smart living lab

Research program HEIA-FR

Hes·so

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

Content

“ A competence center that closely follows the evolution of needs and markets. ”

Editorial

Jean-Philippe Bacher
Professor – Smart Living Lab HEIA-FR Manager

Through its integration in the Smart Living Lab, the School of Engineering and Architecture of Fribourg (HEIA-FR) is reinforcing its role as a competence center in the fields of energy, construction, architecture and environment.

After an initial phase dedicated to setting up its research activities, the competence center has entered a new phase focused on growth. The HEIA-FR's research program at the Smart Living Lab has supported a series of innovative projects, which in turn have enabled a diverse group of researchers to consolidate and refine their expertise. Their competences are the foundation on which effective solutions to challenges such as the climate crisis, the energy transition and carbon neutrality are being developed.

The HEIA-FR is thus strengthening its role as a driver and catalyst for knowledge transfer from fundamental research to the professional sector. By positioning themselves firmly as promoters of innovation, the HEIA-FR and its partners are enabling the development of solutions for private companies, public institutions and society at large.

Whether it's the circular economy, digitalization, carbon footprinting or renovation, researchers are involved in the development of technologies, solutions and processes that accompany the significant paradigm shifts of our time.

This research program allows projects to reach a level of maturity that can unlock further financial support from other funds – a crucial step towards the ultimate goal of market adoption. The acquisition of new major research projects and the fulfilment of the Smart Living Lab's plans to build new state-of-the-art facilities are the next chapters in this success story.

Research Institutes

“ Applied research at the service of the economy, society, and education. ”

ENERGY

Institute of Applied Research in Energy Systems

The ENERGY institute is an active contributor to applied research in the domain of energy management and supply at the scale of buildings and neighborhoods. ENERGY focuses on research subjects such as life cycle analysis, carbon footprints, integration of renewable energy, energy storage solutions, monitoring and post-occupation assessment. The institute also studies the influence of occupant behavior on energy performance.

Thanks to its interdisciplinary expertise, the ENERGY institute promotes a more efficient and rational use of low-emission energy sources in the built environment. This is an essential part of the transition towards a more frugal society.

“Buildings and neighborhoods are at the heart of the carbon neutrality goals and the energy transition.”

—

Jean-Philippe Bacher – Head of the ENERGY institute

TRANSFORM

Institute of Architecture: Heritage, Construction, and Users

The TRANSFORM institute contributes to applied research in the domain of architectural and urban transformation. With a staff made up of architects – both academic and practicing – , urban planners, historians, geographers and building physicists, the institute fosters the interdisciplinary expertise needed to imagine and create the sustainable built environment of the future.
It carries out research at various scales, from the way construction elements are assembled to territorial planning. The process of creating the built environment is thus analyzed in its entirety, including the stages of design (using digital BIM tools in particular), construction, usage, cultural value, renovation, and transformation at the end of the life cycle.

"The city of the future is already here.
The challenge is to transform our existing cities
and to adapt the built environment so we can live
together better while protecting natural resources."
—
Séréna Vanbutsele – Head of the TRANSFORM institute

iTEC

Institute of Construction and Environmental Technologies

The iTEC institute carries out research on various aspects of building technology at every scale, from the territorial level (networks, infrastructure, natural hazards) down to construction materials and elements (buildings).

Composed of experts in civil engineering (construction and mobility) and environmental science (soils and water), iTEC's research staff specializes in design, modeling (physical and digital), and experimental verification on both small and large scales. The solutions developed at iTEC do not only reduce the impact of construction on the environment but also have net positive effects on the local, urban and regional climate.

"The built environment can make crucial contributions
towards net zero carbon emissions and should not
be perceived only as an obstacle to this effort."
—
Daia Zwicky – Head of the iTEC institute

Research Domains

Research activities at the Smart Living Lab focus on four distinct but complementary domains.

Energy systems

Develop energy-efficient systems and technologies, improve their management, and anticipate legal and economic impacts.

Construction technologies

Monitor resource efficiency and accelerate processes of change in construction.

Well-being and behaviors

Improve human health and comfort by optimizing indoor environmental quality and influencing behaviors in a positive way.

Interaction and design processes

Understand and structure the dialogue among stakeholders in the building lifecycle in order to develop tools to design, model and operate buildings.

Interdisciplinary Research

The HEIA-FR's research program allowed for the emergence of collaborative research themes among the different institutes.

The digital transformation of the construction sector

Like other areas of the economy, the construction sector is being strongly impacted by the digital transformation. The emergence and adoption of key technologies such as BIM (Building Information Modeling) and IoT (Internet of Things) is transforming business processes and creating opportunities for new services at the scale of buildings, cities and the territory.

Sustainable neighborhoods

If ambitious sustainability goals are to be achieved, an important part of our focus and effort has to be directed at neighborhoods and their different networks. Research subjects in this area include data management systems, connections between the urban and the social fabric, and the use of energy and natural resources.

Comfort and building performance

Efforts to optimize building performance should always take into account the comfort of occupants in all its aspects. Whether in terms of space, energy consumption, or air quality, ensuring comfortable and convenient interaction is an essential part of improving the built environment.

Transformation and renovation of existing buildings

Existing buildings are a determining factor in the way policies are implemented in the areas of energy and territorial development. Switzerland's ambitious goals in terms of energy efficiency and densification mean that new strategies and guidelines are needed.

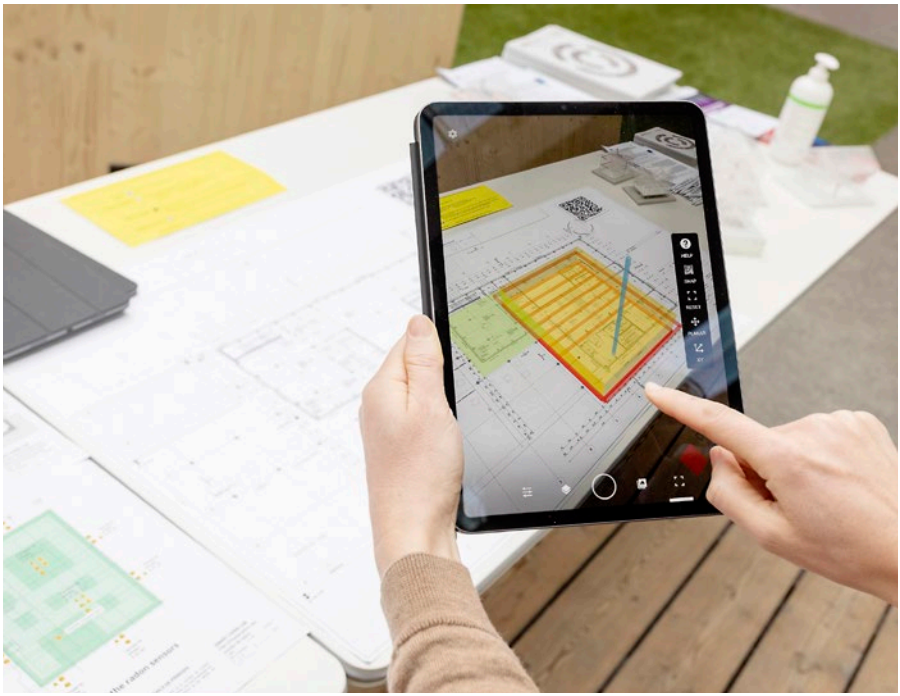
New construction systems

An evolution in construction practices is required for the environmental footprint of the building sector to be reduced. This can be achieved through the development and implementation of new, low-impact construction systems or through methods for the reuse of construction elements.

Impact

The Smart Living Lab is a key component of both the HEIA-FR and the regional innovation ecosystem. Internally, it encourages collaboration among research institutes and enriches the content of educational programs and student projects. Externally, it strengthens the school's role and visibility while creating opportunities for collaboration with institutions and private companies. By forging these connections, the SLL acts as a bridge between fundamental research on one hand and real-world applications in the form of prototypes, products and services on the other.

The role and mission of a University of Applied Sciences involves two ways of promoting research activities. One is through scientific publications and the other through the actual implementation of solutions developed in collaboration with the professional sector. From individual components to urban planning, these solutions operate at different scales. This research also lays the groundwork for more efficient decision making and for the evolution of public policies, particularly at the regional level.



The HEIA-FR's research program at the Smart Living Lab facilitates the launch of new research topics and the development of the competences needed for efficient knowledge transfer to the partners. In this way the research program lays the foundation for future New Regional Policy (NPR) or Innosuisse projects, among others.

The HEIA-FR is pleased to note that its projects are bearing fruit and actively contributing to the Smart Living Lab's role as a competence center with close ties to the evolution and needs of the market.

The Smart Living Lab is developing solutions for some of society's most urgent challenges in the areas of the energy transition and carbon neutrality. More broadly, it has the aim of preserving and enhancing our quality of life in a sustainable way.

" Developing solutions for some of society's most urgent challenges."

A New Building for the Smart Living Lab

Resulting from a partnership between the Canton of Fribourg and the Smart Living Lab, the execution of the project has been entrusted to Bluefactory Fribourg-Freiburg SA (BFF SA). It materialized in 2018 with the launch of an innovative and collaborative Parallel Studies Mandate (MEP). Successive stages of development through an iterative process supported by Building 2050 Group will ensure that the building can serve the needs of its future users.

Opening in 2024 and occupying a surface of around 5'000 m^2, the Smart Living Lab's future facilities will be able to host 130 researchers in 11 research groups variously affiliated to the EPFL, the HEIA-FR and the University of Fribourg. Designed to comply with the long-term goals of the Swiss Confederation's 2050 Energy Strategy, the building will be made of local timber in accordance with an environmentally-friendly construction approach that takes its entire life cycle into account.

> " Designed to comply with the long-term goals of the Swiss Confederation's 2050 Energy Strategy. "

“ The Smart Living Lab’s main resource for experimentation. ”

In addition to being an optimized and comfortable workspace, the new building will become the Smart Living Lab’s main resource for experimentation. Conceived from the start as a multidisciplinary workspace to accelerate innovation, this five-story “living laboratory” will make it possible to perform research under real work conditions.

The building will feature a range of installations to allow for a variety of research activities. An array of sensors will measure parameters related to energy consumption, environmental quality and the use of space.

This permanent monitoring system will feed a common database as well as a BIM (Building Information Modeling) mock-up.

Once built, the Smart Living Lab’s facilities will be kept in a process of constant evolution that will allow them to remain at the cutting-edge of innovation. This will maximize the building’s utility for research and allow its performance to continuously improve, which will in turn guarantee its longevity.

External Perspectives

AETERNUM

The research carried out at the Smart Living Lab lay the groundwork for the creation of our startup. We aim to develop and commercialize buildings that are modular, reusable and adaptable.

—

Alex Muresan
Founder and CEO

JPF

We are delighted to further our collaboration with the HEIA-FR and to build the Smart Living Lab's new facilities, which will become an experimentation and testing platform for their research projects.

—

Jean-Marc Ducret
Director

BFF SA

The presence of the Smart Living Lab is an important component of the attractiveness and positioning of the bluefactory site.

—

Philippe Jemmely
Director general

FEDERAL OFFICE OF PUBLIC HEALTH (OFSP)

The HEIA-FR and the Smart Living Lab have created a leading competence center in the field of indoor air quality. It will enable the advancement of the state of knowledge in this field.

—

Martha Palacios
Acting section manager
Radiological risk
Roger Waeber
Section manager
Habitat pollution

CSD INGÉNIEURS

The HEIA-FR's activities at the Smart Living Lab have a direct impact on our professions and allow us to develop our practices.

—

Fabio Sicurella
Department Head
Building physics

GROUPE E

Our partnership with the HEIA-FR and with the Smart Living Lab in particular is a pillar of our collaboration with Universities of Applied Sciences.

—

Jacques Mauron
General Director

SOTTAS SA

Participating in the HEIA-FR's research allows us to explore new technologies and gives us the potential to enhance our products and systems.

—

Daniel Schaad
Project leader

CITY OF FRIBOURG

By working with the HEIA-FR, we have been able to to raise awareness among the population on the issue of urban heat islands and to test mitigation solutions.

—

Dominique Riedo
Section leader
Ecological transition

W&T AG

With the HEIA-FR as a partner and the support of the Smart Living Lab and Innosuisse, we were able to develop an innovative solution in response to a market need.

—

Marcel Broch
Co-director

Research Topics


ideas
performance
digital mock-up
artificial intelligence
BIM
City Pulse SIM
data
cloud
Digitalization
future
FACILITY 4.0
integrated
PaNBIM
analysis
transformation
technology
sustainable
heritage
habitat
densification
future generations
Renovation 4.0
Renovation
RenoBAT-FR
reflection
transformation
evolution
effective
urban fabric
energy
climate goals
strategy
blueCAD
transformation
planning
resources
DEMO-Mi²
local•energy
sustainability
BlueEnergy
Setup Pro
waste
natural resources
reuse
consumption
recycling
carbon footprint
neighborhood
mobility

Carbon footprint of the construction sector

Thomas Jusselme
Professor
ENERGY Institute

Climate change is one of our society's major concerns. It is essential that we work to measure and reduce the carbon footprint of constructions, which account for 38% of global CO_2 emissions.

Carbon neutrality by 2050: dream or reality?
I would actually say that it is our obligation if we are to avoid the dramatic consequences of global temperatures increasing by more than 2° C. Almost half of the world population is already feeling the effects of this warming trend, which is currently estimated at 1.09 °C. And the fact is that we already possess the technical means to achieve carbon neutrality, which is a lot easier than sending humans into space! The question is knowing how to implement these techniques, and if we are ready to accept the necessary social and economic changes.

What does this mean for the construction industry?
The construction sector is a major contributor to climate change with 38% of global emissions. It therefore represents both a problem and an opportunity. There are a few key solutions whose implementation would result in significant improvements, such as densification, the conservation of structures rather than demolition, and the use of renewable energy or decarbonated materials. On this last point, we know that carbon neutrality will not be attained without first increasing our capacity for sequestration, and the construction industry represents a potentially enormous carbon pool.

How does your research contribute to reaching these objectives?
We focus our research work on the decarbonization of buildings. From cities down to materials, we work at several scales, and our research has an impact on diverse sectors such as the construction industry, energy, mobility, services, etc. We are involved in the development of new eco-designed construction materials, decision-making tools for architects and engineers, and carbon budgeting methods for neighborhoods. We not only publish our results in journals to share them with the international scientific community, we are also involved with local partners to put this knowledge into practice.

Setup Pro

Application of a planning tool concept for the implementation of specific carbon performance objectives at the neighborhood level.

To limit global warming to 1.5 °C, territorial planners should start adopting carbon neutrality goals without delay. This project proposes a method for applying the global carbon neutrality goals at the neighborhood level. In a second phase, the methodology will be adapted to fit the reality of urban planning processes.

In collaboration with the Swiss Federal Institute of Technology in Zürich (ETHZ), we developed a method to determine the carbon budget of neighborhoods committed to a carbon neutral trajectory. This allowed us to define a Swiss-wide climate strategy for a maximum temperature increase of 1.5 °C to 2 °C, and to assess its implications for the construction sector in terms of compatible objectives and building solutions.

Regular workshops were held with representatives from the construction sector's value chain to identify the challenges involved in the implementation of our method. Their operational realities were thoroughly analyzed in order to propose appropriate solutions.

Project duration:
2020–2022

Partners:
OPL, Climate Services, urbaplan, BFF SA, CSD, Nuesch

Adapting to climate change

Marc Vonlanthen
Professor
ENERGY Institute

Climate change poses several challenges to our cities. Our climate pavilion offers simple answers by reinventing the functionality of urban infrastructure.

What are the major consequences of climate change for Switzerland over the next decades?
In Switzerland, temperatures have increased by an average of 2 °C over the last 150 years, which is much faster than the global average of 1 °C. The consequences of this warming trend are numerous and have a significant impact on the health of human beings, biodiversity, natural ecosystems and the economy. In climate terms, it means drier summers, precipitation events that are both less frequent and more intense, more tropical days, and winters with less snow. Cities will be impacted the most. Concentrated human activity generates heat and pollution and therefore degrades environmental conditions, and this is only intensified by climate change. Yet the challenging context should also be seen as an opportunity to rethink urban infrastructure and find efficient solutions. This is what we tried to demonstrate with our climate pavilion.

What can the built environment do to adapt?
The urban environment is a fundamental part of our adaptation to climate change. Successful efforts will have to work on various fronts, such as soil permeability, extension and densification of green spaces (particularly on rooftops and façades), tree planting, choice of materials, water sources, etc. In an earlier study on urban heat islands, we were able to show through digital simulation that a large-scale implementation of these measures at the neighborhood scale by 2050 would almost completely offset the rise in temperatures due to climate change. Effective solutions really do exist.

What are the main factors behind urban heat islands?
The main factor is the process of urbanization, particularly the choices made in terms of materials, design and planning. The process usually results in a set of conditions that trap sunlight in the built environment. For example, asphalt captures heat during the day and releases it at night, leading to tropical nights, whereas trees provide shade and cool the air through the natural process of evapotranspiration. Heat emissions caused by human activity (mobility, industry, cooling systems) also play a role.

DEMO-Mi^2

Design, development and testing of a mobile pavilion that showcases summer microclimate mitigation techniques at street scale.

The DEMO-Mi^2 pavilion demonstrates the potential of urban infrastructure to spearhead the adaptation to climate change. The pavilion employs a variety of simple yet effective heat mitigation techniques, such as green roofs and walls, phase-change materials, water flows, misting systems, optimization of the shade created by the structure, and porous ceramic pots designed to diffuse water vapor.

Considerable effort went into designing a modular construction that would make it possible to exhibit these techniques across the city of Fribourg in locations that are particularly impacted by heat islands. The pavilion provides thermal comfort and creates favorable conditions for social gatherings yet remains a mobile system.

The DEMO-Mi^2 pavilion was funded by various local companies, sponsors, the City of Fribourg and the Canton of Fribourg, which led to a close and fruitful collaboration between these entities. Several cultural groups were also involved in choosing the best exhibition locations for the project. The pavilion succeeded in raising public awareness on the issues of heat islands and heat mitigation.

Project duration:
2020–2022

Partners:
City and Canton of Fribourg, TRANSFORM

Energy production and distribution in urban heating networks

Malick Kane
Professor
ENERGY Institute

Designing smarter District Heating and Cooling (DHC) networks and optimizing their design and operation in relation to locally available renewable resources.

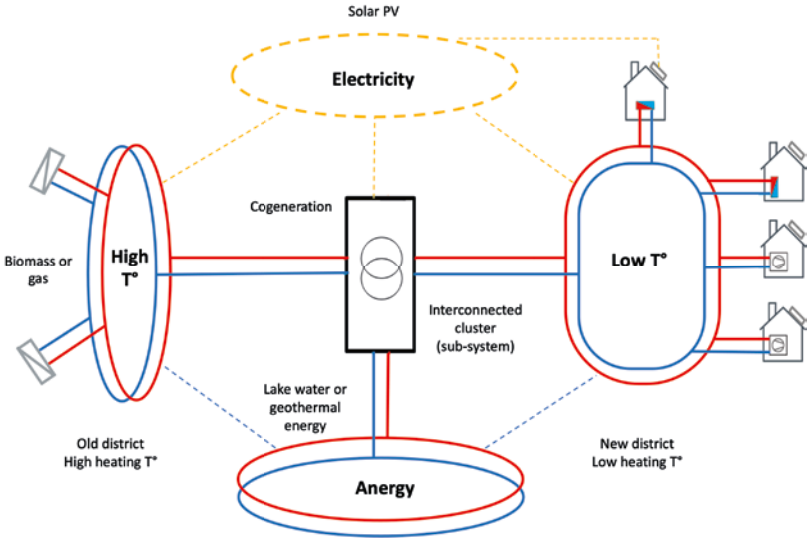
How important are district heating networks for the energy transition in Switzerland?
Urbanization is a major trend. By 2050, two thirds of the population will probably live in urban areas where the demand for energy services will be very dense. There will be many opportunities for synergy between buildings in terms of energy use, and DHC will play an increasing role in meeting this need. The outcome could be reduced pollution levels both locally and globally while maintaining or developing energy services.

What developments can be expected in the field of DHC networks?
A progressive transition from high-temperature networks towards 5th generation anergy or CO^2 smart networks is needed to increase the proportion of renewable energy being used. The technology consists of two-way networks operating at approximately soil temperature that enable heating with local heat pumps and cooling with local cooling units. The increasing demand for electrification makes trigeneration – or combined cooling, heat and power – an important part of our research.

How can your research be used by practitioners?
The Thermal and Energy Lab (LTE) aims to provide companies with the modeling tools needed to simulate, dimension and optimize thermal and electrical networks, allowing them to make the planning and operation of industrial facilities more energy efficient. Practitioners can also develop network designs that maximize the use of renewable energy while keeping production costs as low as possible.

blueCAD

Concept for the integration and optimization of advanced smart heat exchanger networks in the bluefactory innovation district in Fribourg.



The BlueCAD project enabled the creation of a systemic approach to the evaluation and comparative analysis of various types of advanced networks in terms of their energetic, economic and environmental performances. A network's optimal operating temperature can thus be determined as a function of the renewable resources available on site. This methodology offers precious information to network operators both in the design phase and during operation. Its application to the bluefactory site in collaboration with our partners made it possible to develop and propose a new concept for advanced low-temperature urban heating networks. These networks will operate at a temperature level that varies with the seasons.

BlueCAD enables the use of smart regulation units to integrate and maximize electrical self-consumption, pool needs and available resources, and facilitate an efficient thermal energy transfer between networks operating at different temperature levels.

Project duration:
2018–2021

Partners:
Groupe E Celsius, BFF SA, Energy Service of the Canton of Fribourg

Building technology

Jacques Robadey
Professor
ENERGY Institute

Phase-change materials (PCMs) offer thermal storage capacity, but their production remains problematic. The IL-PCM project produced new PCMs in a simple, sustainable way.

Why are PCMs valuable to the construction sector?
Phase-change materials are entirely unremarkable except for the fact that they change from solid to liquid state at temperatures close to the level of human comfort. They absorb or dissipate large amounts of heat as they melt or solidify, storing and emitting surplus thermal or solar energy at the desired moment. And they can be used passively by simply adding PCM microcapsules to construction materials such as plaster, wall elements or ceiling panels. Active temperature management systems, on the other hand, require sealed PCM containers that are connected to the heating system.

Is the wider use of PCMs for thermal energy storage achievable in the mid to long term?
The current environmental context and our strong reliance on fossil fuels makes actively managed thermal storage a necessity. These systems currently employ geothermal probes, large water tanks or PCMs. Geothermal probes store heat partially and reduce consumption during winter, yet remain prohibited by law in many parts of Switzerland. Water tanks are not a practical large-scale solution due to a volume that is five times larger than PCMs. The need for PCMs is therefore strong. In the short term, this technology will impact the market for sanitary hot water systems; in fact, a system developed by an Innosuisse project (32485.1 IP-EE) is already on the market. In the midterm, PCM technology will also enter the market for building temperature management systems.

Are there promising new materials in this field?
The problem with PCMs is their price. Production is too low and materials have to be very pure. The main contenders are paraffins and hydrated salts. The problem with paraffins is their flammability, while hydrated salts are corrosive to most metals. Despite these problems, their advantages are sufficient to make them useful in the context of innovative building projects. For a more generalized application, however, their price has to be reduced. If the already-mentioned limitations are overcome through the use of appropriate containers, the large-scale adoption of PCMs could be unlocked.

IL-PCM

Sustainable ionic liquids as phase-change materials for energy storage in smart buildings.

The IL-PCM project is an attempt to produce PCMs that are non-flammable, weakly corrosive to metals, and attractive in price. The main idea behind the project is to use ionic liquids.
Ionic liquids are organic salts made up exclusively of anions and cations and obtained through simple chemical synthesis. Their melting temperature is close to room temperature. A large number of ionic liquid PCMs derived from simple and sustainable materials were prepared and tested, leading to the discovery of a new series of PCMs with very interesting properties.

A demonstration unit for 25 ml of PCM was developed. Melting temperatures of 42 to 46 °C and a heat of fusion greater than 300 j/K were measured. During solidification, however, a subcooling phenomenon appeared that made heat measurements imprecise. Tests showed that the products were neither flammable nor corrosive to aluminum and stainless steel, although they caused light surface oxidation on copper.
Our research collaboration with Dr. Roger Marti of the ChemTech institute will continue with the aim of finding new ionic liquids that are not prone to subcooling.

Project duration:
2019–2021

Partner:
ChemTech

Data science and buildings

Jean Hennebert
Professor
iCoSys Institute

Data Science and the latest trends in Artificial Intelligence are opening interesting perspectives on every stage of the building life cycle, from design to operation.

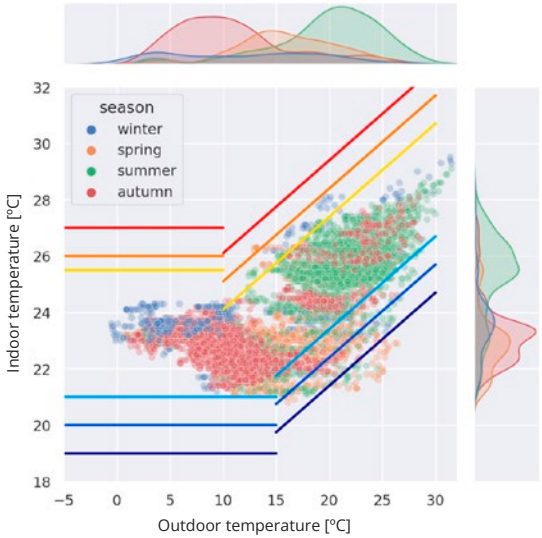
Are Data Science tools mature enough to be used in the world of construction?
Clearly, yes, but with a few qualifications. The amount of data describing our buildings, neighborhoods and cities has literally exploded in the last fifteen years, driven by the increasing digitalization of processes along with the democratization of sensors. In parallel to that, Data Science techniques and tools have matured, especially data-driven approaches such as Machine Learning, which infer models and thus knowledge from collected data. The first areas of application of Data Science with respect to buildings will materialize wherever significant amounts of data are available.

What can they contribute?
The models emerging from Data Science are useful on three levels. The first level is that of diagnostic systems that give insight into the current state of a building. Rapid estimation techniques for structural and energetic performance fall into this category. Secondly, predictive systems make it possible to estimate the future state of a building in relation to external factors. This can be done, for example, to forecast needs in energy supply or ventilation. The analysis of deviations between predictions and observations allows for the detection of anomalies and technical problems. Finally, prescriptive models have the ability to suggest modifications to the configuration of technical equipment.

How do your projects contribute to knowledge transfer?
Using Data Science in building-related projects makes it possible to raise awareness in this important sector of the economy, where the adoption of new technologies is particularly complex. Our projects in this area are systematically carried out in collaboration with specialists from the domain to ensure that a focus on concrete applications is maintained and to make technology transfer more efficient. In return, these projects represent an invaluable learning opportunity for students in our engineering programs, including students specializing in Data Science as part of the Bachelor's in Computer Science and Communication Systems, and Master's students in the MSE-Data Science program. Many student projects actually originate from building-related cases and data sets.

FACILITY 4.0

Building management 4.0: innovative services for performance monitoring and facility management.



The FACILITY 4.0 project enabled the development of innovative monitoring and Facility Management (FM) services based on recent contributions from IT and Data Science, including advancements in the Internet of Things, Big Data and Machine Learning. Guided by a process of co-creation with professional partners such as Groupe E, Estia and Losinger Marazzi, the project focused on concrete applications for diagnostics, preventive maintenance and anomaly detection.

The project had positive results, some of which were published in scientific journals. In addition, three demonstration units were installed and used as a source of real-time field data.

The graph above shows data from one of the demonstration units. The data was used to develop analytical tools for occupant comfort and differences in the energy performance of different living spaces. In this specific case, the distribution of indoor temperatures during the winter revealed a clear potential for optimization of the building is performance.

Project duration:
2019–2021

Partners:
ENERGY, Groupe E, Estia, Losinger Marazzi

Indoor air quality

Joëlle Goyette Pernot
Professor
TRANSFORM Institute

Visualizing the invisible: a sanitary crisis alerts us to the need for fresh air in buildings.

The pandemic proved the importance of indoor air quality. What is your opinion?
The COVID-19 pandemic showed just how important it is to replenish the air in closed and occupied spaces. It made the idea of confinement a concrete reality for everybody. We suddenly became aware that the air – which we need 100% of the time and consume at a rate of around 12'000 liters per day – can be a disease vector, making regular replenishment a requirement for good health. Many schools are now equipping classrooms with CO_2 detectors that serve as indicators of indoor air quality.

What concrete risks is the population exposed to?
Indoor air is subject to various sources of pollution: some are external, others internal, and some even originate naturally, as occurs in the case of radon. Building occupants are actually the main source of indoor air pollution. Their activities and lifestyle can create different kinds of emissions, and the higher the number of sources, the more problematic the mix of pollutants can become. As we spend 80% of our time indoors, we are exposed to these pollutants over long periods of time. Bad indoor air quality can lead to a variety of health problems, ranging from headaches to cancer.

How does your research address these issues?
CroqAIR's research puts occupants at the center of its preoccupations. We seek to understand and raise awareness about the conditions most favorable to human health. The broader context of climate change is also spurring reflections about indoor living conditions, from the issue of thermal comfort during heat waves to the implications of designing ever more frugal and energy-efficient buildings. We believe that measures such as increasing airtightness in order to conserve energy should not be done at the expense of occupant health. Adequate ventilation is an important aspect of the quality of a building. We must not let the perfect become the enemy of the good.

Scol'Air-FR

Improving air quality in Fribourg's elementary schools: opportunities and conditions.

This project has the initial ambition of assessing air quality and occupant comfort in the elementary schools of the canton of Fribourg while facilitating a technical evaluation and presenting working solutions in case of need. The project was made possible by a partnership with the Indoor Air Quality Monitoring Service of Western Switzerland and Ticino (www.ortqai.ch).

24 representative schools comprising a variety of conditions in terms of geography, surrounding environment and building age were selected. Another important criterion for selection was the type of ventilation system; an effort was made to ensure an even distribution in this respect. In each of the selected buildings, measurements will be carried out at regular intervals in two classrooms as well as an outdoor point. The measured parameters are CO_2, fine particles, volatile organic compounds, radon, temperature and relative humidity.

The first set of results was positive and evidenced an increased awareness of the importance of ventilation as a result of the sanitary measures related to the pandemic. A study of this evolution in behavior has been integrated into the project and a new round of measurements is planned for 2023.

Project duration:
2021–2022

Partners:
ORTQAI, QUALIVENTIL, EPFL HOBEL, SUPSI, MINERGIE, OFSP, Energy Service of the Canton of Fribourg

Renovation

Stefanie Schwab
Professor
TRANSFORM Institute

A global approach for a sustainable energetic renovation of existing buildings.

In view of Switzerland's climate change goals, what is the importance of building renovation?
The building sector is responsible for more than 45% of Switzerland's final energy consumption and almost a third of its CO_2 emissions. The energetic renovation of existing buildings is a major component of the Swiss Confederation's energy strategy. In the short term, the aim is to reduce final energy consumption by 60% in relation to 2010 and to upgrade or decommission all fossil fuel and direct current based heating systems.

What opportunities does the renovation of existing buildings represent, in your opinion?
Despite considerable political effort in this area, energy consumption in Switzerland's buildings remains well above target, and isolated renovation projects – rather than a global approach – are still the norm. Such projects are usually limited to upgrading technical installations, adding external insulation and replacing windows. Though helpful in terms of energy efficiency, the overall efficacy of these solutions is often debatable if other criteria such as construction, the cultural heritage, building physics and sustainability are factored in. Renovation work is often executed without planning, its complexity is underestimated and the need for global studies is neglected.

What can research contribute in this domain?
The TRANSFORM institute studies the challenges posed by global energy renovation. How can the number of renovation projects be allowed to increase while at the same time guaranteeing the quality and sustainability of the work? What types of construction methods exist for different buildings, and how can the best-suited renovation scenario be determined? What methodological approach provides an answer to these questions?
The ProREN project focuses on identifying the challenges and obstacles to energetic renovation at the cantonal level. Results show that what is most needed is a renovation counseling or coaching service for building owners, the availability of concrete tools such as guidelines and roadmaps, and the implementation of interdisciplinary strategies among the cantonal offices involved in the process.

RenoBAT-FR

Tools for a global renovation of Fribourg's buildings.

The project RenoBAT-FR aims to establish a typology of residential buildings for the City of Fribourg and to define a set of thermal, energetic and structural performance indicators to describe these buildings in their current state. It also aims to create and disseminate a roadmap for sustainable energetic renovation.
The typology of residential buildings is a tool that will allow professionals to analyze buildings according to the period of their construction, enabling a neighborhood-scale approach to renovation.

A roadmap for the sustainable energetic renovation of both individual houses and residential buildings will offer guidance on how to optimize renovation projects, covering aspects such as the building envelope, technical installations, integrating renewable energy sources, and environmental impact reduction.

Architectural specificities and the obsolescence of building elements will also be considered. A collaboration with Fribourg's Housing and Building Monitoring Center will make it possible to analyze these factors in combination with other relevant data such as vacancy rates and average rent.
The tools developed in collaboration with the CCRB will thus provide both a foundation for professionals and crucial assistance to owners interested in renovation (renovation coaching).

Project duration:
2021–2022

Partners:
iTEC, ENERGY, CCRB, Housing and Building Monitoring Center of the Canton of Fribourg

Urbanism

Florinel Radu
Professor
TRANSFORM Institute

Switzerland is becoming urbanized! Sustainability, densification, quality of life and digitalization are being integrated into the design of our future habitat.

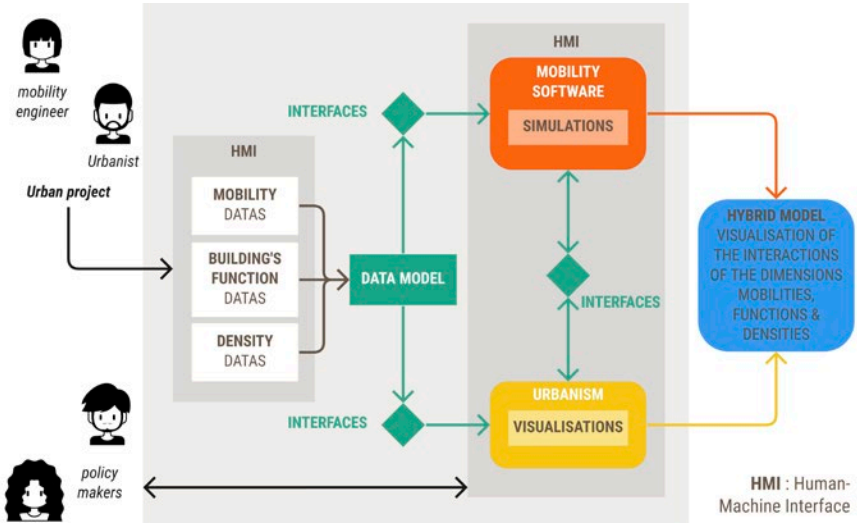
What are the major trends in the field of urban planning?
Urbanism currently faces major challenges in relation to sustainability and climate change. These will force us to modify how we live, but change cannot be limited to the urban environment. Urban planners and other involved parties have to offer a comprehensive vision of neighborhoods and infrastructure that favors soft mobility, conservation of biodiversity, diversity in social and functional terms, and a significant reduction in resource consumption. To achieve this, a whole set of practices must be adapted, and collaborative methods involving all stakeholders must be set up.

Is densification compatible with a high quality of life?
Swiss cities have been undergoing intense densification since the approval of the Federal Act on Spatial Planning in 2014. This has raised concerns among the population about the risk of seeing their quality of life deteriorate. At the same time, a growing number of new neighborhoods is showing that densification need not happen at the expense of living comfort. We should keep in mind that densification is not only about adding residents; it is also about increasing the proximity and availability of services such as public transport and meeting places. The key to high-quality densification is to consider the diversity of residential preferences and to enable the appropriation of indoor and especially outdoor spaces.

How has the pandemic affected your domain?
Quarantining and working from home during the pandemic taught us that the concept of a living space should not be limited to the apartment. Quality spaces both inside the residential building and in the neighborhood are also needed. Two examples will illustrate how this can be addressed: offering residents the possibility of sharing an office or workshop in small groups, and giving access to outdoor natural spaces. For my field, it means that urban planning and architectural design have to be coordinated. Furthermore, the digitalization of society must result in better management of cities (i.e. smart cities).

City Pulse SIM

A simulation tool for urban interaction: building function, density and mobility.



The aim of City Pulse SIM is to make a significant contribution to the digitalization of urbanism projects. Made possible by a collaboration among the TRANSFORM, iSIS (Sandy Ingram) and iTEC (Marc-Antoine Fénart) institutes, City Pulse SIM will allow urban planners to gain new insight into their projects and thus facilitate decision making. This is achieved by using on-screen visualizations of the different types of mobility flows engendered by a neighborhood to offer new ways of representing urbanism projects.

The tool will enable the real-time modification of key parameters such as density and building function in order to estimate the impact on mobility. To obtain this result, it was first necessary to develop a common language and way of working across three disciplines. This was no easy task!

The City of Fribourg supported the project by providing data and ensuring the compatibility of City Pulse SIM with the current management tool.
The city and larger metropolitan area will be able to make use of City Pulse SIM during planning for the tentative "Fribourg – Smart City" project and to manage their territorial development.

Project duration:
2020–2022

Partners:
iSIS, iTEC,
City of Fribourg

Digitalization processes for the construction sector

Redouane Boumaref
Professor
TRANSFORM Institute

Digitalization is changing the construction sector. Should it be seen as a new set of tools, or as a methodological revolution? Does it carry too many risks, or does it effectively optimize business resources? The reality probably lies somewhere at the intersection of these reflections.

Has BIM (Building Information Modeling) been widely adopted in Switzerland?
The digitalization of the construction sector keeps on moving forward in Switzerland. The approval in 2020 of the Digital Switzerland Strategy was a strong message in favor of a generalized adoption of efficient digital methods. The strategy defines a direction and provides the means to make it happen. That is why, despite some concerns – often caused by lack of information – , more project commissions than ever are requiring the inclusion of BIM methods. In response, a growing number of project managers are inquiring about BIM and signing up for training on the subject.

What are currently the main opportunities in this area?
Raising awareness among stakeholders is probably the most decisive factor for a wider implementation of BIM, and it requires the use of efficient strategies for communication, evaluation and action. Umbrella organizations often play a central role in organizing profession-specific communication, but they first need to assess the current state of skills and knowledge with regard to BIM. Whether this is done though self-evaluation or with the help of an auditor, it is essential that they have access to credible and precise context measurement tools. Another important step is to set up training programs to reduce the gap between observed and targeted levels of expertise.

Do you collaborate with regional partners?
Whether it is the Smart Living Lab, the Building Innovation Cluster, the Canton of Fribourg (through its New Regional Policy) or the Council for Architecture, Urbanism and the Environment of Haute-Savoie in France, we maintain close ties with our partners. Our goal is to work together on research projects focused on digitalization in the domains of architecture, construction and engineering. Private partners are also involved in these projects through their expertise and financing.

PaNBIM

Treating BIM data as digital heritage.

The adoption of BIM in the construction sector creates a set of interrelated problems. Ensuring the durability and accessibility of data is a problem faced by every discipline that generates and manages significant volumes of information. The aim of this study is to define the conditions guaranteeing the usability and accessibility of data flows over a time frame corresponding to the life cycle of the building.

Project duration:
2019–2021

Partner:
H-FR

BIM-UP

State of maturity of BIM and support measures for the digital transition.

BIM-UP is a collaborative project with the twofold objective of assessing the state of maturity of BIM in the canton and of establishing adequate targets for Fribourg-based construction companies. The results of a large survey of companies will be analyzed in order to create a support toolkit containing recommended measures and monitoring tools. The toolkit will reduce the gap between the observed level of BIM expertise and the targeted level, which is what companies need to be able to execute and manage construction projects according to the BIM method.

Project duration:
2020–2022

Partners:
Fribourg School of Management (HEG), New Regional Policy of the Canton of Fribourg, Building Innovation Cluster (BIC), Entrepreneurial Association of Fribourg (FFE), Employers' Association of the Canton of Fribourg (UPCF), Building 2050 (EPFL support group), Antiglio, Abvent, BFF SA, Element AG, Grisoni Zaugg, Groupe e, Objectif BIM, SINEF

Structures and renovation

Mylène Devaux
Professor
iTEC Institute

Switzerland numbered 1.77 million residential buildings at the end of 2020 (source: FSO). To comply with current norms and the goals set by the 2050 Energy Strategy, a large majority of these buildings will have to be renovated.

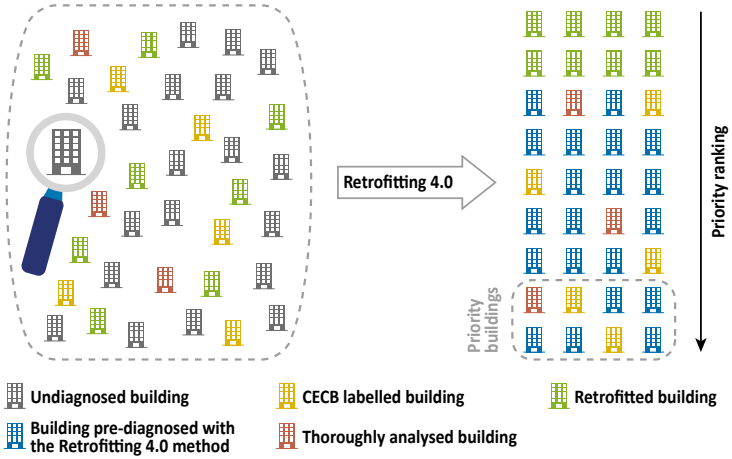
What part of the impact on the environment is rough in construction responsible for?
Today, raising a building clearly has a negative impact on the environment. How big of an impact depends on the ecological footprint of the materials used, which depends on the properties of the raw materials, the conditions of their extraction, the energy consumed during processing and production, the use of polluting substances, etc. And it is also important to remember that the construction phase is not the whole story. The demolition of a building also has a significant environmental impact, especially if materials are not recycled.

What are the most promising avenues to reduce this impact?
Whether in a new project or a renovation, considering the complete life cycle of the building can significantly lower its ecological impact. Rough in construction undoubtedly weighs heavily on the environmental footprint, but the impact of the interior work, the fittings and the overall implementation should not be underestimated. Since additional rough in construction decreases a building's environmental rating, the more sustainable solution is usually to renovate and, if necessary, to raise the building by adding floors.

What does your research explore?
In the case of existing buildings, conservation and renovation are often a more sustainable option than demolition. Nevertheless, existing buildings face a number of compliance problems with regard to current norms. Since upgrading buildings on a wide scale is a necessity, it makes sense to study these challenges comprehensively and to determine a global strategy instead of a series of isolated and partial actions. Performing a global analysis is complex, however, as it involves several disciplines. Fortunately, the skills needed to carry out this task can be found under one roof at the Smart Living Lab, where ambitious research projects with a global approach are currently under way with excellent results.

Assainissement 4.0

Rapid analysis of building complexes using expert systems and AI to estimate their current energetic and structural performance, define appropriate renovation strategies, and reduce their carbon footprint.



Led by the Swiss Federal Council's 2050 Energy Strategy and spurred by recent developments in energy supply conditions, efforts to renovate buildings at a wide scale will intensify in the coming decades. Knowing that, in Switzerland alone, around one million residential buildings were built prior to 1980, and that only a small minority of these structures has been renovated (totally or partially), it is not financially realistic to start analyzing buildings one by one.

In this context, the Assainissement 4.0 project aims to develop a machine learning-based tool to rapidly estimate energetic and structural building performance. The tool will significantly speed up the process and lower the cost of producing strategic intervention plans for towns and buildings using the available digital data. The final objective is to establish a classification system for buildings based on their potential for improvement in terms of both energetic and structural performance.

Project duration:
2020–2022

Partners:
ENERGY, TRANSFORM

Structures and circular economy

Dario Redaelli
Professor
iTEC Institute

Modular and reusable load-bearing systems that will reduce the environmental impact of the construction sector.

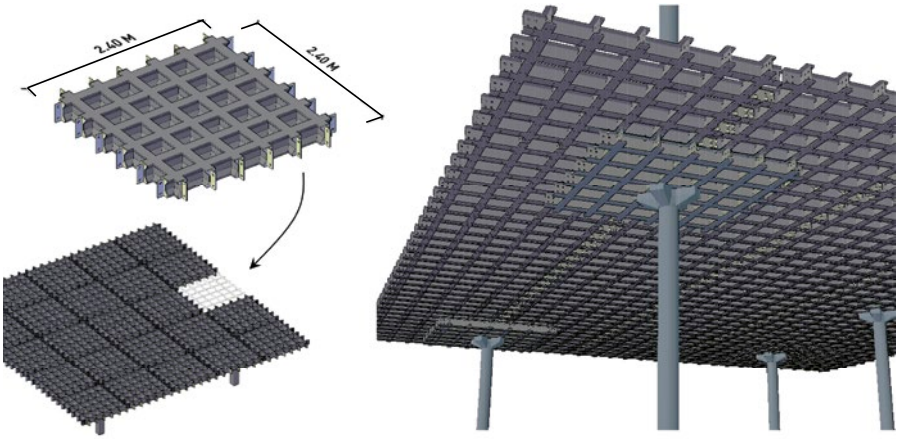
Circular economy: a real opportunity or just wishful thinking?
If we are serious about reducing the construction sector's environmental impact, the adoption of circular economy strategies in structural engineering should be seen as an absolute necessity. Currently, the most common circular strategy consists in using recycled materials to build new structures. A more efficient approach would be to avoid new structures altogether and to focus on lengthening the life cycle of existing structures or employing reusable load-bearing structures. This last option is still underutilized and represents a real opportunity from the economic and environmental point of view.

How can this practice be developed?
Let us consider the case of reusable load-bearing structures. First, new solutions have to be designed and developed allowing for removable and transportable elements in compliance with safety norms and performance requirements for load-bearing structures. Second, these solutions have to remain attractive from the environmental and financial point of view. Third, engineers require guidelines, norms and already-built projects to use as examples. Finally, we need the support of project managers who take environmental challenges seriously and are prepared to implement innovative solutions in pilot projects.

How might this affect the job of a structural engineer?
Working with reusable load-bearing elements requires an adaptation of current methods. Rather than being asked to dimension unique structures in response to a design brief, structural engineers will now have to approach construction as an assembly process using pre-existing pieces with given geometries and properties. Not unlike a construction game! This will create new challenges and opportunities, such as, for example, having to design connectors for load-bearing modules that will not only have to be removable, but also perfectly fitted, very solid and durable. Another example would be defining automated procedures to find optimal spatial arrangements for building elements.

ReuSlab

A modular, reusable and adaptable load-bearing system that balances structural, architectural, ecological and economic demands.



The idea of studying load-bearing systems was launched at the SLL by professor Corentin Fivet (SXL, EPFL). As part of the Build-Unbuild-Repeat project (2017-2019), iTEC and SXL collaborated on an innovative flooring system that was modular, reversible, removable, and extremely versatile. The concept was patented and led to the creation of a start-up named Aeternum Technologies SA.

In 2019, a second research project called ReuSlab was launched to complete the development of the load-bearing system. The larger aim was to industrialize a flooring system that fulfills structural, functional and architectural requirements.

Three versions (wood, steel and UHPC) were studied in detail, and the steel-based version was chosen because of its structural efficiency. In collaboration with Stephan SA, the ReuSlab project was able to define the dimensioning of the system and to demonstrate its technical feasibility. An evaluation of fabrication costs and environmental benefits was also carried out.

Project duration:
2019–2021

Partners:
TRANSFORM, SeSi,
EPFL SXL, Stephan SA

Low-impact materials

Ricardo Serpell
Senior Academic Associate
Institut iTEC

Efficiently transforming material waste is a major challenge for sustainable management of the built environment.

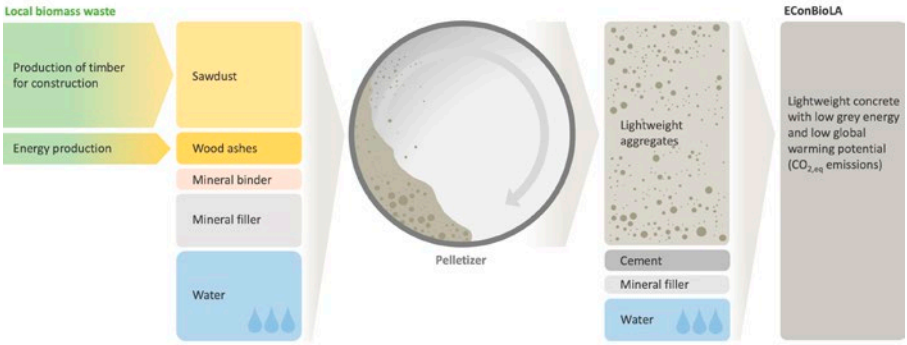
What can be done to reduce the environmental impact of construction materials?
The construction of buildings and infrastructure mobilizes an enormous amount of materials. Their production requires large quantities of primary resources and their final elimination generates an equivalent amount of waste. In a linear economy, the environmental impact of these two processes adds up. By contrast, a circular process based on recycling and reuse has the potential to trim both of these impacts simultaneously. Using waste from other industries as a resource for the production of construction materials has a similar potential.

Is there room for innovation in this space?
Without a doubt. Construction and demolition waste are by far the biggest waste flow in the world. In Switzerland, it represents more than 20% of all generated waste. In a circular economy context, the practice of selective deconstruction to prepare materials for reuse and recycling would be required by law. However, although separation technology is well-established, recycling specific types of waste remains a challenge. In the case of mineral waste (concrete, brick, ceramics, etc.), major technological challenges still prevent their efficient reuse as materials of a value similar to that of materials made from raw resources for the first time.

What research are you carrying out in this field?
My research focuses on the development of new composite materials based on waste from the construction sector and other industries as well. An exhaustive study of the properties and microstructure of raw materials and their assemblies, combined with an experimental analysis of their effects on the properties of construction materials, has allowed us to optimize the performance of these new materials, not only with regard to the demands of the industry, but also in terms of their environmental impact.

ECon-BioLA

Eco-friendly concrete based on low-energy, lightweight synthetic aggregates sourced from biomass waste.



The project aims to contribute to lowering the carbon footprint of lightweight wood buildings. The reduction results from a multidimensional optimization of the poured concrete materials used for structural and physical purposes in these buildings. This was enabled by a holistic evaluation of the impact of the materials on the life cycle performance of the building in realistic application scenarios.

The development of this next-generation concrete requires functional modification and testing of various prototypes of new lightweight aggregates with low-energy consumption. These prototypes were recently developed at the iTEC institute by means of a cold-bonding process applied to local industry by-products. A matrix of compatible binders was also developed in order to obtain the expected improvement to the carbon footprint at the scale of the material, the component and the building, while respecting the performance needs of the targeted application.

Project duration:
2021–2022

Partners:
ENERGY, ChemTech

The water cycle

Michaël Pfister
Professor
iTEC Institute

As a utility and a potential hazard, water plays an important role in urban settings. The evolution of urban areas and climate change are creating new challenges for sustainable management of urban water.

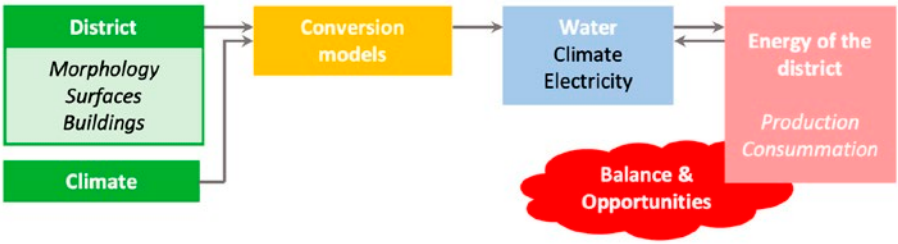
What are the challenges facing water management in the built environment?
Historically, society has chosen to optimize water usage while ignoring the risks. Not surprisingly, despite enabling accessibility to drinking water, water-based waste transport and floodwater evacuation, this approach has proven to be unsustainable as urban water becomes polluted and the hydrological regime is altered. Legal protection of water resources and wastewater purification are relatively recent standards.

How is climate change creating new challenges and opportunities?
Climate change has an impact on the water cycle. Current data and models predict an increase in the number of heavy rain events in particular. If this happens, it will have a two-fold influence on water in the city. First, urban water evacuation systems will face sudden peaks in flow. These flows have to be evacuated safely outside the city or, better yet, be allowed to infiltrate locally. Second, heavy rain events produce powerful surface run-off that does not have enough time to infiltrate. Even if precipitation volumes remain the same, less water is infiltrated, resulting in lower groundwater levels.

How does your research promote the evolution of current practices?
We are assessing the impact of climate change on water cycles in order to design appropriate measures.
In one project, we monitored a water source in an urban setting whose flow levels are known for the last 70 years, during that period of time the catchment area transitioned from rural to urban and the process of climate change began. We created a model to simulate the source's hydrological balance and estimate its future capacity. This allowed us to issue a recommendation on the level of runoff infiltration needed to maintain the targeted water capacity.

BlueEnergy

Assessing the energy and climate potential of local water sources for future habitats.



Among other priorities, urban planning projects have to ensure the wellbeing of residents and integrate the natural environment as much as possible. The water cycle is part of this natural environment.

This study focuses on the thermal potential of water collected and used in neighborhoods, including rainwater, drinking water and waste water. Initially, these water flows were quantified in three Fribourg neighborhoods. Their thermal potential was analyzed and compared to the neighborhoods' heating demand.

A generic model, represented in a simplified way by the illustration above, was created to describe all meaningful links. Next, a set of indicators was defined. In the project's second phase, these indicators will be applied to the model neighborhood being developed at the bluefactory site. They suggest the presence of an untapped potential that will hopefully be integrated into future development plans.

Project duration:
2021–2022

Partners:
ENERGY, TRANSFORM, SINEF

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