housing thermodynamics.
08.10.2016	**End of the smart living days**
05-06.10.2016	**Building 2050: International Workshop** A team of twenty international experts from academic and economic backgrounds as well as around fifteen members of the smart living lab, got together in Gruyères to discuss the research studies leading to the construction of the smart living building.
22.02.2016	**Kick-off participation Solar Decathlon**

The smart living lunches were introduced in 2015 and are designed for the smart living community. The following sessions took place in 2016:

08.11.2016	- The Solar Decathlon architectural challenges - Energetic Refurbishment - a global approach for the building envelope
06.09.2016	- Stronger Buildings with Less Resources and Waste - Principles, values, propositions: The ideas behind FAR, the new ENAC laboratory for construction and architecture
07.06.2016	- The Urban project reloaded: towards new links between actors, processes and time frameworks - Invisible architecture
05.04.2016	- Building Information Modeling (BIM): Defining the Legal Issues - Tiny House Movement for Switzerland?
01.03.2016	- New tools for assessing solar access in urban master planning - The Swiss Living Challenge project for the Solar Decathlon competition 2017
02.02.2016	- Smart windows / Smart algorithms for improved visual comfort and energy savings in buildings - Future users of the smart living building: results of an online survey

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A PANEL OF EXPERTS DURING THE SMART LIVING TALKS

The smart living lab also participated in the following events in 2016:

02.12.2016	Conférence des Gouvernements de Suisse occidentale (CGSO)
23.11.2016	Députation fribourgeoise aux Chambres fédérales
05-06.11.2016	Open House event EPFL
09.05.2016	ENAC Research Day at EPFL
03.05.2016	HEIA-FR Research Day
02.02.2016	Greater Geneva Bern Area (GGBA) deleguates

Media coverage 2016

08.10.2016, La Liberté	« Découvrir les habitations du futur »
08.10.2016, Freiburger Nachrichten	« Startschuss für neue Blue-Factory-Plattform »
08.10.2016, Le Temps	« Un laboratoire fribourgeois se dédie à l'habitat du futur »
17.08.2016, Le Nouvelliste	« Vers un changement des pratiques de construction »
21.06.2016, La Liberté	« Il faut passer à la vitesse supérieure »
01.05.2016, Propriété magazine	« Accroitre la durée de vie d'un bâtiment »

800 PEOPLE CAME TO SEE THE SMART LIVING LAB DURING THE SMART LIVING DAYS

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Finances

Consolidated financial report for the smart living lab and EPFL Fribourg

KCHF	EXPENSES 2014-2015	EXPENSES 2016	BUDGET 2014-2018	AVAILABLE ON 31.12.16
Operational working budget of the smart living lab				
BUILD Group	0	0	750	750
Operating expenses	345	322	1750	1083
Total working budget smart living lab	**345**	**322**	**2500**	**1833**
Ongoing and demonstration projects				
Solar Decathlon	0	200	800	600
Comeback Prototype	0	0	100	100
Other incentive projects	0	0	667	667
Total ongoing and demonstration projects	**0**	**200**	**1567**	**1367**
EPFL – Academic				
Program Building	787	1428	3660	1445
EPFL chairs	0	1667	11333	9666
TOTAL EPFL – Academic	**787**	**3095**	**14993**	**11111**
TOTAL EPFL – Academic Fribourg	**1132**	**3617**	**19060**	**14311**
Contributions from Fribourg academic institutions				
UNIFR	414	628	3060	2018
HEIA-FR	276	898	4056	2882
TOTAL Fribourg academic institutions	**690**	**1526**	**7116**	**4900**
TOTAL SMART LIVING LAB PROJECT 2014-2018	**1822**	**5143**	**26176**	**19211**

Annexes

List of research projects (2016 – ongoing). Only in English

Active Interfaces	Jean-Philippe Bacher	Building-integrated photovoltaic systems (BIPV) could be a high growth market with high impact for the economy and the Energiewende". A better understanding of the technology acceptance and of the needs of the market is required for the design of optimised solutions and to ensure efficient knowledge and technology transfer.	HEIA-FR ENERGY EPFL CSEM
ArQua	Florinel Radu	Conception of an ideal process for SLL building and definition of the first brief	HEIA-FR TRANSFORM EPFL Building 2050
BBDATA	Jean Hennebert, Jean-Philippe Bacher	Analysis and implementation of a scalable cloud platform for storing, accessing and processing the data history of a building (sensors and actuators status, metering ...).	HEIA-FR iCOSYS HEIA-FR ENERGY
BEANS	Yves Hertig, Stephanie Teufel	Behavioural Analysis for Network Sustainability.	UNIFR iimt
BIM und Recht	Martin Beyeler	Identification and investigation of legal issues raised through the application of the BIM methodology in the construction sector (in particular contractual, procurement, and public construction law).	UNIFR Institute for Swiss and international construction law
Building Flexibility	Yingying Jiang, Thomas Jusselme	Identification of users' needs. Space design and user-building interactivity study.	EPFL Building 2050
CARBCOR	Lavinia Niederhäuser	The scope of synchronising a low-environmental-impact electricity supply and the building's electricity consumption is addressed in this experiment. The scope of the study is limited to the smart living building.	HEIA-FR ENERGY EPFL and UNIFR
Carbon correlation experiment	Didier Vuarnoz	Establishing a correlation between the building's electricity consumption and the low carbon energy supply.	EPFL Building 2050 HEIA-FR ENERGY UNIFR Human-IST
CEISec	Mohamad Aldabas, Dominic Feichtner, Stephanie Teufel, Bernd Teufel	Crowd Energy information security culture - security guidelines for smart environments.	UNIFR iimt

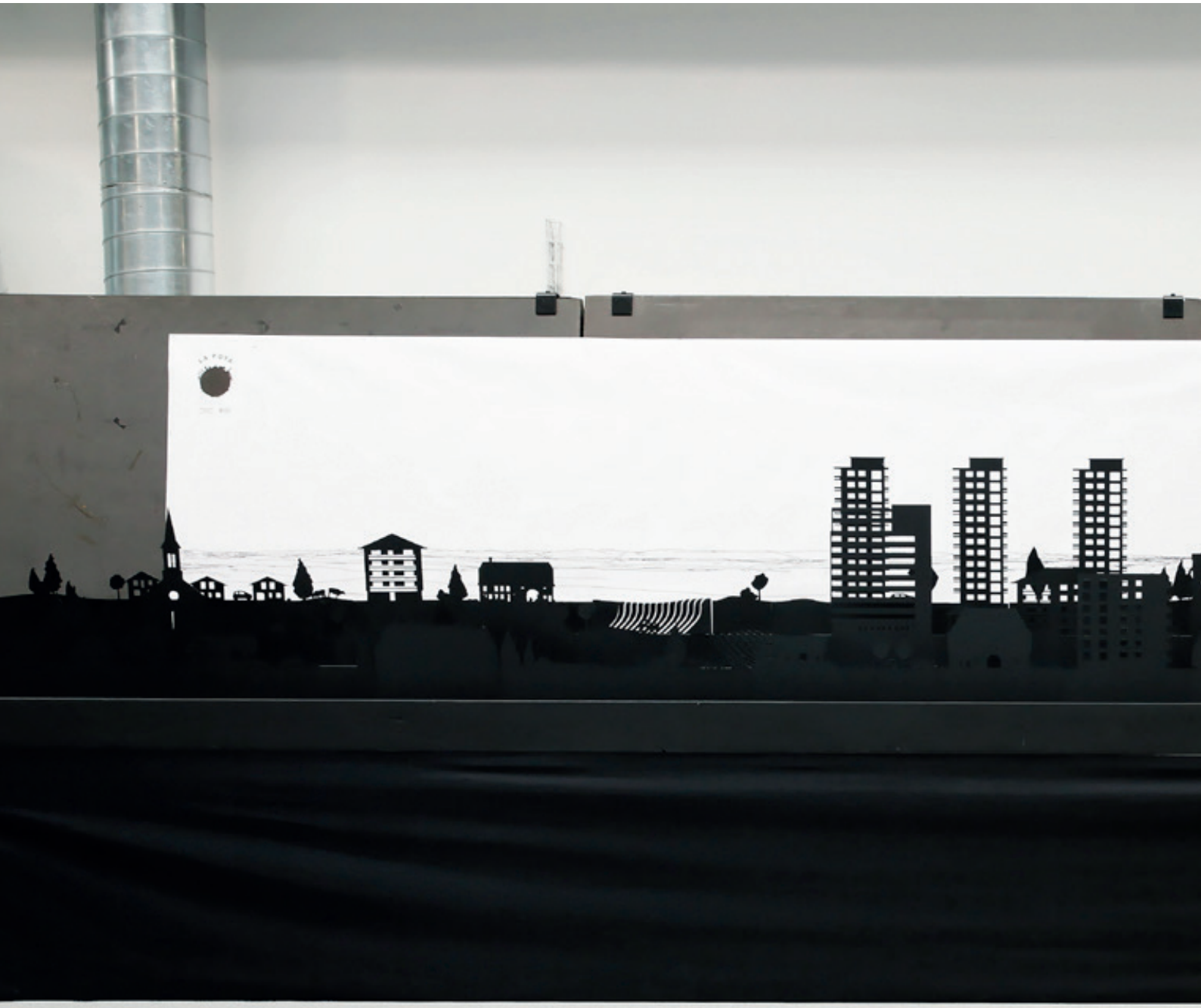
CIMI	Daia Zwicky, Elena-Lavinia Niederhäuser, Hans Büri	Use of an integrated design approach to hybrid construction elements, using a multi-objective assessment methodology.	HEIA-FR iTEC HEIA-FR ENERGY HEIA-FR TRANSFORM
Climate Change Issues 2050	Thomas Jusselme	Definition of the comfort requirement of the external context and the 2050 targets. Proposed solutions for the smart living building	EPFL Building 2050
CO2 expert tool experiment	Stefano Cozza, Thomas Jusselme	Creation of a CO2 expert tool prototype to better understand the design space and to demonstrate the potential of design efficiency by simplifying the inclusion of performance criteria in the design process.	EPFL Building 2050 EPFL ECAL Lab UNIFR Human-IST
Comfort Box	Hamed Alavi, Denis Lalanne	An interactive device that through making a dialogue with its users learn their preferences in terms of four dimensions of comfort: thermal, visual, acoustic, respiratory.	UNIFR Human-IST
Crowd Energy	Stephanie Teufel, Bernd Teufel	Identification of socio-economic motivation and regulatory measures as well as specific and sustainable funding policies supporting the crowd energy concept and with it the energy turnaround.	UNIFR iimt
CUSO: People, Spaces and Technologies	Hamed Alavi, Denis Lalanne	A seminar organized with internationally recognized lecturers in the field of human interactive experience in built environments.	UNIFR Human-IST
DevEco	Florinel Radu	The need to formulate proactive land policies to improve Fribourg's economic appeal is undermined by the lack of concrete tools for its facilitation. The "Urban development : key condition for economic development » project aims to overcome this shortcoming by establishing a framework for urban development that will galvanize the economic growth in and around Fribourg	HEIA-FR TRANSFORM
Digital fabrication technologies: Analyzing patterns of adoption and innovative transformations in architectural design and practice	Paolo Tombesi, Bharat Dave	A comparative study between three buildings built using digital fabrication techniques on the relevance of the techniques used and on the achievement of the objectives.	EPFL FAR

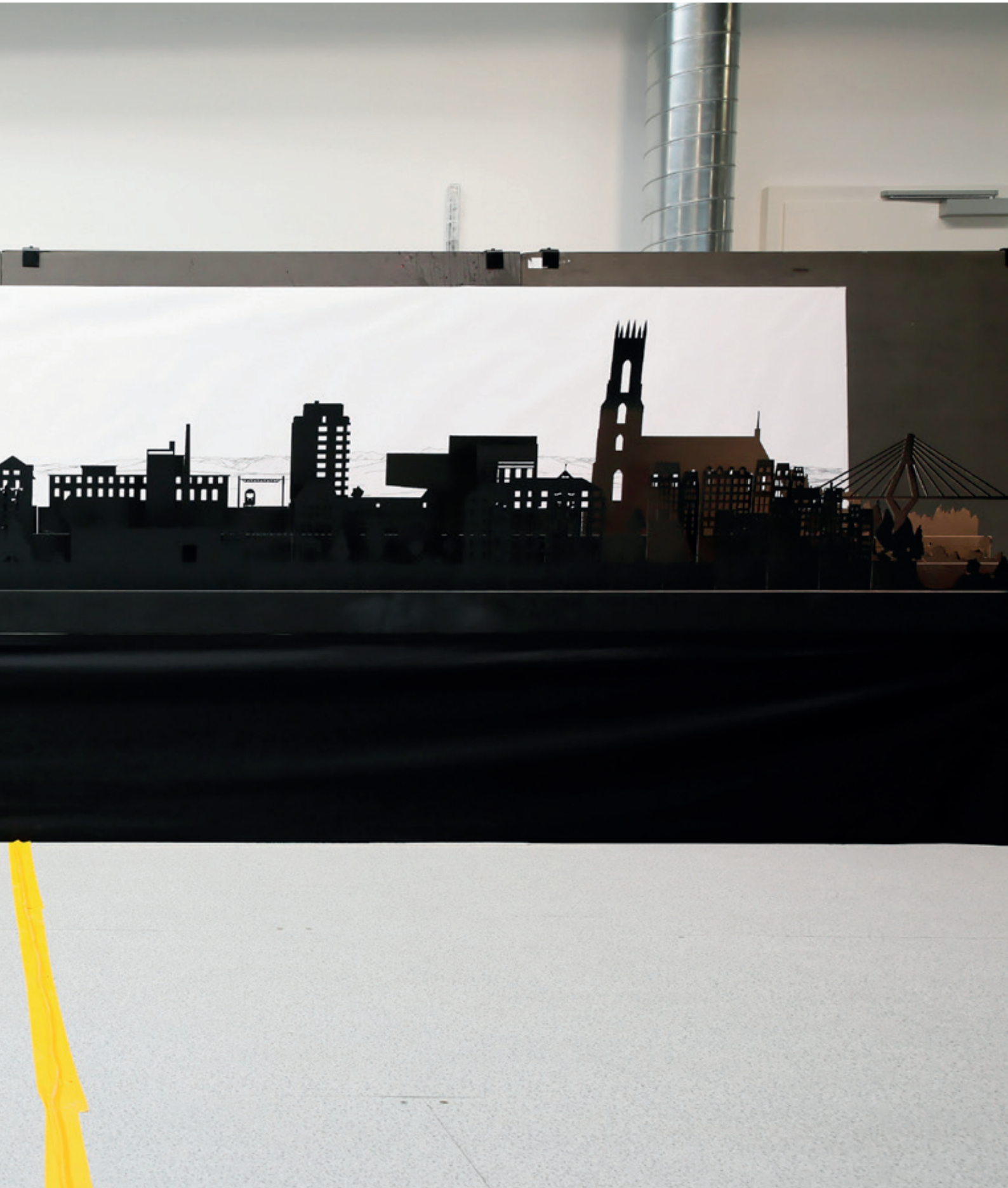
Disputes in Construction Law	Arnold Rusch	Finding ways to prevent and solve disputes in construction law	UNIFR Institute for Swiss and international construction law
EET-CEA	Stephanie Teufel	JEST special section on energy efficient technologies – Crowd Energy applications.	UNIFR iimt University of Electronic Science and Technology of China
Environmental performances	Endrit Hoxha, Thomas Jusselme	Path to the 2000W society. Definition of the Life Cycle Assessment (LCA) methodology. Definition of an ideal project.	EPFL Building 2050
eREN	Stefanie Schwab	The eREN project led the developments on the building envelope based on a global and interdisciplinary approach seeking the optimal balance between energy efficiency, construction related aspects, building physics, cost-effectiveness, co-benefits and co-losses, and heritage value.	HEIA-FR TRANSFORM Hepia Genève HEIG-Vaud HES Valais
eREN2	Stefanie Schwab	This project is the continuation of the eREN research project. It is based on models and renovation scenarios of apartment buildings that are common in the Swiss-French part of the country that highlight the potential, but also the challenges, of the energetic renovation of the building envelope based on a building's characteristics.	HEIA-FR TRANSFORM HEIA-FR iTEC Hepia Genève
Façade experimentation	Arianna Brambilla	Definition of an optimum low-carbon façade in relation to users' perception of comfort according to different design choices.	EPFL SXL EPFL Building 2050 EPFL LIPID Lab EPFL LAST Lab
Future of Human-Building Interaction Workshop	Hamed Alavi, Julien Nembrini, Denis Lalanne	A workshop that invited experts from fields of architecture, HCI, and psychology to discuss the vision of future living.	UNIFR Human-IST Google US New Castle University
IER-BAT	Philippe Couty, Stefanie Schwab	Study of the integration of active solar components (thermal and photovoltaics) in a portfolio of existing buildings previously studied from an energy efficiency perspective	HEIA-FR ENERGY HEIA-FR TRANSFORM

Indoor Localization	Himanshu Verma, Nico Faerber, Denis Lalanne	Master thesis of Nico Faerber aimed at increasing the accuracy of indoor localization using Bluetooth Beacon technology.	UNIFR Human-IST UNIBE Sinus AG
INNOfit	Dominic Feichtner, Amber Singh, Stephanie Teufel	Study to evaluate the innovative fitness of Swiss power companies	UNIFR iimt
Is your building disassemblable?	Valeria Didonna, Corentin Fivet	Survey of chosen construction details according to their ability to be disassembled without destruction.	EPFL SXL
J.C.Maxwell and the Geometry of Structures	Corentin Fivet	Translation in modern terms of James Clerk Maxwell's seminal paper on Reciprocal Diagrams, 1872.	EPFL SXL MIT ETHZ SOM
Jurad-Bat	Joëlle Goyette	Develop a trans-border platform to promote the pooling and sharing of experience and competencies as well as training of professionals in the area of radon risk management, which particularly affects the trans-border region of the Jurassic Arc. The platform will serve as a decision-making tool.	HEIA-FR ENERGY
MODD	Florinel Radu	Creating sustainable neighborhoods often comes up against reduced acceptance of densification by the public. The MODD project seeks to develop a business process as well as tools and methods to design and evaluate such neighborhoods while considering social criteria.	HEIA-FR TRANSFORM
ModSTOCK	Lavinia Niederhäuser	The main objective of this project is to develop a tool to easily design, model, and optimize thermal storage for SMEs.	HEIA-FR ENERGY
PerEn	Florinel Radu	The applied research project PerEN seeks to develop a tool to reduce the observed discrepancy between the calculated energy efficiency of a building during the design phase and the actual energy efficiency measured during its exploitation.	HEIA-FR TRANSFORM
PriSE	Jovita Vasauskaite, Stephanie Teufel	Private households in smart environments.	UNIFR iimt

R-Sur	Joelle Goyette	The Air-SÙR project aims to demonstrate the feasibility and the value of a remote and continuous monitoring of the air-quality in a building that houses young children with the aim of ensuring a healthy indoor environment and optimal conditions for the health of its occupants.	HEIA-FR TRANSFORM
SCSC	Bettina Irnhauser, Stephanie Teufel, Bernd Teufel	Societal Cyber Security Culture.	UNIFR iimt
Smart Mobility Mapping	Jean-Frédéric Wagen, Werner Halter	Mobility has a major impact on the lifecycle assessment of a building according to the 2000W society standard. This project aims to develop a tool that enables to easily map the mobility of the occupants of a building and provide them with information and advice.	HEIA-FR MobySysCG, Swiss Climate SA
SmartWall	Jacques Robadey, Elena-Lavinia Niederhäuser	Exploring solutions to integrate phase-change materials (PCM) into an active (dynamic) climate control strategy	HEIA-FR ENERGY
Streiterledigung im Bauwesen	Martin Beyeler	Analysis of existing methods to deal with disputes and conflicts in the construction sector.	UNIFR Institute for Swiss and international construction law
Structural Form-Finding from Reused Elements	Jan Brütting, Corentin Fivet	Definition of algorithms for the topological optimization of structural systems made of prescribed elements.	EPFL SXL
SVEN	Mario Gstrein, Stephanie Teufel	Smart Value Energy Networks.	UNIFR iimt
THE4BEES	Jean-Philippe Bacher	THE4BEES focuses on the behavioural changes of users in public buildings needed to achieve reduction of energy consumption. Such changes will be originated by the use of innovative ICT applications developed by a transnational ecosystem. Those applications will be used by the target groups in the demonstration sites (schools, houses, factories) to encourage behavioural changes for energy efficiency and carbon footprint reduction.	HEIA-FR ENERGY 13 partners from IT, FR, DE, AU, SL
Tiny House Movement	Arnold Rusch	The reduction of the ecological footprint: Legal challenges of tiny houses and the mobility of single person households.	UNIFR Institute for Swiss and international construction law

TransHabNat	Florinel Radu	This project has shown that urban biodiversity goes hand-in-hand with the diversity of human habitats. It led to the development of an innovative tool to aid the design of projects that combine densification in peripheral urban zones with the improvement of the biodiversity. The tool contains a typology of forms of human-nature cohabitation, as well as a presentation of the interdisciplinary design process.	HEIA-FR TRANSFORM Hepia Genève
User environment experiment	Cédric Liardet, Thomas Jusselme	Definition of a strategy for the user environment based on user behavior as well as on the identification of indoor components/furniture according to their performances and impact on the comfort. Prototyping and experimental campaign research in the Blue Hall regarding the user's feedback.	EPFL Building 2050 UNIFR Human-IST EPFL LASUR Atelier OI
User Experience Study I	Himanshu Verma, Hamed Alavi, Denis Lalanne	Designing and conducting a user study to understand occupants' mobility and space usage behavior.	UNIFR Human-IST EPFL Building 2050 Atelier Oï EPFL LaSUR
User Experience Study II	Himanshu Verma, Hamed Alavi, Denis Lalanne	Defining policies for the re-design of office spaces within the Halle bleue based on the Human-Centered Design paradigm.	UNIFR Human-IST EPFL Building 2050 Atelier Oï EPFL LaSUR
Visualizing the user in the building data	Roberto Sanchez, Julien Nembrini, Denis Lalanne	Using real building management system data, the aim of this master project is to infer the presence and behaviour of users through visual analytics techniques.	UNIFR Human-IST
Zero Waste Elastic Gridshell	Sofia Colabella, Corentin Fivet	Design and Construction of an elastic gridshell from reclaimed material.	EPFL SXL





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