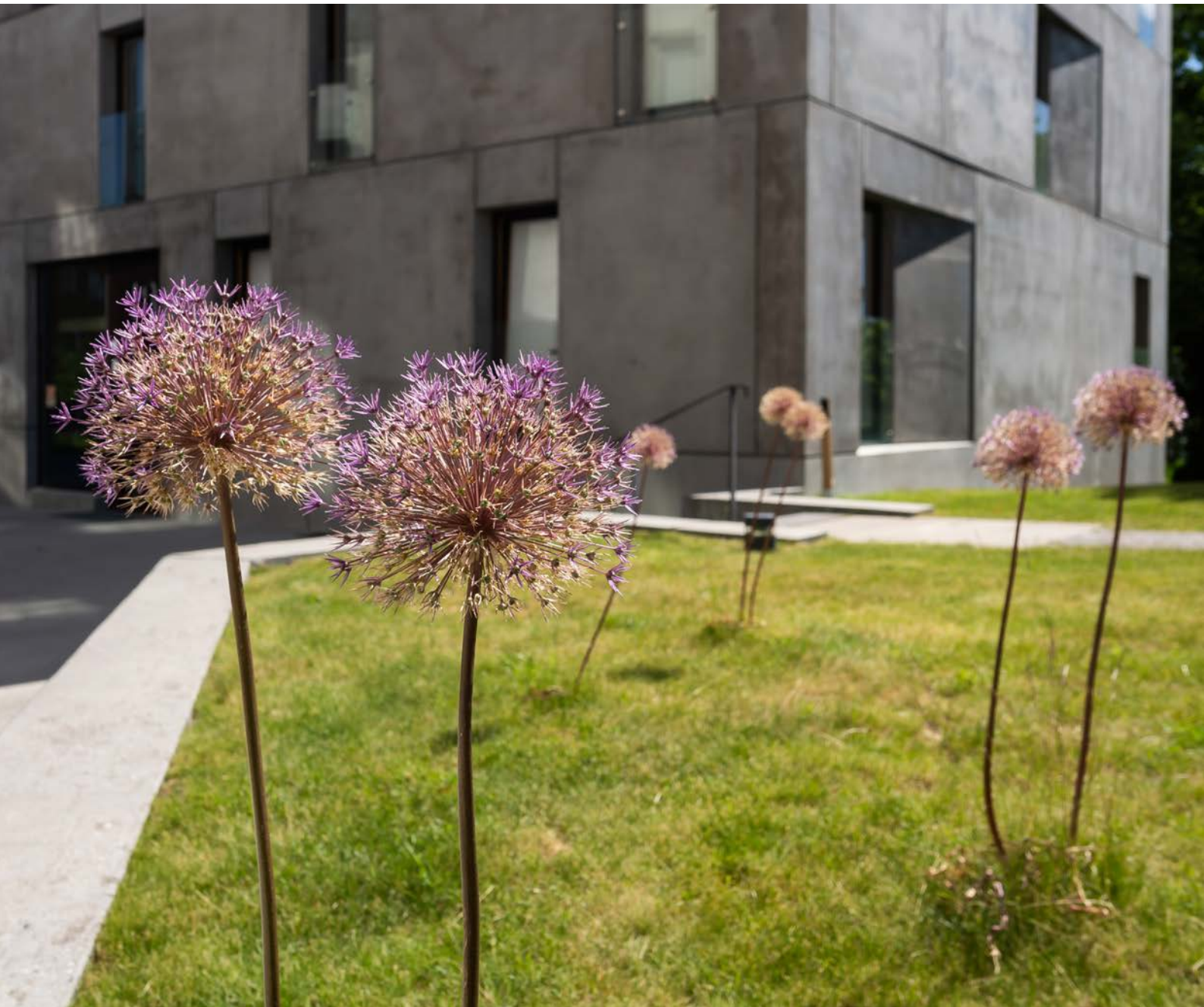
KTH Live-In Lab

Annual Report 2023



KTH Live-In Lab in short

KTH Live-In Lab was initiated in response to the multifaceted and multi-disciplinary issues regarding the construction and use of buildings. It has proven to work as a bridge between different research areas and between academia and industry.

Our work

The three foundations of KTH Live-In Lab are research, education, and collaboration. KTH Live-In Lab offers something as unique as full-scale testbeds with everything from apartments in building-exempt premises to a changeable and scalable infrastructure. KTH Live-In Lab can match customer projects with researchers from relevant interest areas and create individual offers within the framework of each project. KTH Live-In Lab also enables collaboration between different study programs and with the industry, and works as a link between students and companies, which many educational programs lack today.

Our contribution

Over the years, KTH Live-In Lab has facilitated tests and collaboration in real-life environments, with real, working systems, including everything from incoming resources and technical systems to users and organizations. Thanks to KTH Live-In Lab, ideas, theories, and products can be tested in real-life systems resulting in validated research and test results on an unprecedented level.

Our Testbeds

KTH Live-In Lab currently consists of three Testbeds: Testbed KTH, Testbed EM, and Testbed AH. The KTH Live-In Lab Testbeds have a joint database where data can be collected for research or educational purposes.

About us

KTH Live-In Lab is a competence center and a research infrastructure at the School of Industrial Engineering and Management (ITM). The idea behind KTH Live-In Lab came in 2013, and the concept was established during 2016–2017, mainly thanks to a donation from Einar Mattsson-Group. KTH Live-In Lab became a competence center in 2019, with KTH, Einar Mattson, Akademiska Hus, and Schneider Electric. In 2021, Bengt Dahlgren Stockholm joined KTH Live-In Lab as a center partner. We are currently around 15 people actively engaged in running KTH Live-In Lab, and more than 200 people have been involved in different research projects over the years.

Contents

KTH Live-In Lab – Testbeds for Accelerated Innovation

KTH Live-In Lab is an important infrastructure enabling the research required to tackle the multidisciplinary challenges related to buildings, services and climate change. The center acts as a bridge between academia and industry, and is a neutral arena for collaboration between small to medium-sized companies, large established companies and research groups from different research areas.

Our vision, purpose, and goals

KTH Live-In Lab is a platform that handles multiple Testbeds for accelerated innovation and development of sustainable solutions in the built environment. The purpose of KTH Live-In Lab is to reduce the lead times between testing, research results and market introduction. By doing this, KTH Live-In Lab aims to enable the sustainable and resource-effective buildings of the future. The goal of KTH Live-In Lab is to help accelerate the introduction rate of new competitive and sustainable products and services for the construction and real-estate sectors.

Impact and outreach

Visits to KTH Live-In Lab by ministers, royalty and TV celebrities show that what we do here appeals, touches, and leads to sustainable changes in our built environment. Being asked to give an introductory speech at “Forskarfredag” in front of thousands of middle and high school students shows that what KTH Live-In Lab does is not only of academic interest, but it also affects and can influence everything from children and young people to researchers and politicians.

KTH Live-In Lab's structure

Our organization and management

Although KTH Live-In Lab is located within the ITM school, the center currently has a board and management team consisting of people from ITM (School of Industrial Engineering and Management), ABE (School of Architecture and the Built Environment) and EECS (School of Electrical Engineering and Computer Science).

Our management groups

The steering group currently consists of Per Lundqvist, professor KTH ITM, chairman, Karl-Henrik Johansson, professor KTH EECS, Martin Fors, property manager, Einar Mattsson, Richard Petersson, area manager at Akademiska Hus, Erik Bolander, CEO at Bengt Dahlgren Stockholm, and Roger Larsson, sale manager at Schneider Electric. The executive group of KTH Live-In Lab helps carry out the center's activities in accordance with the business plan, partner agreements and the center's rules of procedure. The executive group is also in charge of assessing received applications regarding requests to conduct research or education within the framework of KTH Live-In Lab. The executive group currently consists of Agnieszka Zalejska Johnsson (ABE), Davide Rolando (ITM), Marco Molinari (ITM), Folke Björk (ABE), Tobias Oechtering (EECS), Ute Besenecker (ABE), Cyril Holm (Stockholm University), Linda Teng (Akademiska Hus), Shima Dehvari (Bengt Dahlgren), Micke Dimadis (Einar mattsson) and Valentin Monteiro (Schneider Electric).

Our research fields

During 2023 KTH Live-In Lab as the intermediate link between academic research and industry, classified the lab's projects in its major fields of activity in order to effectively manage, promote and support them. The lab's projects, due to their multidimensional goals, may belong to more than one research field enabling the multifaceted work of the researchers. The projects could be categorized but are not limited to one of the following research fields: infrastructure and innovation, resource management and behavioral change and social responsibility.

Infrastructure and innovation

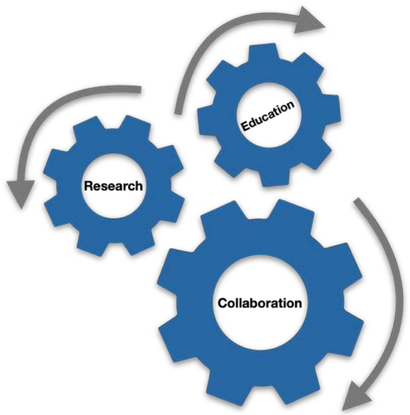
The first major sector of the lab consists of projects which are related to both the physical and digital infrastructure. In more detail, KTH Live-In Lab physical infrastructure are the three Testbeds: Testbed KTH, Testbed EM, and Testbed AH. The joint database, where data can be collected for research or educational purposes, is part of the digital infrastructure of the lab. The projects of this sector aim to upgrade the products and services of the construction and real- estate sectors.

Resource management

The second sector of the lab consists of projects which focus on the sustainable consumption of resources such as water and energy. The projects of this sector are developed on the lab's physical and digital infrastructure, especially on the Testbed KTH utilizing the data of the lab's database. Modern management methods and state-of-the-art technological equipment are exploited in the optimal way with the aim of rational use of precious resources fostering innovation.

Behavioral change and social responsibility

KTH Live-In Lab has innovative projects that have social ramifications and focus on social sustainability by studying human habits and behavioral changes towards sustainability. This interesting sector of the lab puts the users of the infrastructure on the focal point examining their needs and preferences.



New KTH Live-In Lab Director: **Meet Marco Molinari**

He has been part of the KTH Live-In Lab for most of the center's existence, working on conceptualization and education, as well as his own research on smart building controls. Marco Molinari is now taking over after long term Director Jonas Anund Vogel, to continue the development of the center together with the three co-directors.

***Marco Molinari** has a background in mechanical engineering and a Ph.D. in building technology.*

Hi Marco, what have you been doing before becoming Director of KTH Live-In Lab?

I have been Researcher at the KTH Department of Energy Technology since 2017 and I worked on the conceptualization and operation of the KTH Live-In Lab. During my postdoc at the ACCESS Linneaus Center I became part of a multidisciplinary research team on advanced building controls in one of the buildings of the KTH Campus, which, by coincidence, was right in front of where the Live-In Lab Testbed KTH and Testbed EM are right now.

What are you bringing to KTH Live-In Lab as Director?

In my career, I had the opportunity to work in teams with different backgrounds, which allowed me to understand the challenges and the strengths of multidisciplinary research. Many of the societal and sustainability challenges that we face today call for more multidisciplinary research. Many projects in the Live-In Lab stem from a bottom-up approach – interested researchers proposing projects. We have covered many of the relevant areas for sustainable developments of buildings and cities, but interconnections and opportunities among the projects have not been valued sufficiently. I believe that we can use innovative conceptual tools, like the Cyber-Physical-Human (CPH) model, to manage the complexity of smart buildings and cities through horizontal and cross-thematic research and foster more accessible communication.

" I believe that we can use innovative conceptual tools to manage the complexity of smart buildings and cities through horizontal and cross-thematic research."

KTH Live-In Lab has been around for a while, and developed in new directions. What is most important for the next two years?

Since its foundation, the KTH Live-In Lab has been good at bridging industry and academia, with researchers developing scalable solutions in collaboration with societal stakeholders. The value of the KTH Live-In Lab is not only in its unique infrastructure, but also in its ecosystem, made of human capital, the testbeds, the sensors and IT equipment available outside the testbeds, in addition to the galaxy of laboratories and centers at KTH and the partners and funding institutions. Over time, we have become excellent at solving three types of challenges: hard-to-develop problems, which typically require theoretical and applied research, hard-to-test problems, to mitigate liabilities and operational risks, and hard-to upscale problems, looking at complex and multifaceted challenges.

Three medium term actions are needed to keep growing in state-of-the-art research and societal impact. First, we need to increase the number and types of building testbeds: office spaces and neighborhoods are examples of new enabling experimental setup. Second, we have the potential to further diversify research; we spend the majority of our time indoors and living labs can be excellent experimental setups for monitoring residents' health and to carry out more research in sociology, psychology and innovation business models. Third, the network of the Live-In Lab has an important expansion potential, creating synergies with KTH's laboratories and centers and forming durable international partnerships with new building living labs in Europe.

What are the mayor trends and themes affecting the building sector right now?

Buildings have become smarter but there is a need for a better understanding of occupancy patterns, occupant behavior and wellbeing in buildings. Often poor ventilation and thermal comfort result in unexpected behavior from building users, for instance opening of the windows in the heating season to get fresh air. Advanced controls, fault detection and understanding of behavioral patterns can improve significantly the performance of buildings and wellbeing. The recent project DOCENT, financed from Rebygg, will develop and test occupant centric controls in the KTH Live-In Lab.

Building digital twins is another innovative area of research. Few examples of building digital twins exist, due to their complexity. The project and competence center Dig-It Lab tackles the challenges with a multidisciplinary approach, targeting technical demonstration and scalability, organization challenges and regulations and laws related to the digital transformation in the building sector.

Finally, building living labs are emerging as an innovative approach for impactful research, and many universities and research centers are working towards the creation of living labs with different features. We have initiated a collaboration with existing building living labs with several European universities and research institutes. We believe that this collaboration has the potential to grow into a stable network for collaborative research and knowledge transfer.

How do these trends affect your projects and collaborations?

To make an impact in these emerging topics strong team work is essential.

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Research at KTH Live-In Lab

In 2023, a total of 21 projects were ongoing within KTH Live-In Lab. These projects are the result of collaboration between industry and academia. The projects successfully completed during 2023 fostered innovation with their transparent, validated and significant results.

KTH Live-in Lab's operation is focused on acting as a platform for collaboration through enabling multidisciplinary research, and running testbeds and a database.

Challenge-driven projects

Most of the projects initiated by KTH Live-In Lab are challenge-driven and explore opportunities related to new theories, products, and services. In challenge-driven projects, KTH Live-In Lab actively works with bringing forward new innovative theories, products, and services, and to enable collaboration within academia and between academia and industry.

Idea-driven projects

Some projects are idea-driven rather than challenge-driven. In idea-driven projects, KTH Live-In Lab actively works to manage the projects to ensure they are aligned with the challenges KTH Live-In Lab exists to overcome.

How to start a project

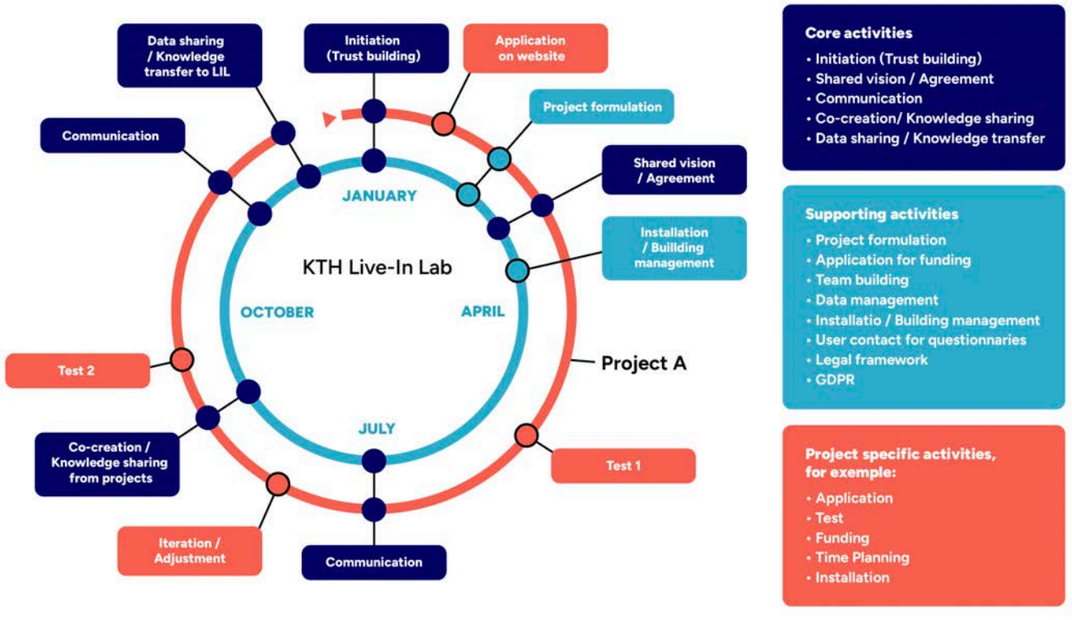
KTH Live-in Lab offers infrastructure and data to researchers and companies. Those interested in collaborating with KTH Live-In Lab on a project can apply on our website.

Application Process

All applications must include information about the project, such as a project description and the goals and purpose of the project. Applications are reviewed by the executive group and approved by the board of KTH Live-In Lab. If a project application is approved, the applicant will receive a letter of intent (LOI) confirming that the project can be performed in KTH Live-In Lab during a specific time, and that the project will independently pay for its costs. The project must also financially contribute to KTH Live-In Lab's operating costs. This normally amounts to between 50 000 – 300 000 SEK per year.

KTH Live-In Lab's support

The individual projects apply for funding and once the projects are finished their results are saved and stored. This enables other projects to pick up where previous ones left off. KTH Live-In Lab will assist with all necessary installation, support collaboration between ongoing projects, handle communication and data storage. KTH Live-In Lab can also assist in applications for funding, ethical reviews and more.



The KTH Live-In Lab project process.

Our projects 2023

Until 2023 KTH Live-In Lab has received 106 applications for use of the Testbed. Out of these, 89 applications were approved for use of the Testbed infrastructure. Moreover, 53 of these projects have been initiated, 33 projects have been completed, and 21 are still ongoing.

The initiated projects at KTH Live-In Lab during 2023 have an estimated total value of 206 million SEK, divided into 26 million SEK of co-funding and 180 million in applied funding. Additionally, the center has received a total of 22 million SEK through various donations as well as materials and technology to a total value of 5 million SEK.

The applicants include both research groups from across KTH (Architecture, Building Technology, Electrical Engineering, Energy Technology, Philosophy, Automatic Control, Real Estate and Construction Management and Information science and Engineering) and SMEs and larger corporations such as KTH Live-In Lab's strategic partners Akademiska Hus, Ericsson and other innovative companies such as Schneider Electric, Northvolt, Nordic Choice Hotels, Einar Mattsson and HSB Living Lab.

Other collaborative partners include Karolinska Institutet, Karolinska University Hospital, Stockholm University, Umeå University, Chalmers, Lund university, AMS Institute, MIT, University Technology Sydney, Max Planck Institute, and Florida University.

Read more about the projects:
www.liveinlab.kth.se/projekt

Summary of projects in KTH Live-In Lab

Projects	2015	2016	2017	2018	2019	2020	2021	2022	2023	Total
Applications	3	17	13	10	8	18	10	17	10	106
Started	2	1	2	9	13	7	5	9	5	53
Finished	0	0	3	3	5	4	8	5	5	33
Ongoing										21

Projects running in KTH Live-In Lab in 2023

Projects		Project Manager	Companies / Organizations	Status
2302	PV-related disturbance and safety issues: analysis of risks and mitigation measures	Makarand Kane		Completed
2215	Datasets for research	Marco Molinari		Completed
2210	Datasets for education	Jonas A. Vogel	KTH LIL, Digitalisation platform, KTH Sustainability	Completed
2016	Distributed sensing Lab	Jonas A. Vogel	KTH LIL	Completed
2212	Optimal flow rate for maximizing ground source heat pump performance	Alberto Lazzarotto l	KTH, Thermia, ToM Energy Consulting Company, Unige, Sindeq borrteknik AB, Rototec, Asplan Viak, Dandelion, Bengt Dahlgren AB, NIBE, HP, Nowab, Wilo	Ongoing
2211	Boosting energy saving competences	Yavor Paunov	KTH, KTH LIL SSSB, EM	Ongoing
2309	Dig-IT Lab	Jonas A. Vogel	RISE, Umeå universitet, Uppsala universitet,Akademiska Hus, Bengt Dahlgren, Castellum, Einar Mattsson, EQUA, Myrspoven, Noss Invest, ProptechCore, Sally-R, Schneider Electric, SISAB, Swegon, Vasakronan	Ongoing
2304	Unlock the source of blackwater: from seperated wastewater to value added products (NEEDED)	Zeynep Ceteciogl Gurol		Ongoing
2207	Advanced and cost-effective indoor monitoring of school environments	Davide Rolando	KTH	Ongoing
2206	Heat by Data cost-effective AI-driven integration of mobile network to the built environment"	Hatef Madani	KTH, Ericsson, NOWAB, ETM Kylteknik	Ongoing

Projects		Project Manager	Companies / Organizations	Status
2205	Development of semantic data infrastructure for smart building monitoring system: preliminary study	Jonas A. Vogel	KTH LIL, SISAB, Schneider Electric	Ongoing
2203	Improved energy efficiency for waste recycling	Jörgen Wallin	KTH/ Energiteknik	Ongoing
2202	Thermal Energy Storage Solutions	Saman Nimali Gunasekara; Qian Wang	KTH- ITM (EGI) & ABE	Ongoing
2108	Buildings Post Corona	Jonas A. Vogel	KTH LIL, Umeå University, Chalmers, Lund University	Ongoing
2107	Optimal drift – smart built	Jonas A. Vogel, Cyril Holm	KTH LIL	Ongoing
2104	Cyber-secure learning control systems	Marco Molinari	KTH LIL, SSF	Ongoing
2103	Humanizing the Sustainable Smart City (HiSS)	Marco Molinari	KTH LIL, KTH Digital Futures	Ongoing
2208	Digital twins	Marco Molinari	KTH LIL	Ongoing
2209	H + Forest	Linda Teng, Agnieszka Zalejska Jonsson	Lunds Tekniska Högskola, KTH, Akademiska Hus, Boiler, Arken, Sustain Lab, Volvo cars	Ongoing
2012	Sonic interaction design to support energy efficiency behavior in the household	Sandra Pauletto	KTH EECS Media Technology and Interaction Design	Ongoing
2003	PV+BESS in KTH Living Lab	Farzin Golzar	KTH	Ongoing

Results from projects at KTH Live-In Lab

In 2023, projects conducted at KTH Live-In Lab resulted in a total of five scientific papers, one of which is a conference paper, one doctoral thesis, one symposium contribution, three conference contributions, and three final reports.

Research areas for projects

- Management of Smart buildings and smart home services
- Building automation and resource efficiency improvement
- Building energy performance and energy savings
- Indoor environmental quality
- Use of buildings, behavior and building management
- Collaboration platforms and Living Labs
- Co-living and sharing of spaces and services

Scientific Articles and Reports

Adversarial Inference control in Cyber-Physical Systems:
A Bayesian Approach with Application to Smart Meter

Project: Smart Meter Privacy with Real Energy Storages

Main research questions

Smart meter data contains information about the daily life and activities of the consumers, which may include sensitive information that should not be shared. A manipulation of the smart meter reading using energy management strategies is a promising privacy-by-design approach to enhance consumers privacy. The main research question is how to enhance the technology readiness of such approaches? The design of energy management strategies with provable privacy guarantees is challenging since small characteristics in the energy profile can reveal appliances. To enhance the technology readiness of existing approaches, experiments and designs of strategies with real consumer data are necessary.

Case studies

Collect and make available relevant energy consumption data in the KTH Live-In Lab that can be used for the design of privacy-preserving energy management strategies.

Results

In this project, we created datasets of energy consumption profiles in a co-living student apartment, which is so far not available. The dataset focus has a focus on privacy sensitive appliances as well as larger consumers which are used for disaggregation. Moreover, the dataset contains reference data that enables a quantitative performance assessment of the approaches and therewith enables further research. In our most recent research work, we have used the real smart meter data for the first time to design privacy-enhancing energy management strategies using a reinforcement strategy to learn the optimal control policy. The work will also give a comprehensive description of the data set and its setup.

Read the report:

https://www.liveinlab.kth.se/en/projekt/r-d-projects/energy-storage-for-smart-meter-privacy-1.980434

Read the relevant doctoral thesis:

http://kth.diva-portal.org/smash/get/diva2:1754000/FULLTEXT03.pdf

Project: Smart Building Management Systems LISB Project manager

Project manager: Marco Molinari,
Researchers: Katarina Bäcklund, Davide Rolando

Project description

This project aims at demonstrating cost-effective solutions able to increase the system energy efficiency. Databases of high-resolution and high-quality data can lead to new valuable insights and the creation of new opportunities. Research testbeds offer unique resources to develop and test smart monitoring and control solutions that have a valuable impact on increasing the energy-efficiency in the built environment. This project exploits the high-resolution, real-time data gathered in the KTH Live-in Lab research testbed through an advanced sensor and data infrastructure, in order to evaluate the cost-effectiveness of smart buildings.

As a result, the operative definition of smart building is enabled. Sensor measurements are used to identify common faulty settings in buildings' ventilation and heating systems, estimating their impact on the energy use. Particular attention is dedicated to the user experience, the impact of the users' energy use, and visualization techniques to promote energy-efficient behaviours.

Implementation

Three building facilities are used as implementation and prototypes: The KTH Live-In Lab's Testbed KTH, Undervisningshuset and the neighbourhood of Uppsala Backe. The first round of data analysis is carried out in the Testbed KTH and Undervisningshuset; this will help to identify the room for improvement in both buildings and support the design of the ICT infrastructure in Botrygg's Uppsala Backe.

Project: Real-time user feedback: monitoring campaign in student apartments

Project description

We have created a user-friendly web-app; people in a building can use it in real-time to provide a feedback about their perceived indoor comfort. This feedback helps buildings operators to improve the wellbeing of the building users. The web-app is currently being used by the students living in the four apartments in the Live-In Lab Testbed KTH. The students use the web-app to respond when they think it is too cold, too warm, too noisy or to let us know some other aspects about their indoor comfort. This research is linked to a project funded by the Swedish Energy Agency (link); the purpose is to evaluate the relation of users – indoor comfort – sensors – control systems and energy efficiency and to ultimately provide more comfortable and sustainable living spaces.

Implementation

This project scales up the pilot test study in the Live-In Lab Testbed KTH to test the web-app on the Akademiska Hus student apartments at KTH, Draconis. People living in the apartments are free to use the mobile app and provide real-time feedback about perceived indoor comfort. We also envision to organize informative workshops to discuss people response and improvements of the app. A non-intrusive sensor module will be installed in the participants' apartment, monitoring temperature, relative humidity and air quality, and optionally energy use. All data will be anonymous and only used for the purpose of the research project. Any participant can at any time with no reason decide to leave the study.

Publications

- Mahsa Farjadnia, Amr Alanwar, Muhammad Umar B. Niazi, Marco Molinari, Karl Henrik Johansson, Robust Data-Driven Predictive Control of Unknown Nonlinear Systems using Reachability Analysis.
- Bäcklund, K., Molinari, M., Lundqvist, P., Karlsson, P. Showcasing the First Steps Towards a Digital Twin for Campus Environments, BuildSim Nordic 2022:10th BuildSim Nordic conference and the 2nd International Nordic conference for IBPSA,2022, Copenhagen, Denmark
- M. Molinari, D. Rolando, A. Lazzarotto. Energy and indoor environmental quality monitoring of a lecture building: preliminary results from the KTH Live-In Lab Testbed AH, MIT A+B 2022, MIT, Cambridge, USA (pdf 451 kB)
- Rolando D., Molinari M., Mazzotti Pallard W., Long-Term Evaluation of Comfort, Indoor Air Quality and Energy Performance in Buildings: The Case of the KTH Live-In Lab Testbeds, Energies. 2022; 15(14)
- Read more about the publications: https://www.liveinlab.kth.se/en/projekt/r-d-projects/kostnads-och-energi/cost-and-energy-efficient-control-systems-for-buildings-1.945916

PROJECT

HYSTORE – Energy storage in practice

Saman Nimali Gunasekara and Qian Wang are the researchars behind HYSTORE – an industry-driven Horizon Europe project between 18 partners across academia, research institutes and industry. The goal is to increase the performance of thermal energy storage-integrated buildings and energy systems.

Saman Nimali Gunasekara is an Assistant Professor at Energy Technology (with specialization on Thermal Energy Storage) at KTH. She is collaborating with KTH-Live-in-Lab in the project HYSTORE for thermal energy storage solution implementation, as the project leader for the school of Industrial Engineering and Management (ITM).

Qian Wang is a Researcher at Civil and Architectural Engineering Department, with specialization on HVAC control and smart buildings at KTH. Qian Wang is the project leader of KTH team in project HYSTORE, and in close collaborations with KTH-Live-in-LabKTH live in lab for system integrations and data semantics.

Hello Saman and Qian, what is the HYSTORE project about?

HYSTORE is a four-year project that aims to address and deploy several goals related to thermal energy storage. One goal relates to the design, manufacturing and characterization of four types of modular and plug-and-play thermal energy storage solutions for daily to monthly storage with different functions: heating, cooling, domestic hot water.

Other goals are to develop and deploy optimised control strategies from thermal energy storage at controller level, aggregation and community-levels for efficient thermal energy storage operation and energy services provision, to provide full integration of the thermal energy storage solutions with the building heating/cooling system and energy management for grid-aware demand response, and to validate all technical solutions and information and communication technology (ICT) In Circuit Testing tools in the four representative demonstrators that are able to simulate different building sizes and usages, in four different climates.

Finally, we want to create an exploitation and capacity building plan for wide scalability and replication of HYSTORE through the engagement of technical and non-technical stakeholders to ensure a long-lasting appeal of the HYSTORE solutions and platforms.

Thermal energy storage has shown not only environmental, but also technical competitiveness from an energy-coupled system perspective – at a rather lower cost than batteries.

What are the potential sustainability gains from HYSTORE?

Historically, thermal energy storage systems have been considered mainly as an auxiliary component for the energy systems at user levels, and only very recent developments have identified thermal energy storage as an asset for decentralized energy generation.

As an alternative solution, thermal energy storage has shown not only environmental, but also technical competitiveness from an energy-coupled system perspective at a rather lower cost than batteries. The advantages here come, such as with peak shaving and load shifting, improving efficiencies, recover waste thermal sources and accommodate an increased deployment of intermittent renewables as both heat but also as electricity, by combined operation with heat pumps, chillers and such.

The main importance and significance of HYSTORE is elaborating thermal energy storage from new component design to energy network levels, to unlock new demand, leading to innovation, and lowered costs, and increase the performance of thermal energy storage-integrated buildings and energy systems.

How are you addressing this?

We want to address the gaps where exploitation at large is still limited due to relative complexity, the lack of data at real application scales, the lack of standard engineering guidelines for the installation and operation, as well as the lack of knowledge on the potential of thermal energy storage in flexible sector coupling.

In this context, HYSTORE serves as a technology readiness level enhancer particularly for compact phase change materials/thermal energy storage (using phase change materials and thermochemical heat storage) as a whole, and a flexible sector coupling enabler between thermal and power sectors.

Who, besides yourselves, are involved in the project?

KTH is the technical coordinator, developing several key innovations across three of four pilots in HYSTORE. The project is also a joint effort among three leading teams within KTH in the area of thermal energy storage solutions and their integration with buildings, heating, ventilation, and air conditioning and further to the energy community levels.

What does your collaboration with KTH Live-In Lab look like?

As one of the key pilots in HYSTORE, KTH Live-In Lab facilitates to deploy a key thermal energy storage solution. KTH Live-In Lab also facilitates thermal energy storage solutions and their integration and control strategies with existing heating, ventilation, and air conditioning, and surrounding infrastructure.

For HYSTORE, this is a pilot-scale thermal energy storage using phase change materials (PCMs), designed, constructed and techno-economically optimized, operated in combination with a heat pump in KTH-Live-in-Lab, for space heating. This is called HYSTORE PCM Heating solution.

How is the data going to be used?

As a final overall objective of HYSTORE, the results and data we get from KTH Live-in Lab will be compared with other HYSTORE solutions at other demo sites, to benchmark and propose optimal energy management strategies with thermal energy storage at energy community level.

What is the next step?

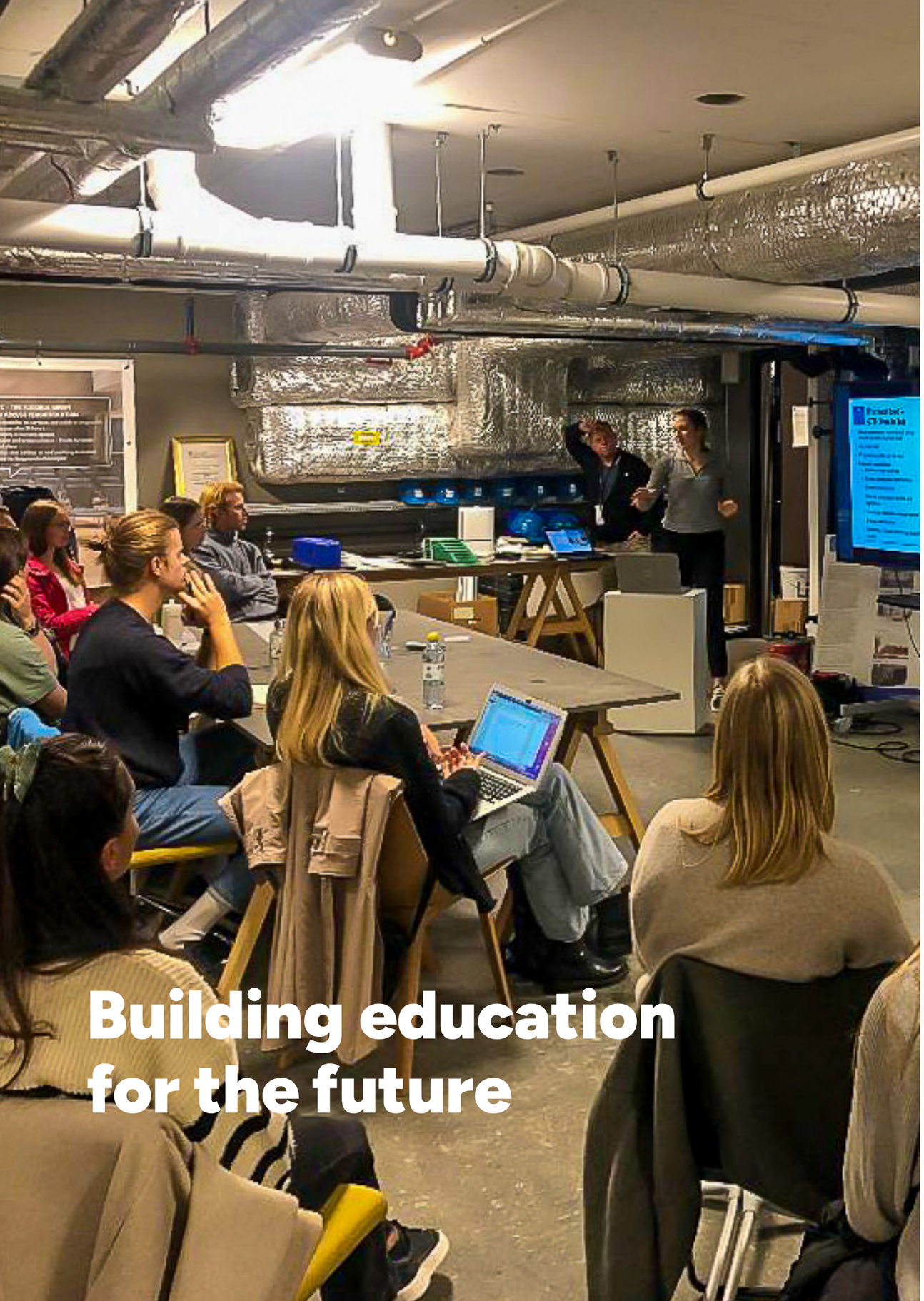
During the first year of HYSTORE, the KTH team have developed a collaboration framework that enables researchers from different backgrounds to work together to find solutions. Thorough experimental analyses were performed for optimal material selection. Extensive simulation and data analytics have been performed to understand the current market gap, map the data status of the Live-in Lab pilot, and hardware component analysis.

Now we have entered the stage where we prepare the testing and system installations for the real-life deployments, as well as preparing all the considered scenarios for integrations. This will be used both as a benchmark, but also as a basis for further community level analysis. At this stage we will also install the heat pump and heating system at Testbed KTH Live-In Lab.

Project teams

The KTH team is led by Civil and Architectural Engineering at the School of Architecture and the Built Environment. They lead the development of thermal energy storage (TES) integrations with building and heating, ventilation, and air conditioning (HVAC) systems, as well as the data harmonization with building management systems from single building to community levels.

In close collaborations, Energy Technology at Industrial Engineering and Management School lead one of the four key TES solutions: Phase Change Materials (PCM) heating solution.



Building education for the future

Education at KTH Live-In Lab

KTH Live-In Lab provides essential input to courses and theses internationally. The growing interest in its work is reflected in the increasing number of site visits by students and researchers from all over the world.

The interest in using KTH Live-In Lab in courses and theses is big and growing. So far, the involvement in courses has been limited to site visits, workshops and presentations / lectures. The aim is to develop course packages that can be included in already-ready existing courses at KTH, focusing on cross-disciplinary co-creation.

KTH Live-In Lab provides a natural point of contact between students and the industry. KTH Live-In Lab can therefore be used as a case or project assignment in course curricula at KTH. This gives students from different study programs the opportunity to contribute to the evaluation and validation of tests currently in progress in the Testbeds. Students are also given the opportunity to collaborate with the team designing the constellation of the innovation-area in the Testbeds for the coming year.

Course highlights

In 2023 KTH Live-In Lab contiuned its focus on education, especially on integration between the physical space and the digital infrastructure, with further developed datasets for education and a new course on AI in buildnings.

In 2023, a new course focusing on application of AI to the energy and building sector has been initiated using the KTH Live-In Lab as a case study. The course aims to bring the students knowledge about key concepts that form artificial intelligence (AI), and their applications within the field of sustainable energy engineering. The course also introduces potential implications for energy businesses, as well as ethical aspects of using artificial intelligence.

The students learned to manage data for the purpose of machine learning applications as well as to create, integrate and use ML for analysis and design in an energy context. In the project part of the course, eight groups of students trained and applied machine learning algorithms with data from the Testbed AH of the KTH Live-In Lab for forecasting of energy demand.

Cases and case studies

KTH Live-in Lab recognizes the importance of an experimental learning environment. A smaller incentive package has been designed to support courses that use KTH Live-In Lab as a case study. A part of the package contains introductory lectures from KTH Live-In Lab, and contributions to the exhibition or catalogue. KTH Live-in Lab supports dissemination of knowledge and exchange of information through different channels.

Lifelong Learning

KTH Live-in Lab is exploring forms in which Lifelong Learning could be further developed. Current collaboration with fastighetsbranschens Utbildningsnämnd reveal the great need of technical competence for managing smart and sustainable future. A need that currently cannot be sufficiently met through higher education, vocational higher education or other education providers. However, to harvest the benefits of digitalization there is a need for collaboration also around education.

Courses that visited or used KTH Live-In Lab during 2023

- MJ2507 AI applications in Sustainable Energy Engineering,Farzin Golzar, KTH ITM
- AF2507 Sustainable Buildings – Concept, Design, Construction and Operation, Ivo Martinac, KTH ABE
- AG1815 Sustainable Development, ICT and Innovation, Anna Björklund, KTH ABE
- AI1145 Property Management with a Financial Perspective, Agnieszka Zalejska Jonsson, KTH ABE
- AI1146 Property Management, Agnieszka Zalejska Jonsson, KTH ABE
- MJ1141 Energy Systems and Sustainability, Per Lundqvist, KTH ITM
- MJ2146 Energy Systems, Business and Management, Per Lundqvist, KTH ITM
- MJ2443 Heating, Cooling and Indoor Climate, Samer Sawalha, KTH ITM
- GECKO EU Marie Skłodowska-Curie Innovative Training Network Summer School 2023

Institutes and organizations that visited or used KTH Live-In Lab during 2023

- GECKO EU Marie Skłodowska-Curie Training Network
- New York IVL Smart City Sweden
- Amsterdam Institute for Advanced Metropolitan Solutions (AMS)
- Delft University of Technology
- Engineering school ECAM LaSalle
- Lund University
- Rocky Mountain Institute
- Rutgers University
- Sintef
- Swedish Energy Agency
- Swedish Real Estate Association's Education Committee
- UNITE! University Network for Innovation, Technology and Engineering
- Uppsala University

Datasets for education – part two

The purpose of the project is to make data from buildings in the KTH Live-In Lab available for use in teaching at KTH.

In a continuous effort to simplify the access to data in buildings for research and education, the project Datasets for Education involved researchers and teaching staff at KTH to identify needs and opportunities liked to data availability in buildings.

Using a co-creative approach, the project established a framework to create useful datasets. This will enable easy and efficient access to data for use in education, lifelong learning, and further education courses. By doing so, students can enhance their digital skills, learn how to use digital tools effectively and contribute to achieving global sustainability goals and KTH's sustainability objectives.

As a tangible outcome of the project, sample datasets from the three KTH Live-In Lab testbeds (Testbed KTH, Testbed EM and Testbed AH) have been created. The datasets are GDPR-compliant and have been checked against current best practices for privacy.

Cases and case studies

To maximize the outreach, the files are openly available in the Live-In Lab webpage in an accessible and common format, .csv and .xlsx files. The datasets are provided with additional information, like the layout of the testbeds, and are available in time spans ranging from one day to three months

Download sample datasheets.

PROJECT

Unlock the source of blackwater: from separated wastewater to value added products (NEEDED)

Zeynep Cetecioglu Gurol's research project at KTH Live-In Lab uses municipal wastewater in KTH Live-In Lab to produce fatty acids for industrial applications. An approach allowing cities to become future hubs of the biobased industry by transforming their waste streams into valuable products incorporating flexible and adaptive biorefineries.

When did your collaboration with KTH Live-In Lab begin?

My collaboration with the Lab began in October of 2023 by installing a small tank in the basement to collect black water from Testbed KTH. This tank was installed to homogenize the water and store the blackwater from the flat, i.e., Testbed KTH. We will collect samples from this tank as part of NEEDED, a three-year project set to begin in 2024 when my Ph.D. student begins their doctoral thesis. While the ÅFORKS grant is for three years, I hope to continue collaborating beyond 2027 as this piping is invaluable to my research on blackwater.

How did you come up with the idea for your project on black water?

As an environmental engineer and molecular biologist with expertise in resource recovery processes from waste streams, I have primarily focused on food waste, sludge, and primary sludge from municipal wastewater treatment plants. Initially, our goal was to produce biogas methane, but we then expanded into volatile fatty acid production, as intermediate products of anaerobic digestion that includes acetic, propionic, and nitric acids. In my first projects in Sweden, I realized that because we work with mixed cultures in wastewater treatment plants, the products are also mixed, making it challenging to produce a single type of VFA. This led to another research question: how can we separate these mixtures? The separation and purification processes are a bottleneck, but I wanted to know if producing tailor-made VFAs could make separation easier. This became my research question following our initial projects.

In addition, sustainable or circular cities have brought attention to the need for separated wastewater systems in residential areas. Currently, most areas in the country produce groundwater from all sources of wastewater, which is then sent to municipal treatment plants. However, a relatively new approach involves collecting black water (from toilets) and grey water (from sinks, dishwashers, etc.) separately. While grey water can be easily handled and recycled using membrane separation, black water is more complex. Limited studies have been conducted on black water, but we have begun running experiments this year and found it quite promising. Black water can produce VFAs or biogas, which is truly unique. While the organic pollutant concentration can sometimes be too high, we are progressing.

What is this project about?

The notion is to utilize the black water from KTH Living Lab to produce platform chemicals, commonly called VFAs. These chemicals have various applications in various industries, such as animal feed production, cosmetics, and rubber production. However, the current practice is to use petroleum-based VFAs rather than bio-based ones. Starting after the new year, our plan is to use this black water to develop a semi-synthetic mix culture and produce tailor-made products through different cascade reactors. By manipulating the production process using microorganisms and operational parameters, we can produce acetic acid or other acids like butyric or caproic, depending on the requirements. This approach will allow us to manage and optimize the production process efficiently.

What is the project's plan?

We have a comprehensive plan consisting of four work packages. The first involves characterizing the black water and different microbial consortiums, setting up batch experiments, and utilizing microbial community analyses. In the second year, we aim to develop synthetic cultures and characterize them. Moving into the third year, or possibly the second to third year, the focus will shift towards reactor operation and bioaugmentation of these synthetic cultures into the mixed cultures. Finally, we will continue reactor operation in the fourth year while designing a cascade reactor through software.

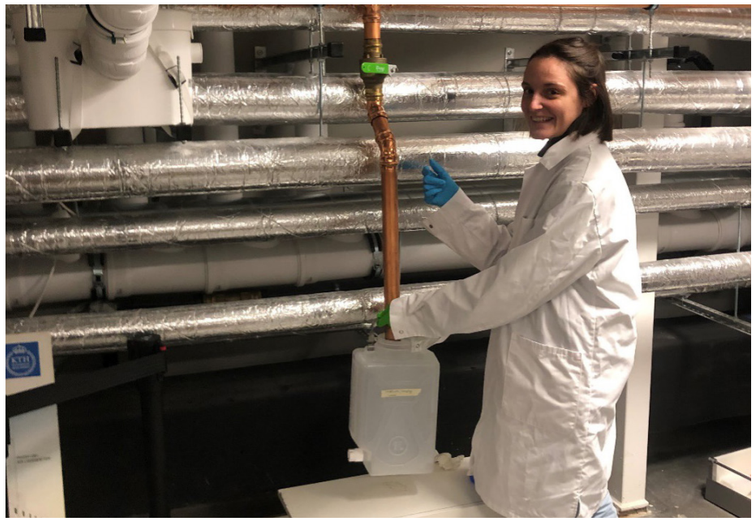
We aim to use black water to feed anaerobic reactors and develop semi-synthetic cultures for various products. After the project, we will focus on post-stream processes and other related tasks. For work package 4, we plan to design a cascade reactor system using software. I aim to develop synthetic cultures for different products, and I plan to run several reactors in parallel for butyric acid, propionic acid, and acetic acid production. Caproic acid is another valuable product that we can produce by combining butyric acid, acetic acid, ethanol, and lactic acid separately for chain elongation. We will operate each reactor individually and connect them through software rather than using a cascade reactor system.

In the last workpackage, we will stop at the practical part and design the remaining aspects using the appropriate software. Our work packages include characterization, culture design, reactor operation, and designing a cascade reactor through software.

What do you believe sets this project apart in the research community?

This project has been a long-time dream of mine, dating back to 2018. Despite facing numerous rejections from various grant schemes, I've noticed that similar topics have been gaining support this year. I recently encountered a ERC project focused on a comparable subject, though I need to familiarize myself with its specific

Timing is crucial for any project or new idea; sometimes, it's a matter of submitting too early or too late. I'm confident that now is the right time for this project or similar subjects. If we're successful, it will benefit not only me but also other researchers in the transition from linear to circular economy. While biogas production from waste streams is currently our primary focus, numerous studies on VFA production have already been done. However, these products have yet to be widely available in the market. Our main challenge lies in separating and purifying a dominant product type. I firmly believe that if we can achieve this concept, we'll be able to utilize waste streams for the biorefinery concept beyond just biogas.



Jade Mallauran, Msc student at KTH, harvesting black water in KTH Live-In Lab.

Zeynep Cetecioglu Gurol is an Associate Professor that works for Division of Industrial Biotechnology at the School of Engineering Sciences in Chemistry, Biotechnology and Health (CBH).

About the project

The aim of NEEDED is to establish a new biobased production platform by embracing microbial communities for achieving sustainable production of specific biobased chemicals from source separated municipal wastewater (blackwater). The project seeks to develop biobased production platform by combining three elements:

- Nature-inspired synthetic complex microbiomes in granular form which provides more robust operation
- Bioaugmentation of the derived microbiome to already existing biosystems to produce enhanced and target volatile fatty acids (VFAs) for other post stream processes
- Designing and evaluating an innovative system by integrating both current and novel biobased processes to create a sustainable value chain from source-separated municipal wastewater.

"The buildings of the future compose sustainable cities where people actively and vibrantly engage with their physical and non-physical environment meeting the challenges of climate action"

Designing buildings for the future

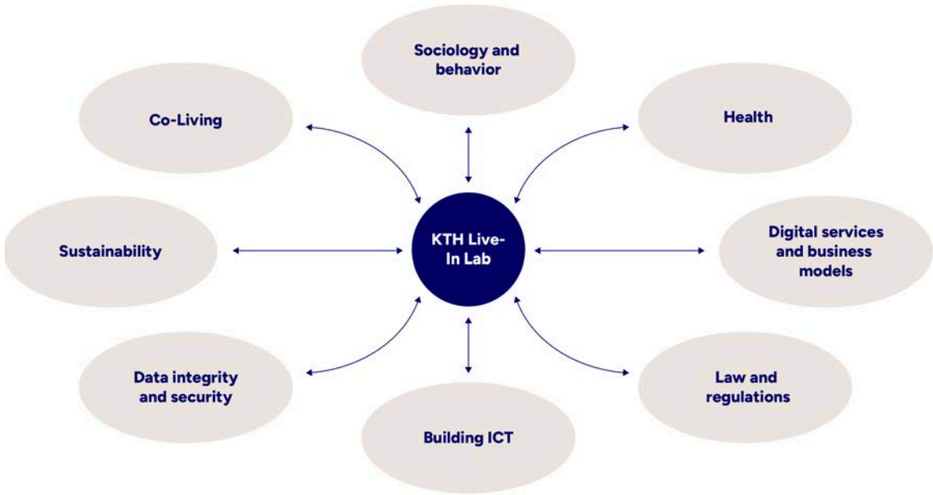
Sustainability

KTH Live-In Lab enables sustainability transformations and reinforces the sustainability work at KTH. The projects we select for collaboration are those that aim to foster sustainability.

The multidisciplinary nature of buildings, the ongoing digitalization and the future energy and environmental goals are all major challenges. By bringing together academia and industry, KTH Live-In Lab increases the opportunity for external funding and creates win-win situations.

Increasing the pace of innovation in the public construction sector, based on excellence in research, education, and collaboration ensures that KTH becomes a sustainable campus and that Stockholm retains its leading position in sustainable urban development. KTH Live-In Lab primarily enables projects in the following areas of the global sustainability goals:

- Health and well-being (SDG 3)
- Clean water and sanitation (SDG 6)
- Sustainable energy for all (SDG 7)
- Sustainable industry, innovation and infrastructure (SDG 9)
- Sustainable cities and communities (SDG 11)
- Sustainable consumption and production (SDG 12)
- Fighting climate change (SDG 13)
- Implementation and global partnership (SDG 17)



KTH Live-In Lab main areas of research

PROJECT

Building automation for energy-efficient smart buildings

A project using KTH Live-In Lab to investigate the behavior of building occupants, their role in building energy consumption, and their interaction with building systems. The research, conducted by Mahsa Farjadnia, Angela Fontan, and Marco Molinari, paves the way for the development of advanced control strategies for reduced energy consumption in buildings.

What is the project about?

Building automation has become increasingly significant due to its pivotal role in tackling societal challenges related to sustainability and energy policy. The building sector is responsible for approximately 38 percent of global energy-related emissions and about 35 percent of total final energy consumption. In response, recent efforts have focused on developing efficient technologies to enhance the sustainability of the built environment while simultaneously improving occupant well-being.

One of the project goals is to investigate the behavior of building occupants, their role in building energy consumption, and the interaction between occupants and the building system. This research paves the way for the development and improvement of advanced control strategies to reduce, e.g., (heating and ventilation) energy consumption of buildings.

Additionally, the integration of advanced control approaches into the building simulation environments, such as Indoor Climate and Energy (IDA-ICE) – a detailed and dynamic multi-zone simulation environment for studying thermal indoor climate and overall building energy consumption – is a key focus. Furthermore, experimental studies and campaigns of the environmental and social drivers of energy-efficient and sustainable behaviors are also a significant part of the research direction.

“ To balance comfort and efficiency, it is essential to integrate building design, climate control, and the needs of occupants, modeling buildings as cyber-physical-human systems.”

What is the role of Living Labs in this research?

There is a growing focus on understanding and accounting for the dynamics of building occupants. In particular, to balance comfort and efficiency, it is essential to integrate building design, climate control, and the needs of occupants, modeling buildings as cyber-physical-human systems.

Living laboratories serve as crucial testing grounds for new technologies in CPHSs, ensuring the sustainability of the built environment while taking into account the human component. They present valuable opportunities for industry and academia to research, develop, and test new technologies.

What does your collaboration with the KTH Live-In Lab look like?

The collaboration with the KTH Live-In Lab has taken various forms, from visits to the facilities, to usage of collected state-of-the-art sensor data, to the open link of communication with the tenants established by the KTH Live-In Lab, which was required for some of our research and experimental studies.

What have you done in the project so far?

Two parallel experimental studies feature/stand out among the ongoing research efforts, one is investigating the role of social influence in sustainability-significant choices of tenants, the other evaluating the mutual relationship of interaction between environmental conditions in a residential building and the behavior of occupants.

Specifically, the first work (Fontan, A. F., et al., 2023) outlined a longitudinal experimental study of social influence in behavioral changes toward sustainability, in the context of smart residential homes. Participants were students residing in the housing on campus referred to as KTH Live-In Lab, whose behaviors were observed concerning key lifestyle choices, such as food, resources, mobility, consumption, and environmental citizenship. The study hypothesized that sustainable living can be promoted through the digitalization of a household into a social network of interacting tenants.

The second work (Farjadnia M., et al., 2023a) investigated the influence of physical environmental variables (i.e., indoor and outside climate parameters) and categorical variables (i.e., time of the day) on occupants’ behavior patterns related to window operation, utilizing a multivariate logistic regression analysis and data collected during the winter months at the KTH Live-In Lab, when the effect on the energy consumption of the window operation is the highest.

Alongside experimental studies, a co-simulation environment is currently under development to integrate advanced controller strategies, designed using software such as MATLAB and/or Python, in conjunction with building simulation environments/software, such as IDA-ICE. One of the advantages of this co-simulation environment is its capability to evaluate the performance of the designed controller using the latest physical models available within IDA-ICE.

What is the next step?

Future work includes designing an advanced data-driven control technique inspired by (Farjadnia M., et al., 2023b) using data from KTH Live-In-Lab, as well as synthetic data generated by software such as IDA-ICE, to reduce the energy consumption of HVAC systems while ensuring occupant comfort.

Angela Fontan is an Assistant Professor at the Division of Decision and Control Systems, KTH, working in the area of cyber-physical-human systems, with applications to Live-in Laboratories, collaborating closely with the KTH Live-in Lab.

Mahsa Farjadnia is a Ph.D. student conducting her doctoral thesis in collaboration with the Energy Technology Department and the Division of Decision and Control Systems at KTH. Her research area includes data-driven control, with the application in the KTH Live-In-Lab, and modeling occupants’ behavior within smart building environments.

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Testbeds and data

for multidisciplinary research and development

Infrastructure & Database

KTH Live-In Lab is a significant piece of the puzzle in the work towards creating the smart and sustainable building of the future. The idea behind KTH Live-In Lab is to offer buildings, operations, and data to enable multidisciplinary research and development. Additionally, KTH Live-In Lab aims to accelerate the pace of innovation in the public construction sector.

KTH Live-In Lab has three interconnected functions, two of which are infrastructures.

- Collaboration platform
- Data and IoT-platform
- Testbeds

There are currently three Testbeds in KTH Live-In Lab: Testbed KTH, Testbed EM, and Testbed AH. There are also some trusted buildings that deliver data to KTH Live-In Lab, for example multi-family buildings in Uppsala, buildings owned by Botrygg.

Testbeds within KTH Live-In Lab

KTH Live-In Lab currently consists of three Testbeds: Testbed EM, Testbed AH and Testbed KTH. The KTH Live-In Lab Testbeds have a joint database where data can be collected for research or educational purposes.

Database and data management

Data from the Testbeds are collected and shared via KTH Live-In Lab's data pool. The database is located on KTH's servers. Our data pool consists one of the most valuable infrastructure that supports research and innovation not only for KTH but also for other institutions. In 2023, the interest in our data pool increased, creating the opportunity to build new partnerships with other institutions and laboratories.

Access to the testbeds

The KTH Live-In Lab Testbeds are open for all who wish to conduct research and tests on products, services or processes within an area that has bearing on the real estate and construction sectors. Research on new business models and collaboration structures are also possible.

Testbed AH (Akademiska Hus)

Testbed AH consists of Undervisningshuset on KTH Campus Valhallavägen and is equipped with hundreds of sensors. These sensors measure relatively common values such as ventilation flows, CO2 and electricity and water usage, but also moisture levels and concrete movements in individual parts within the test bed.

Testbed EM (Einar Mattsson)

Testbed EM consists of 305 student apartments in three plus-energy buildings, located on KTH Campus Valhallavägen. Hot water and heat are generated via heat pumps connected to 12 boreholes of a total length of 3600 meters. The Testbed has approximately 1150 square meters worth of solar panels and 64 wastewater heat exchangers.

The Testbed will also have a battery energy storage system connected to the solar panels with a capacity of around 300 kWh in collaboration with Northvolt. Hot water, electricity, CO2, and light are measured in all apartments and the control and monitoring systems can be influenced for research purposes.

Testbed KTH

Testbed KTH is placed in building-permit exempt premises in one of Einar Mattsson's three plus-energy buildings on KTH Campus Valhallavägen. The premises are a total of 305 square meters divided into a living area distributed over approximately 120 square meters, a space for the technology of about 150 square meters and a project office of roughly 20 square meters.

Within Testbed KTH, various apartment configurations are built on an annual basis and KTH sublets these to students who have applied to live in the test apartments. The KTH Testbed is fully flexible regarding both geometry and installations. Moreover, the Testbed has its own solar panels and a borehole making it possible to change the collector.

What's new in Testbed KTH?

During 2023 the Testbed KTH continued to be one of the most effective shared living experiments in a smart apartment. The Testbed KTH provides significant results in a wide range of research fields. In essence, this Testbed creates a channel for direct communication between researchers and students – tenants. Reliable and valuable results are produced in a fast rate thanks to the direct feedback of the tenants and their active participation.

Partnerships and multidisciplinary collaboration

Collaboration

KTH Live-In Lab bridges academia and industry promoting collaboration between research projects and research fields to foster innovation, new knowledge and competence development The testbeds in KTH Live-In Lab can be used for innovative environmental technology – for research, development or education.

KTH Live-In Lab offers workplaces, space for necessary installations and the infrastructure and context needed for research and development of technology in a real residential environment. Moreover, KTH Live-In Lab promotes collaboration between research projects supporting multidisciplinary cooperation. There are different ways to collaborate and different levels of involvement.

Project collaboration

Companies and researchers use the testbeds for research and postgraduate education, basic education, assignment research or assignment training. Companies and / or researchers proceed with a project description including budget and agreement. Project collaboration can then take various forms.

Letter of Intent

Small companies, startups or researchers can obtain a ‘Letter of Intent’ with the aim of facilitating project collaboration, if their idea, product or service is considered relevant to KTH Live-In Lab.

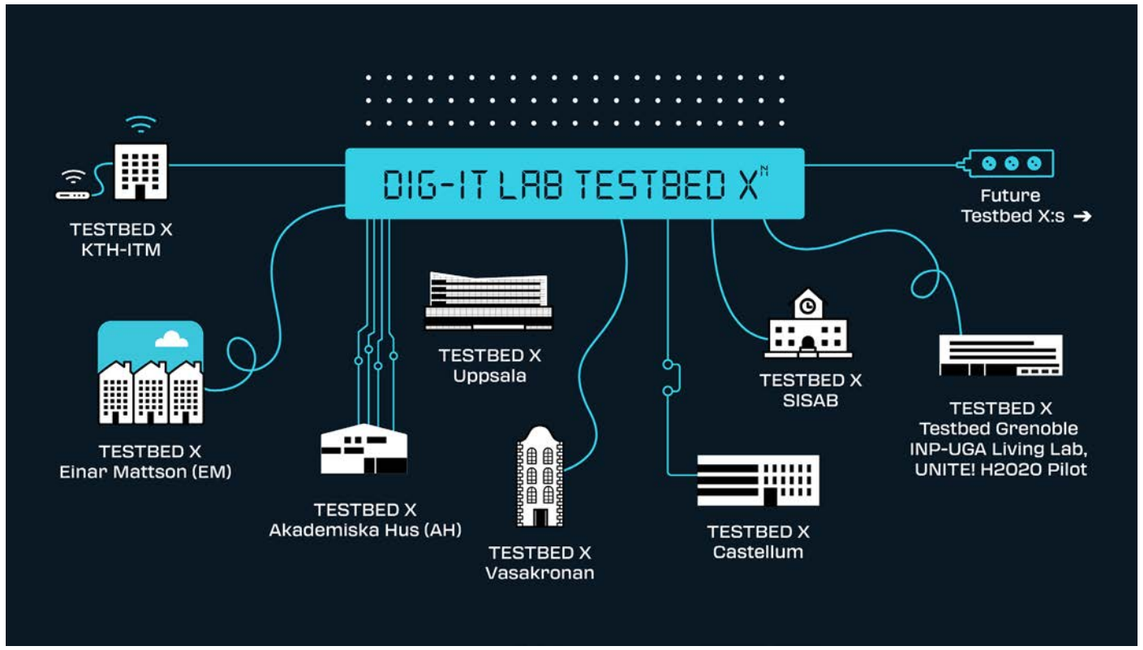
Strategic collaboration and center membership

Companies may also want to collaborate with KTH Live-In Lab at a strategic level, outside the scope of the application. The purpose of a strategic partnership is to create collaboration between KTH and the business community. Strategic partners are also involved in undergraduate, research and/or postgraduate education.

Application

After the application process, collaboration between researchers / companies and KTH Live-In Lab is formulated and formalised.

Read more about our project process on our website:



Dig-IT Lab – a collaborative project promoting sustainable digitalization of buildings

In 2023, the new competence center Dig-IT Lab was launched, aiming to reduce the environmental impact of buildings through digitalization. The center complements KTH Live-In Lab, and is similarly based on collaboration between academia and industry.

Dig-IT Lab is a project that builds on experience and knowledge produced within KTH Live-in Lab, focused on exploring the digital aspects of the built environment. It is a research collaboration established as a center in autumn 2023 with joint funding from Vinnova, KTH, and industry.

”The objectives are to maximize the benefits of digitalization throughout a building’s lifespan. We do this by building and increasing our shared knowledge, and by developing the essential competencies for a digitally driven built environment,” says Jonas Anund Vogel, director of Dig-IT Lab.

Dig-IT Lab is now working on several shared projects, as well as continuing to envision its future direction. The focus is on co-creation and collaboration between academia and industry to update policy, produce innovative solutions and accelerate the market introduction of new technologies. The center also promotes cross-disciplinary collaboration and research in key areas like digital twins.

It is not all about technology. The strength in bringing all actors together is the possibility to integrate many aspects on the built environment. With its five main research themes, Dig-IT Lab focuses on the ethical, legislative, economic, social, and health aspects, just as much as on technical solutions. This is important to reduce potential value conflicts and adverse outcomes.

Dig-IT Lab is currently working on establishing new virtual testbeds within its framework. They will provide a testing environment for joint research and development and technology transfer.

www.digitlab.kth.se

”We hope that KTH and Dig-IT Lab can act as a bridge between various actors in the industry.”

The industry is facing great challenges, and we believe that traditional business models need to change. We participate in Dig-IT Lab with the belief that working together moves us forward. We want to achieve development, expertise, and unleash the innovation capabilities and opportunities it can bring to the industry. We are particularly interested in digital twins and how we can train AI to create digital twins that can collect and analyze data in real time and build relevant responses. We need to understand how to do that, what conditions we can provide now, and what needs to be added.

Anders Kallebo,
Myrspoven

”It is important to understand that collaboration is not easy. It requires perseverance and trust.”

Dig-IT Lab is really interesting as an academic and industrial frontier. It is a competition-neutral place where the industry can collaborate and build trust with each other. Being part of DL aligns well with our driving force, which comes from the desire to always develop technology that allows us to build smarter. It is also a bit like coming home, as EQUA Simulation was founded in 1995 based on the IDA Simulation Environment program developed at KTH in the late 80s.

Per Sahlin,
Equa

”We need to change our working methods, incorporate new technology, and systematically integrate these solutions in the management of buildings.”

Improved digital infrastructure can help us meet sustainability goals and deliver a good indoor environment and low energy consumption, but it requires collaboration between industry actors and property owners. We are convinced that this collaboration can be achieved through Dig-IT Lab’s projects, and look forward to collaborating. We think Dig-IT Lab can lead to the development of common ground and standards for the application of digitalization to various properties with different conditions, as well as the new mindsets and solutions needed to manage the scope and complexity of the challenges posed by digitalization in our industry.

Fredrik
Gunnarsson,
Castellum

A platform for collaboration

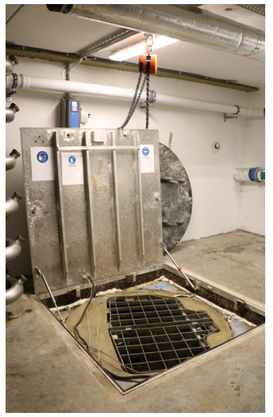
Impact & Outreach

KTH Live-In Lab functions both as a collaboration platform and an infrastructure, generating knowledge, commitment and results. In 2023, the center continued its outreach activities to both stakeholders and the broader society.

Highligts from 2023

- Due to its pioneering work the KTH Live-In Lab hosted the Swedish Minister of Education and the EU Commission, starting an important dialogue on sustainability.
- KTH Live-In Lab co-hosted the HiSS International Workshop 20232, 3-5 May 2023. The project is financed by Digital Futures and focuses on human behavior and decision making in complex environments like smart buildings and smart cities. The workshop spanned over three days and featured a three-day sessions with keynote speakers, panel discussions on smart cities and a visit to the Live-In Lab testbeds.
- Among the international delegations visiting the KTH Live-In Lab, KTH Live-In Lab was visited by a New York City delegation, including industrial and academic partners. The focus of the visit was Swedish solutions for low-carbon buildings. The event was part of Smart City Sweden initiative and was joinly organized with IVL, the Swedish Energy Agenc, Beex and Nyserda.
- KTH Live-In Lab has supported and played an important role in the start-up of Lund University Living Lab, and in the UniZEB, a living lab for Zero Energy Buildings based at the University of Padua.
- KTH Live-In Lab Open House was held on 23 August 2023. More that 50 participants from industry and academia attended the event and took part of poster sessions, project presentations and discussions with the aim to identify areas for future cross-disciplinary research and development.
- KTH Live-In Lab's concept of testing and sharing results and data has been presented in national TV, radio, industry press such as Kyla & Värme, Energi & Miljö, Byggindustrin, and Fastighetstidningen.
- Representatives from KTH Live-In Lab were involved in the development of the coming building codes, "Möjligheternas byggregler", focusing on how to enable innovation.
- KTH Live-In Lab is a test bed in ERA-Net Smart Energy Systems: eranet-smart-energysystems.eu/ll/708/preview.html
- KTH Live-In Lab is actively collecting and sharing data from the test beds and projects carried out within the framework of KTH Live-In Lab. KTH Live-In Lab's database (or Datapool) is used by researchers, collaborators, teachers and students. Many degree projects and courses have used data regarding everything from ventilation and water studies to cyber security and user behavior.
- Through research projects, KTH Live-In lab has contributed to three buildings, containing 305 student apartments on KTH Campus, built as plus energy buildings.

KTH Live-In Lab open house 2023



KTH Live-In Lab hosted an open house on August 23rd, attracting about 80 visitors and featuring presentations from around 20 researchers and project managers.

The 2023 open house took place during lunchtime, at Malvinas Väg 12–18. Researchers and industry partners showcased and discussed various technologies and research projects. General presentations on ongoing and future R&D were held in the Laundry Room, and a poster session was held in the basement of KTH Live-In Lab. Visitors also had the opportunity to see the battery room, the sub-central with heat pumps and waste heat exchangers, and the innovative co-living unit.

Among the highlights of the program was a presentation by architect Maria Grunditz, who described how research results are being applied in practice – particularly focusing on co-living and elderly care. Other parts of the program that attracted a lot of visitors were Schneider's presentation on Digital Twins, Bengt Dahlgren's presentation on Building Information Models (BIM), and Einar Mattsson showcasing a project on heat pipes.

"We are very happy with the turnout and the big interest in our sessions and presentations," says co-director Jonas Anund Vogel.

Key performance indicators

In 2023 KTH Live-In Lab has developed according to the business plan and established Key Performance Indicators (KPI). KTH Live-In Lab has decided on three focus areas: methods for knowledge transfer, value-creating data from buildings and education connected to KTH Live-In Lab. Results from all three areas are used in the daily operations of KTH Live-In Lab.

KTH Live-In Lab's method for knowledge transfer

Develop methods for knowledge transfer from project activities to society. In this project, two processes have been developed: the project process (see figure 1) and the dissemination of knowledge and impact (see figure 2 below). Commitment and knowledge are partly linked to the project participants, which is why a model for trust and collaboration has been developed (figure 1) and a model for disseminating so-called implicit knowledge (figure 2).

It is of utmost importance that the focus area members' knowledge from collaboration as well as from project implementation is managed and followed up to ensure that it is disseminated within the organizations. Further collaboration, joint activities and follow-up studies lead to societal change and real impact.

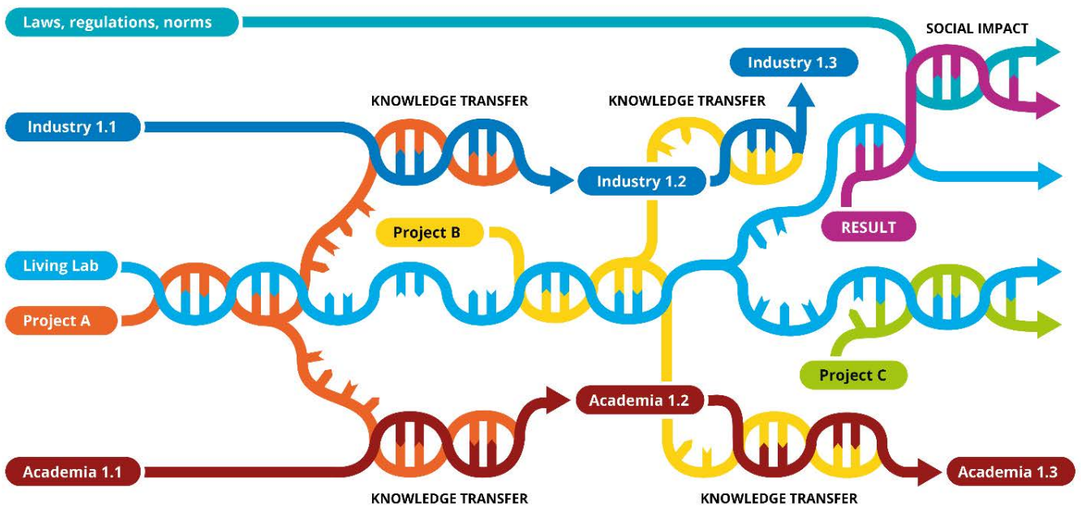
Value making data from buildings

KTH Live-In Lab collects data from testbeds, from so called 'trusted buildings', and makes this data available to researchers and students. KTH Live-In Lab also ensures that the data made available is in accordance with current rules and laws, such as GDPR.

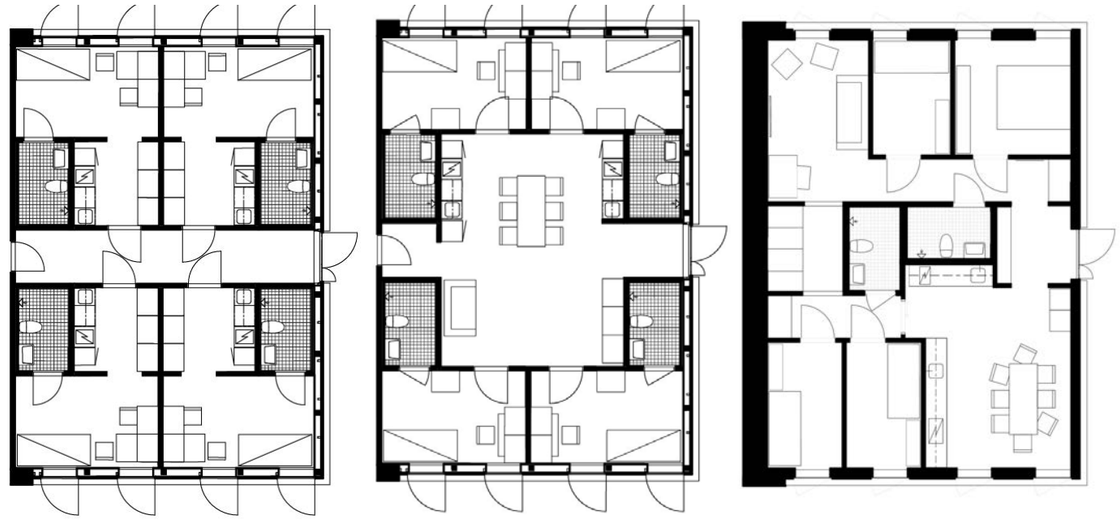
The work revolving around data management has been carried out in collaboration with the center partners Schneider Electric and Akademiska Hus, as well as partly in collaboration with KTH IT, Stockholm University and HSB Living Lab. The work has been partially financed by the Digitalisation platform at KTH. The work has resulted in KTH Live-In Lab being able to collect and make data available. Aspects such as GDPR and ethics reviews have been investigated by two consecutive research projects funded by Smart Built Environment.

Education 2023

The focus of this focus area lies on developing an education operation linked to the project operation and the utilization of knowledge. This task has resulted in proposals for the design of future education linked to KTH Live-In Lab, and several ongoing and completed activities such as week-long case studies in collaboration with the industry.



Knowledge transfer and impact in the form of DNA and m-RNA in relation to KTH Live-in Lab.



The evolution of the Testbed KTH: Testbed 1.0 (left image), Testbed 2.0 (middle image), Testbed 3.0 (right image)

KPI - Research

Table 3 – Research targets and results of KTH Live-In Lab for 2021 – 2023

KPI	Target 2021	Results 2021	Target 2022	Results 2023	Results 2023
Number of ongoing projects	10	16	12	12	21
Number of new projects	6	5	6	6	10
Number of projects initiated by the KTH LIL management group	1	3	4	4	5
School-wide project collaboration	50%	56%	50%	50%	56%
Number of spin-off projects	1	3	6	6	6

KPI – Impact and Communication

Table 4 – Impact and communication targets and results of KTH Live-In Lab for 2021 – 2023

KPI	Target 2021	Results 2021	Target 2022	Results 2022	Target 2023	Results 2023
Public presentations (discussion articles, newsletters, communication activities, study / site visits)	10	15	15	48	15	43
Seminars and Workshops	6	10	6	3	6	4

Partnerships

to enable multidisciplinary research

Center partners

During its active years KTH Live-In Lab has developed projects with 150+ partners, establishing collaborations between academia and industry, in Sweden and internationally. Today KTH Live-In Lab has four center partners – Einar Mattson, Akademiska Hus, Schneider Electric and Bengt Dahlgren – and 50 partners for ongoing projects.

Project Partners 2023

- Akademiska Hus
- Arken
- Asplan Viak
- Bengt Dahlgren AB
- Boiler
- Castellum
- Chalmers University of Technology
- Charles Strand Design AB
- Dandelion
- Digital Futures
- Einar Mattsson
- EQUA
- Ericsson
- ETM Kylteknik
- HP
- KTH ABE
- KTH Digitalisation platform
- KTH EECS
- KTH Green Leap
- KTH ITM
- KTH Media Technology and Interaction Design
- KTH Sustainability
- KTH
- Lund University
- Lunds Tekniska Högskola
- Myrspoven,
- NIBE
- Northvolt
- Noss Invest
- NOWAB
- Padua University
- ProptechCore
- RISE
- Rototec
- Sally-R
- Schneider Electric
- Sindeq borrteknik AB
- SISAB
- SSSB
- Stockholm University
- Sustain Lab
- Swegon
- Thermia
- ToM Energy Consulting Company
- Umeå universitet
- Unige
- Uppsala Universitet
- Vasakronan
- Volvo cars
- Wilo

Einar Mattsson

Einar Mattsson has built 305 high-quality student housing units on the KTH Campus. Totaling 6,329 square meters. These include the KTH Live-in Lab testbed, built in collaboration with KTH, with Einar Mattsson as the main financier.

The units are rented to KTH and owned and managed by Einar Mattsson. The first students moved in in September 2017. KTH Campus plays an important part in the city of science, together with Stockholm University and Karolinska Institutet. Nature and green spaces are prominent parts of the area's character, including a steep slope with visible hills and mountains.

The design of the three detached buildings, which are located at KTH's highest point, was inspired by this natural setting. The houses, designed by Semrén and Månson, have a smooth concrete facade with French glass balconies that can be likened to sculptural stone blocks. They are built of solid materials for long-term durability. The boundary between the landscape and the built environment is important and sharp.

Outdoors, simple but powerful materials are used that relate to the materiality and feel of the buildings. Meeting places, in the form of a common bicycle room, a large laundry room with a study area and the common post room, have large windows to create safer outdoor environments.

The houses constitute a 'plus energy' property, which is made possible by, among other things, waste heat exchangers, geothermal heating and solar panels on the roofs. Einar Mattsson is a long-term property owner who sees the investment on the KTH Campus and the KTH Live-in Lab as an investment in creating an attractive and sustainable city.

The Einar Mattsson Testbed

The building

- Built in 2016-2018
- 305 apartments
- 10 590 m2 (Atemp)
- Concrete exterior wall elements outer wall: 0.11 W/(m2*K)
- Windows U-value: 0.64 - W/(m2*K)

The energy system

- 3 heat pumps x 60kW
- 667 solar panels
- Battery Storage System from Northvolt (186 kWh) connected to PV
- Microgrid system that enables energy sharing between the three buildings
- 4+1 ventilation units (FTX)
- Geothermal heating, 12 bore holes, 3 185 meters
- Data collection units in all apartments for smart management of technical systems

Akademiska Hus

Akademiska Hus has built 230 student apartments at Teknikringen on the KTH Campus in Stockholm, with room for more than 400 students. The need for student housing in Stockholm is strong, and housing availability is crucial for the city's future attractiveness.

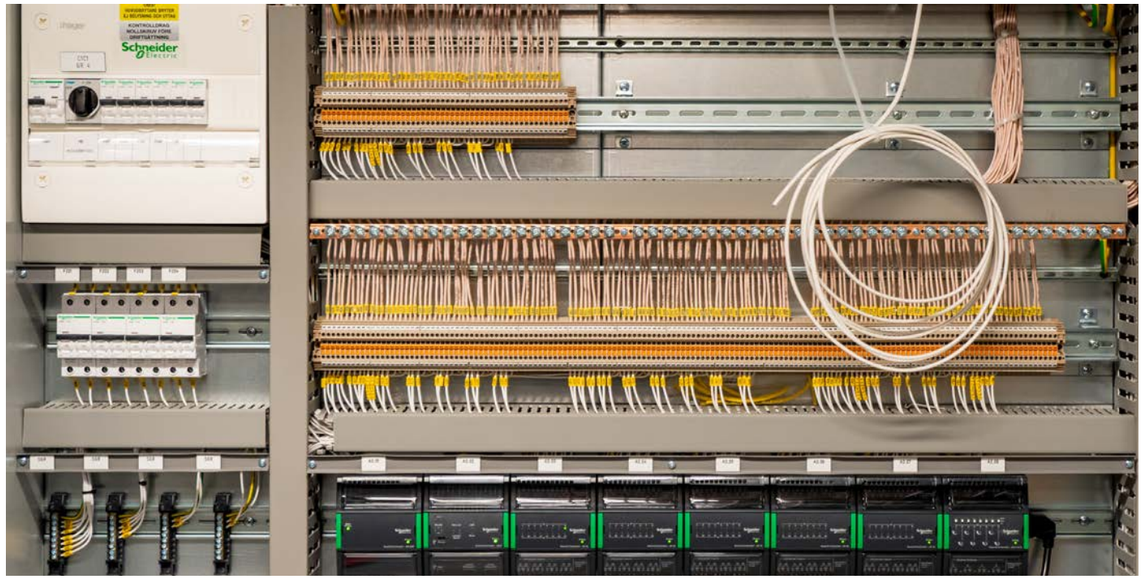
Akademiska Hus provides the Teaching House at the KTH Campus as a testbed to enable testing and research in collaboration with KTH Live-In Lab. More housing contributes to a more vibrant campus as people are present, living their lives at all hours of the day, something that both Akademiska Hus and KTH strive for.

The engagement of Akademiska Hus in KTH Live-In Lab aims to make it possible for new competitive, environmentally sound and sustainable products and services to reach the market more quickly, in the end resulting in smart and sustainable buildings and campus areas.

Akademiska Hus, together with Einar Mattsson, Schneider Electric, and Bengt Dahlgren cooperated with KTH to enable an increase in the number of testbeds within KTH Live-In Lab. Also, to ensure impact from the research being performed at KTH and other universities. The sand-boxing methodology, going from ideas to physical installations within years instead of decades is Akademiska Hus way to solve problems for the future.

The Akademiska Hus Testbed

- Inaugurated October 2017
- Total area 3500 m2
- Designed according to the wishes of teachers and students
- Educational tool for aspiring architects and community builders
- 363 study places + 6 exercise rooms + 11 group rooms & break-out areas
- Undervisningshuset is built according to the environmental certification Miljöbyggnad Guld, which is the highest ranking (Gold, Silver, Bronze).



Schneider Electric

Schneider Electric wants to contribute to a more innovative construction sector and therefore deepened its cooperation with KTH Live-In Lab in 2019. Schneider Electric will actively participate in research and development at KTH Live-In Lab for three years through consulting, services, and technology.

‘With an increasing world population, digitalization and increased energy use, especially in buildings, the demand for innovation and sustainable solutions for buildings is greater than ever,’ says Andreas Finnstedt, Vice President, and Head of the Digital Energy business area at Schneider Electric. ‘We need to collaborate and together create solutions for sustainable buildings and cities that utilize our resources in a smart way.’

‘Our ambition is to contribute to this development and create tomorrow’s buildings and projects that can meet new demands and needs. The KTH Live-In Lab is an opportunity for us at Schneider Electric to test new solutions, products and services that contribute to more sustainable development.’

So far, Schneider Electric has installed smart home solutions. The installations are monitored and optimized and can be adapted by property owners, partners, and residents.

Schneider Electric at KTH Live-In Lab

Schneider Electric tests new solutions, products and services at KTH Live-In Lab.

So far they have installed:

- Smart home solutions (Wiser Energy, KNX)
- IoT platform EcoStruxure TM Buildings Operation
- Connected security system Security Expert
- Electric car charger EVlink

Bengt Dahlgren

The technology consulting company Bengt Dahlgren wants to contribute to a more sustainable and innovative construction sector and therefore joined KTH Live-In Lab as a center partner in 2021.

Bengt Dahlgren provides KTH Live-In Lab with knowledge about among other things, digitalization, and digital twins. A key activity and area where Bengt Dahlgren’s competence as a technology consultant is of the utmost importance is the development of Testbed X – a virtual Testbed made to enable research into the potential of digitalization for the design, production, and management of smart and sustainable buildings.

‘The digitalization of the construction sector is one of the major challenges the industry is currently facing. A digital test bed will enable the necessary development of tools for planning, production, and operation of smart and sustainable buildings. At the same time, the test bed will be a neutral platform where various universities and companies can test and develop the systems and services of the future for smart and sustainable buildings and cities,’ says Jonas Anund Vogel, co-director of KTH Live-In Lab.

For Bengt Dahlgren, this means that the company will invest in research and development at KTH Live-In Lab during a three-year period through consulting, services, technology and more.

‘Research and development are an important part of Bengt Dahlgren’s work and permeate our entire business. It therefore feels very exciting and important for us to expand the collaboration with KTH and contri bute with our knowledge within KTH Live-In Lab, and thereby enable future systems and services for a sustainable society,’ says Erik Bolander, CEO of Bengt Dahlgren Stockholm AB.

The Bengt Dahlgren testbed

Bengt Dahlgren’s collaboration with KTH Live-In Lab will run from 2023 to 2024. Bengt Dahlgren plays an important part in the development of KTH Live-In Lab’s new, digital testbed: Testbed X.

Bengt Dahlgren operates in the public construction sector and works with installation, fire and risk, construction, real estate, energy and the environment.

Thank you all for the great year!

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