KTH Live-In Lab

KTH Railway group seminar (Järnvägsgruppens vårseminarium)

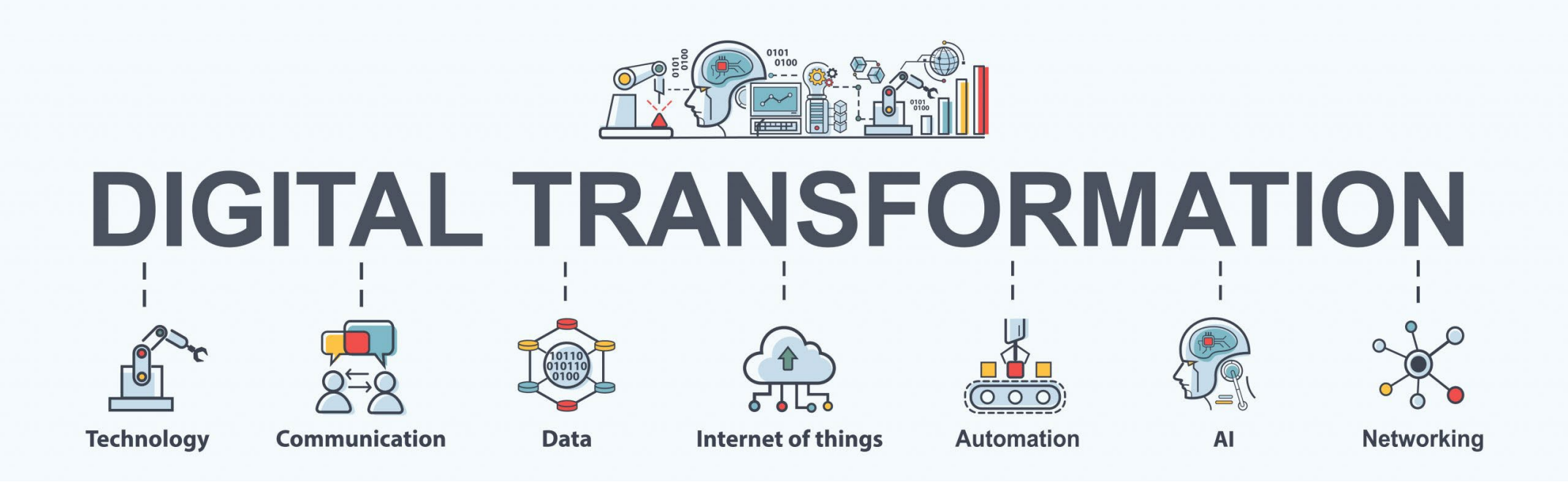
21st May 2026

Marco Molinari

Director

KTH Live-In Lab

Innovation bottlenecks in the building sector



"*Data is the new oil*", Clive Humby, 2006

96% UNUSED DATA

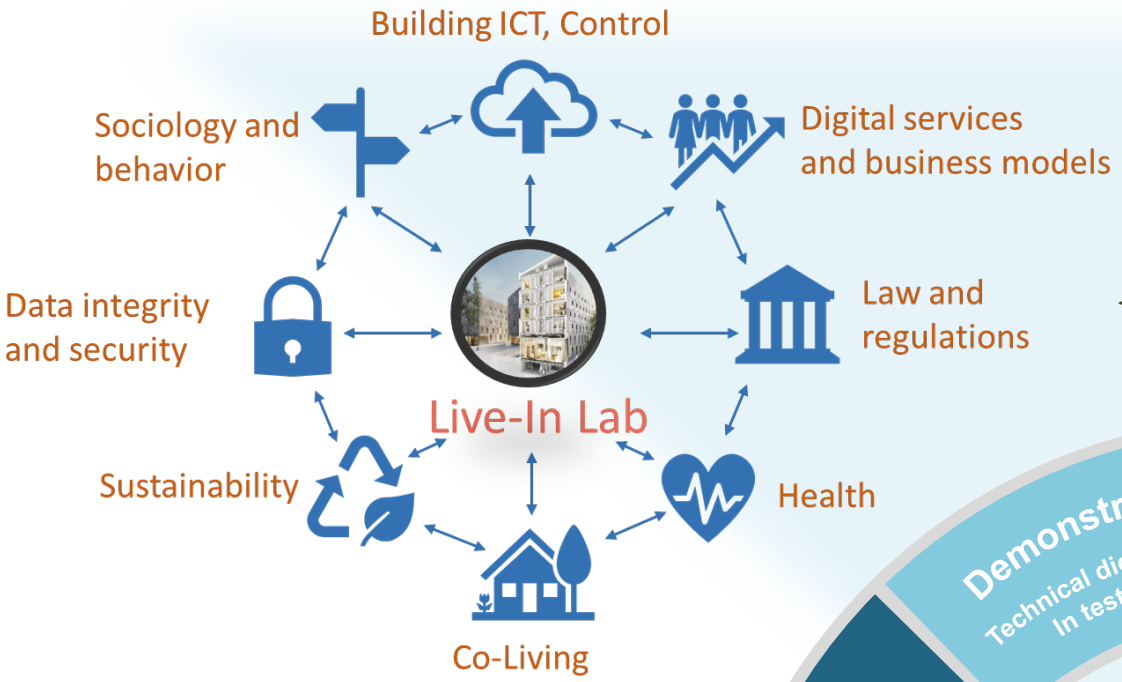
90% UNSTRUCTURED DATA

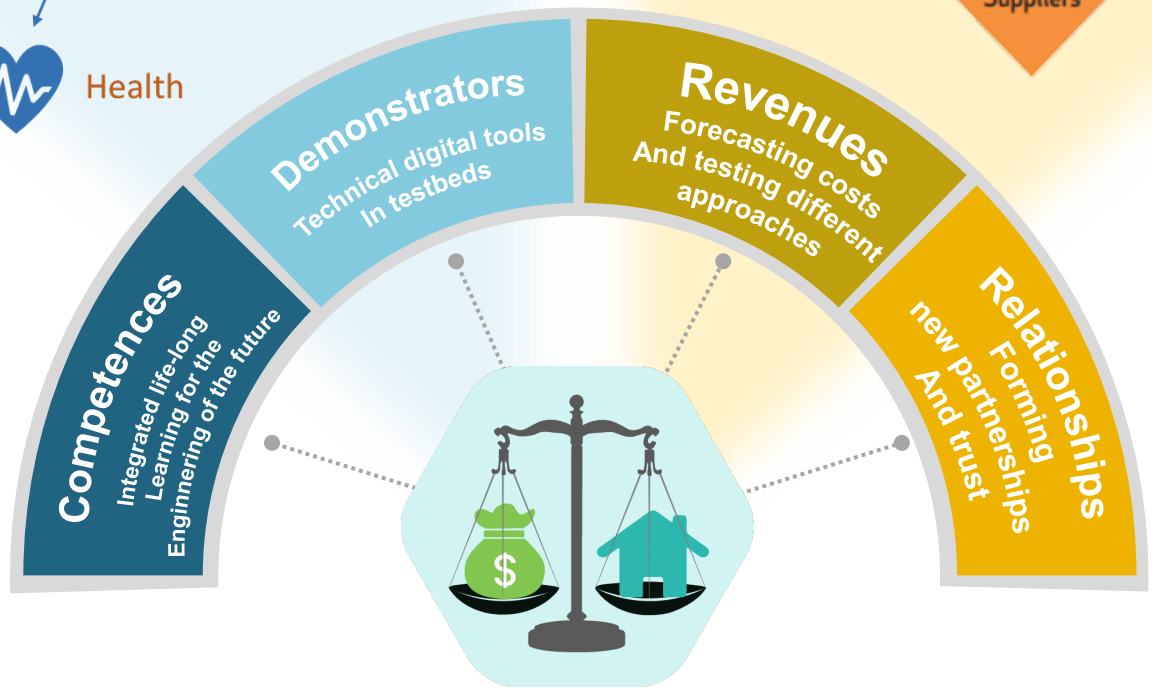
Vision

The KTH Live-in-Lab is an **infrastructure-enabled** *idea incubator* and *research facility* which bridges academia and practice in the built environment.

We mitigate risks along the innovation chain and we support novel tools to enhance sustainability in buildings.

Bridge the industry-research gap





Our assets

An ecosystem of internal and external skills and interests

Sensors and IT equipment

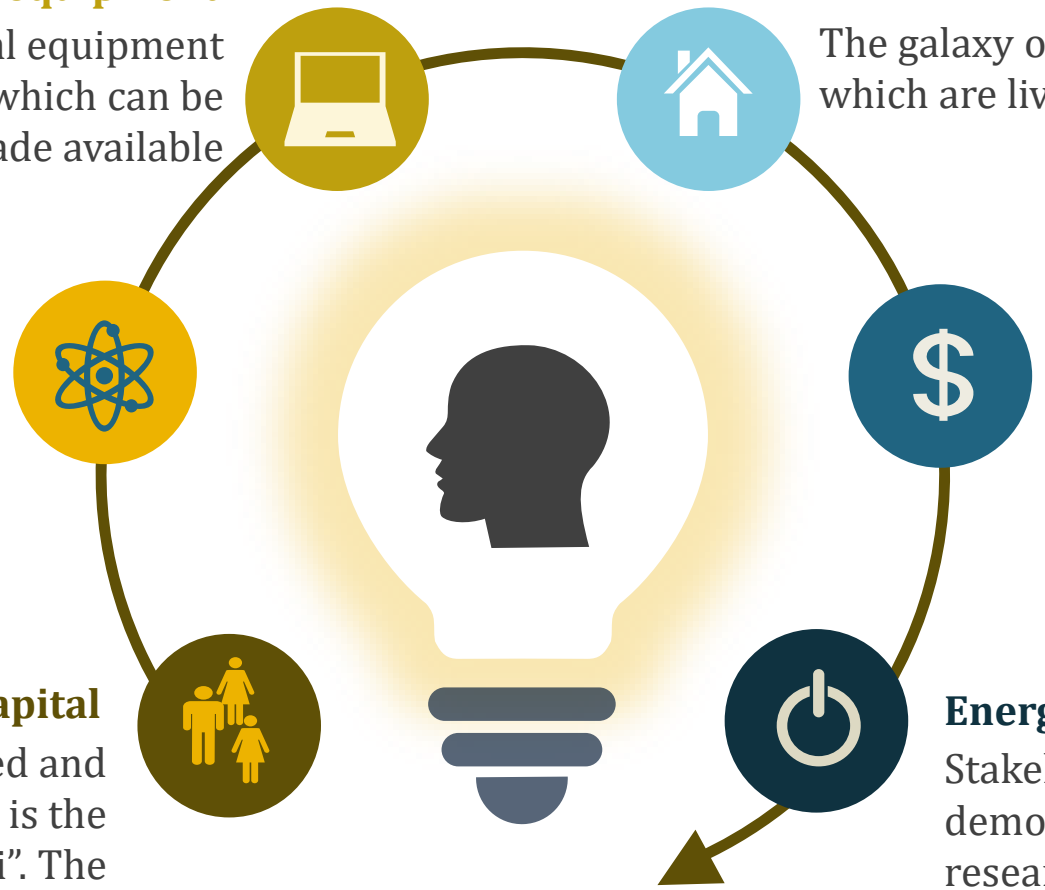
The technical equipment and tools which can be made available

KTH laboratories and competence centers

The galaxy of KTH in-house centers, some of which are living labs

Our testbeds

Three facilities which enable us to showcase and test different solutions



Partners and funding institutions

Internal (Digital Futures, KTH Sustainability Office) and external (VINNOVA, FORMAS)

Human capital

Our portfolio of awarded and completed projects is the network of our “alumni”. The core team is running the lab

Energy agencies

Stakeholders interested to demonstrators and applied research

The problems we solve

Acting as risk mitigators

Targeting innovation

Hard-to-test

As the sector is exposed to liabilities and innovation calls for high reputational and operational risks, the KTH Live-in-Lab **fit-for-purpose** competences to partners

Hard-to-develop

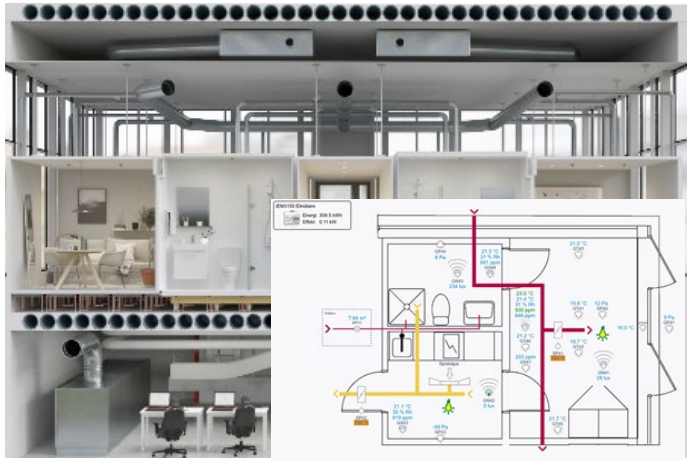
In presence of scarce human and financial capital, we help partners in the built environment with **theoretical and applied research**.

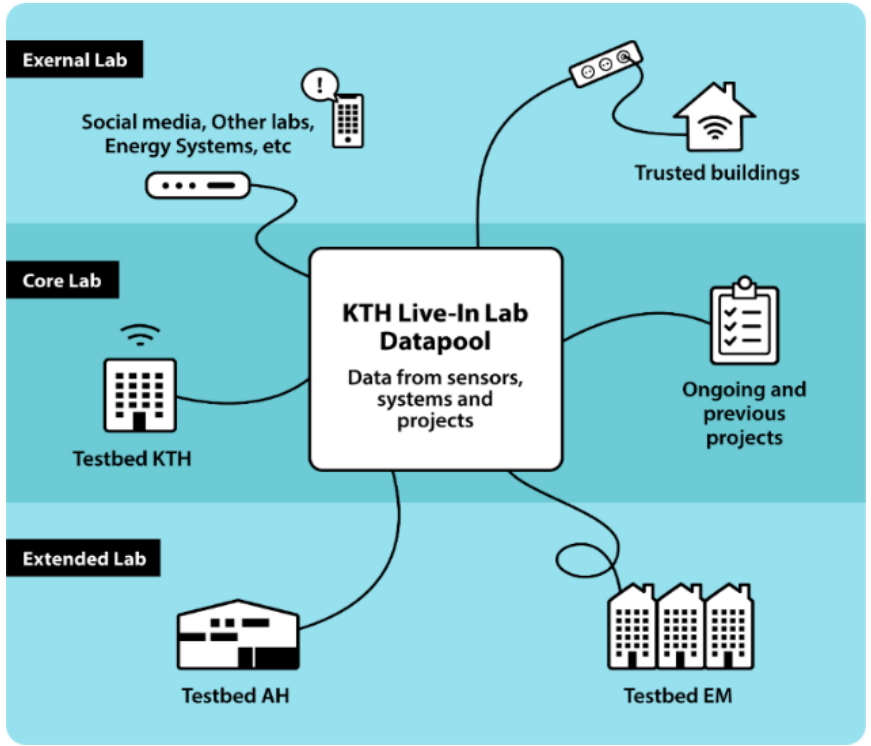
Hard-to-upscale

As knowledge owners, we are supporting partners by combinig smaller solutions for **multifaced, complex challenges**

KTH Live-In Lab: testbed and datapool

Testbed KTH



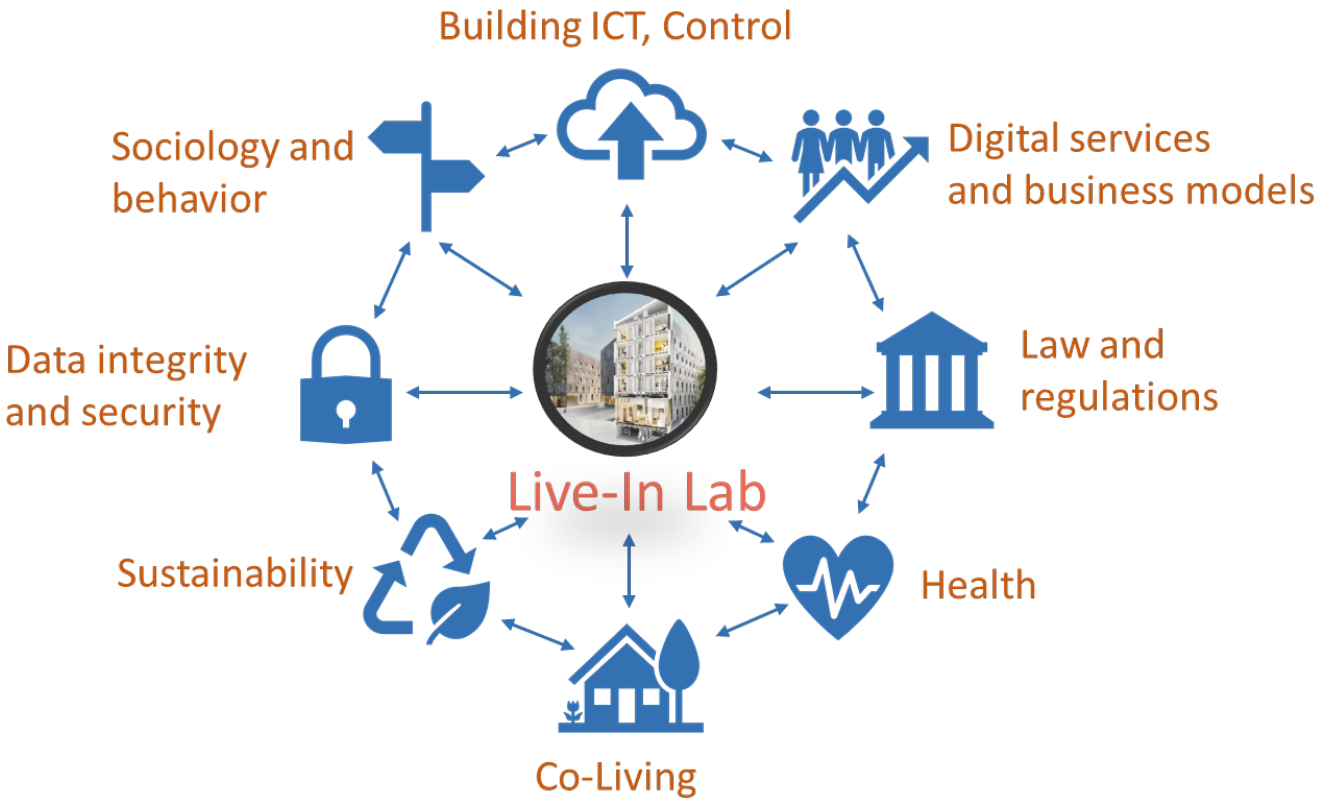


Testbed THS

Testbed Akademiska Hus

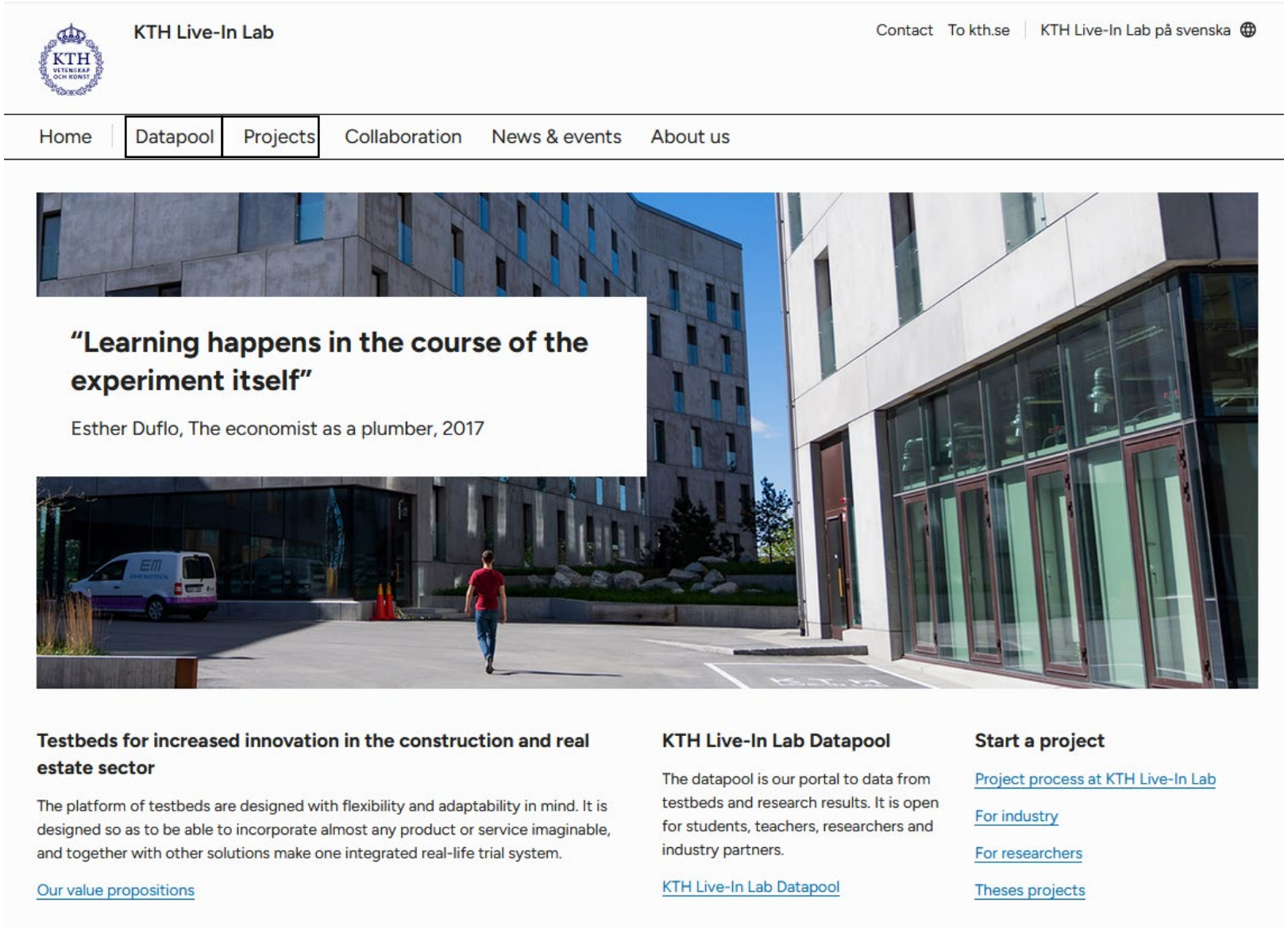
Testbed Einar Matsson

Why a center based on testbeds?



- Experimental testing and demonstration at various scales, including time, physical, and TRL.
- Simultaneous management of multiple projects – lean management and scale.
- Validated and reliable data and infrastructure.
- Network development and project-generated knowledge.

KTH Live-In Lab website



- Datapool
  - Building testbeds description
  - Access to datapool
  - Virtual tour
- Existing projects
- Collaboration
- News and events
  - Workshops
  - Joint seminars with other research centers (e.g. Dig It lab, Climate Action Center)

KTH Live-In Lab Residential Testbeds

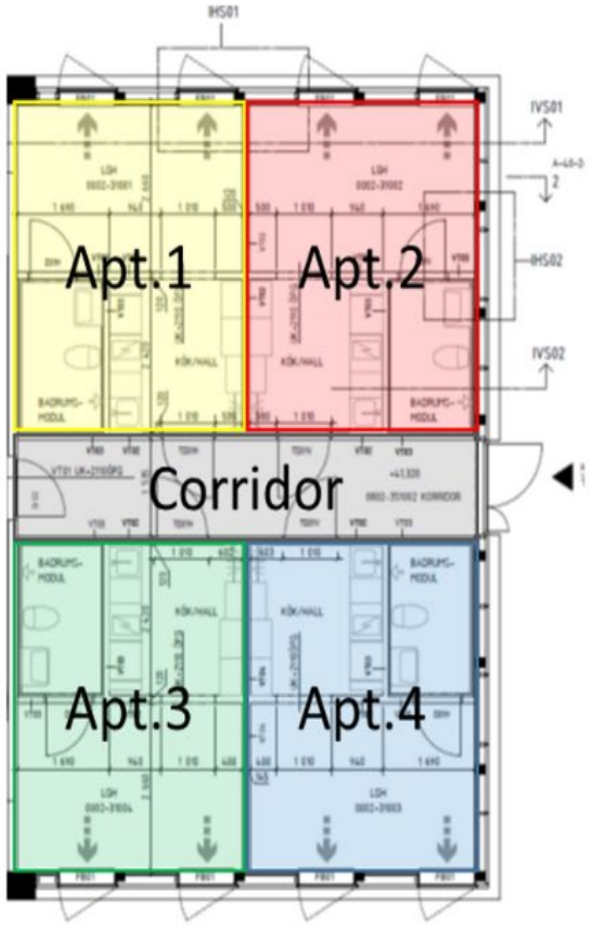
Plus-energy building design

- Low energy building envelope
- Ground source heat pumps: 12 boreholes
- TABS, thermally activated building systems
- Wastewater heat recovery
- PV panels mounted on roof
- Monitoring of the temperature distribution in the boreholes (optical fibers)
- Indoor sensors and weather station
- Energy storage systems

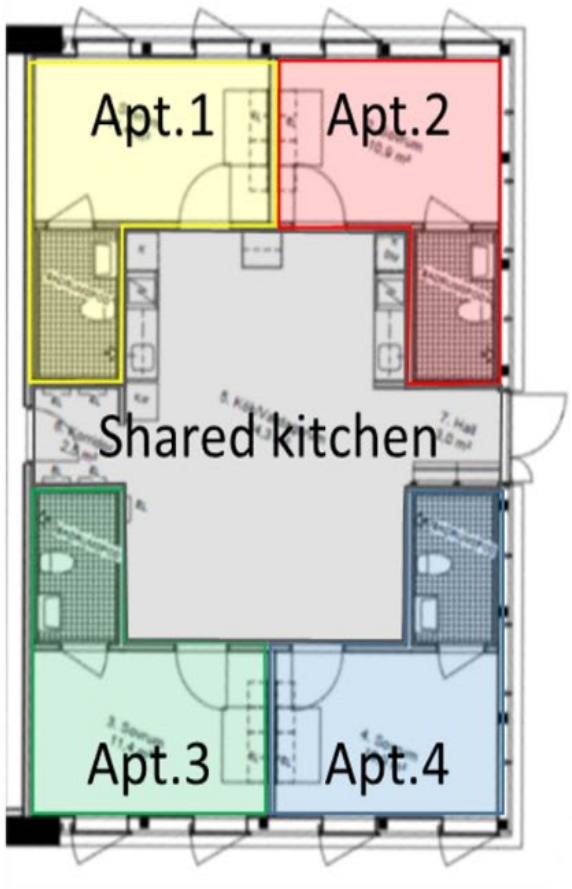
Three buildings, two testbeds

- **Testbed Einar Mattsson**: ~300 apartments
- **Testbed KTH**: 300 m^2

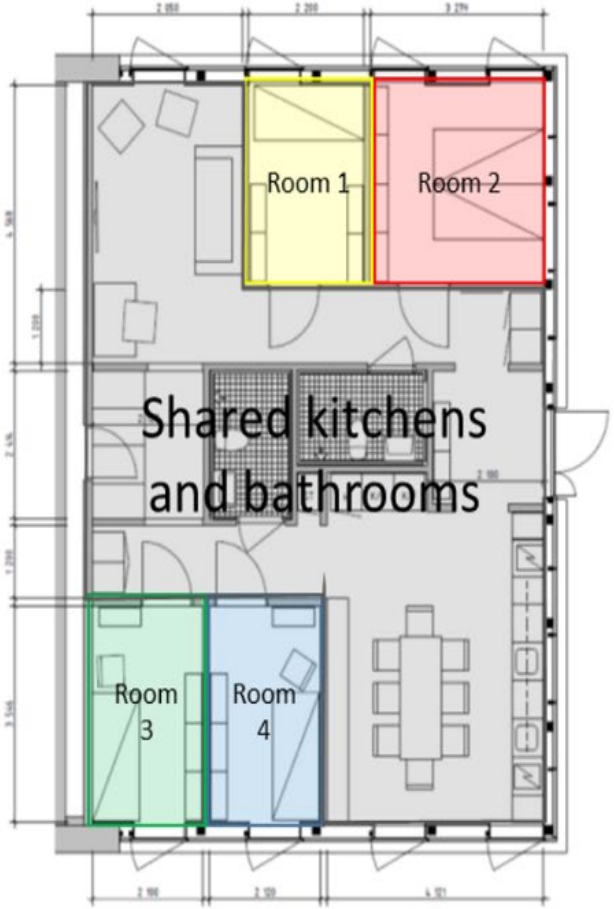
Testbed KTH: flexible layouts



Testbed 1.0
Aug 2018- June 2020

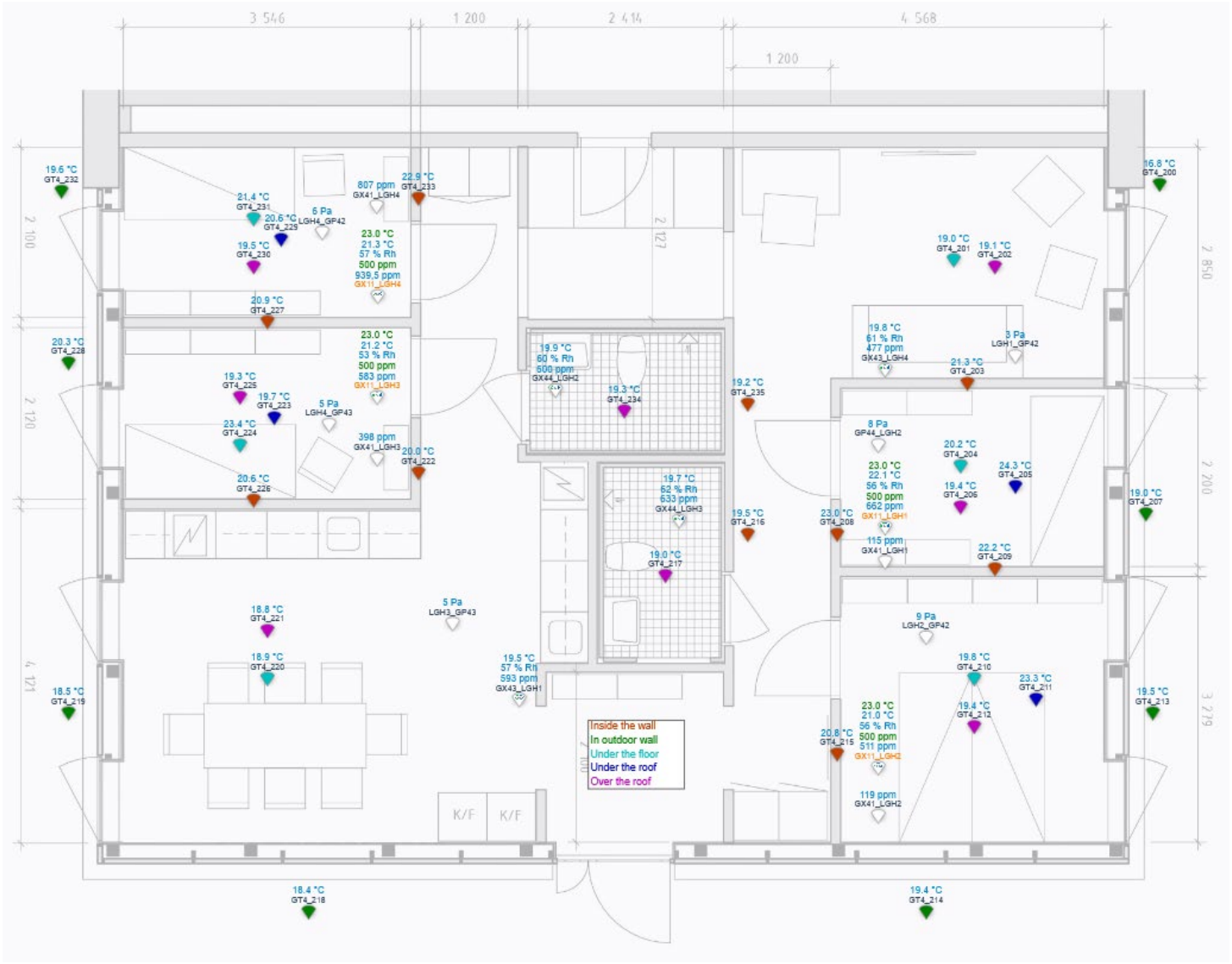


Testbed 2.0
Aug 2020- June 2021



Testbed 3.0
From Aug 2021

Testbed KTH: sensor placement



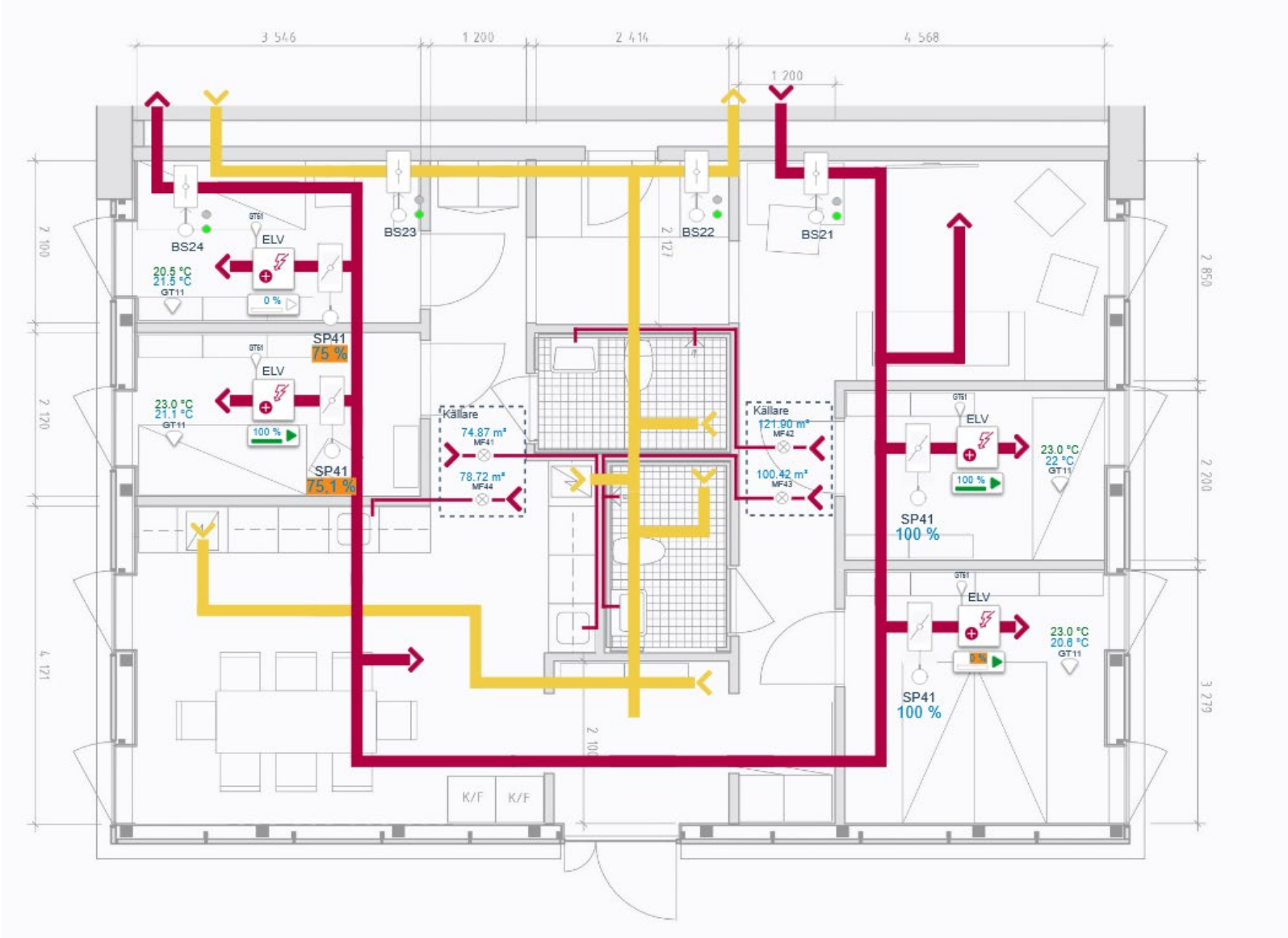
Indoor Environment Sensors

- Temperature
- Relative humidity
- **CO_2**
- VOC (Volatile Organic Compounds)
- **Window and door opening (magnetic sensors)**
- Light monitoring
- **Occupancy detection**
- Plug-based electricity metering
- Tap domestic fresh water use
- Tap domestic hot water use

HVAC

- Temperature
- Relative humidity
- Ventilation flows
- Energy flows

Testbed KTH: user interface



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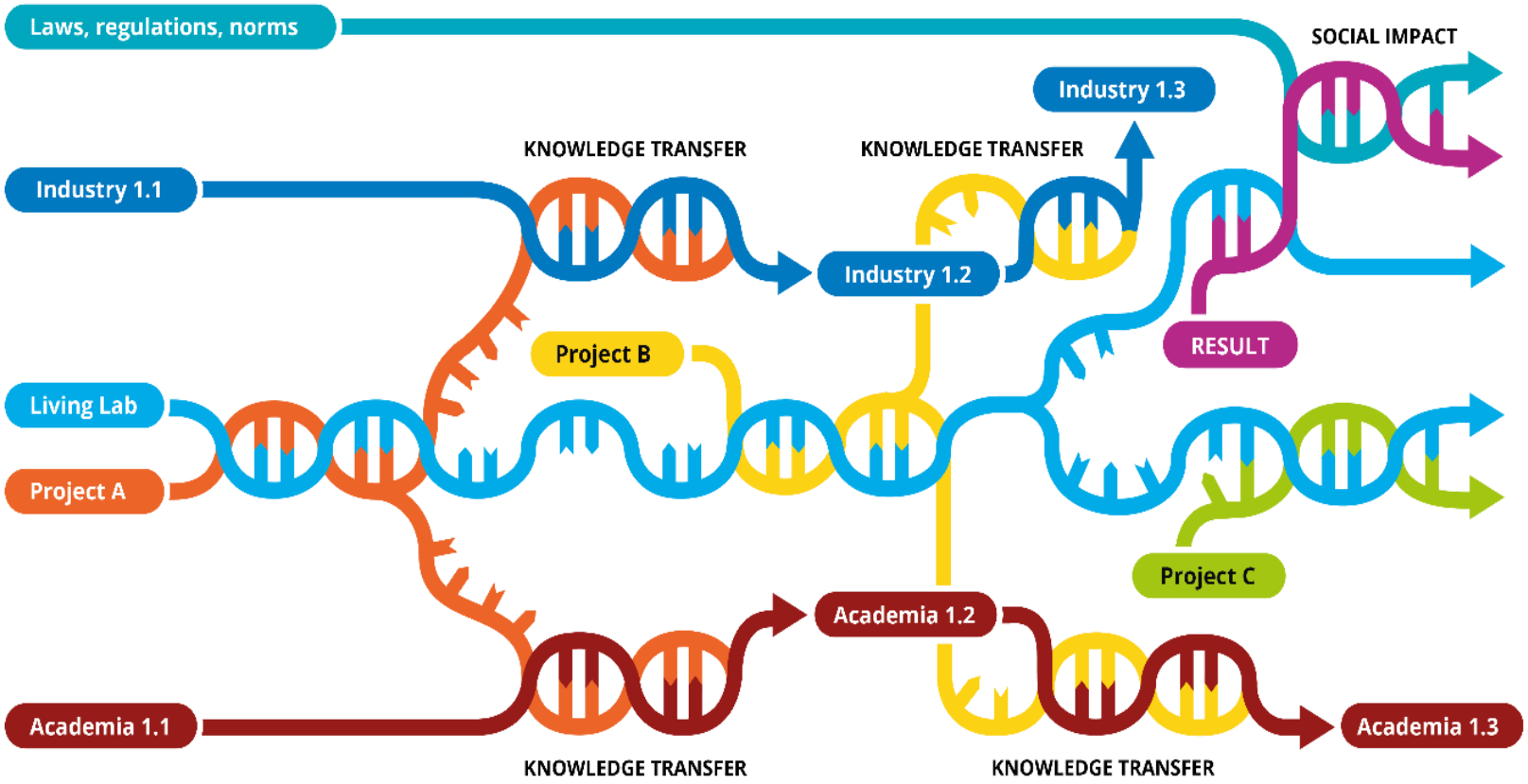
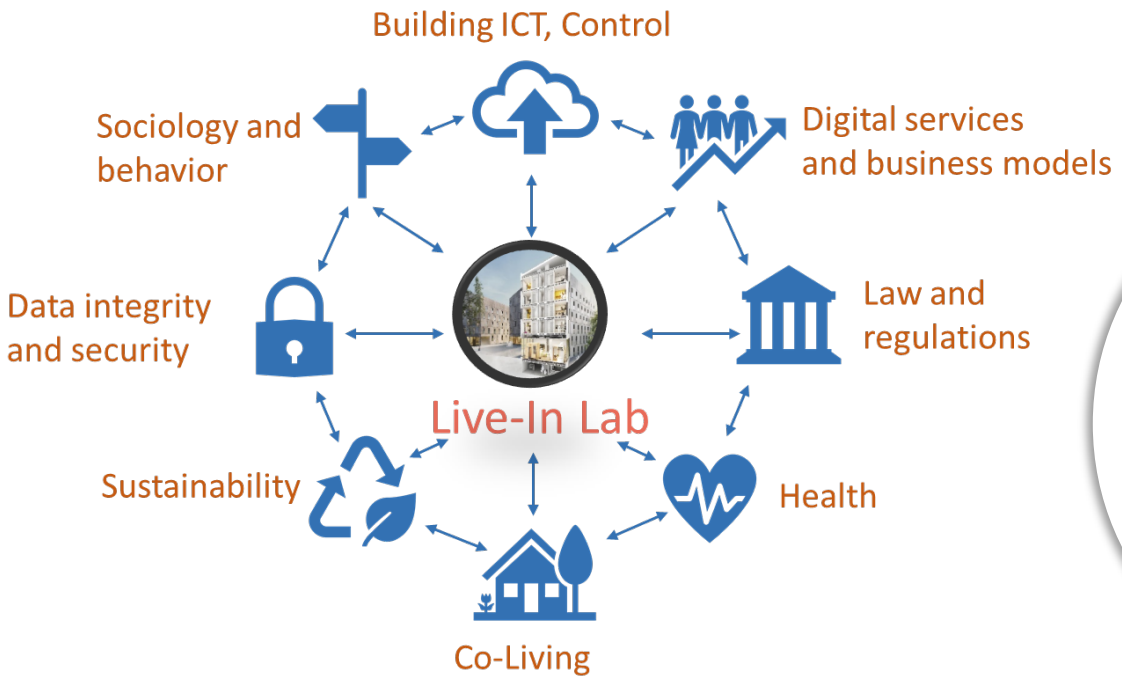
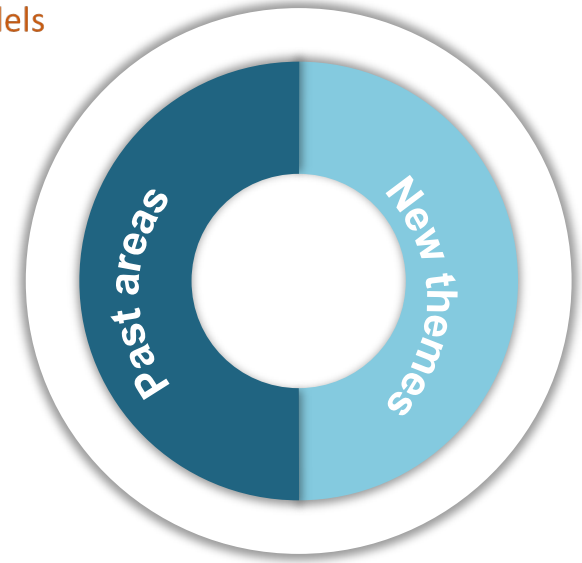
Knowledge transfer model - M-RNA



From research areas to themes





Sustainable innovation
Sustainability, law and regulation and business model innovation

Digital transition
Data integrity and security, digital services, building ICT

Humans-in-the-loop
Co-living, sociology and behavior, health

Horizontal research
Cross-theme applied research

Increase testbeds **Diversify research** **Expand network**

Network of building living labs

Existing network

- **KTH Live-In Lab**
- UniZEB, University of Padua
- HSB Living Lab, HSB/Chalmers
- NEST Empa Lab, Dübendorf (Zurich)
- Sisslerfeld living lab
- Lillestrom city lab
- Intelligent Human-Buildings Interaction Lab, Umeå University
- Green Campus Living Laboratory TU Graz
- UPV Living Lab, Valencia University

Financing channel for exchange:
COST action and New European Bauhaus Initiative

cost EUROPEAN COOPERATION IN SCIENCE & TECHNOLOGY

New European Bauhaus

Center partners

EINAR MATTSSON

AKADEMISKA HUS

Schneider Electric

BENGT DAHLGREN

KTH LIVE-IN LAB

Funding agencies

VINNOVA Sweden's Innovation Agency

FORMAS

SMART BUILT ENVIRONMENT

Energimyndigheten

IQ Samhällsbyggnad

Swedish Foundation for Strategic Research

digital futures

HORIZON 2020

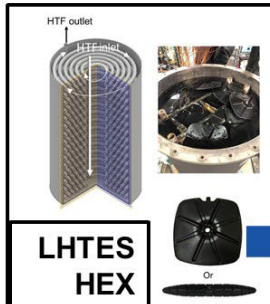
Project partners

AMS Institute, Arkitektkopia, Barkarby Science Park, Botrygg, Boverket, Chalmers, Charles Strand Design, Ecophon, Electricity, Energi och Miljötekniska Föreningen, EQUA, FM Mattsson, Geberit, Grunditz Göransson Arkitekter, Gustavsberg, HSB, HSB Living Lab, Invisense, Labtrino, Lidner Group, Lokalförvaltningen Göteborg, Lunds Universitet, Länsgården Fastigheter Örebro,Nibe, Northvolt, NREP, Podcomp, RISE, Saint-Gobain, Savvy, Stockholms Stad, Stockholms Universitet, Svenska Kyl -och Värmepumpsföreningen SKVP, Swedish Ventilation / Svensk Ventilation, Swegon, Thermia, Theory Into Practice Architects, Tovenco, Umeå Universitet, Vattenfallsgymnasiet

Projects (selection)

HYSTORE

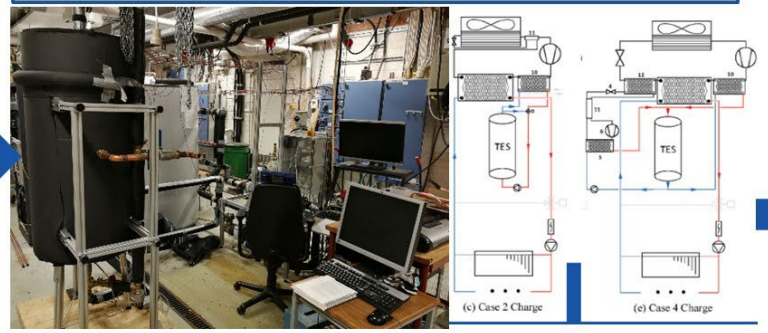
Hybrid services from advanced thermal energy storage systems



LHTES HEX

Improved design of LHTES+ HEX (submerged: HEX in PCM or encapsulated PCM in HTF

Pilot-scale LHTES to be further designed & optimized **for combined operation with a HP**



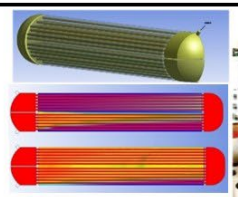
LEFT: The pilot-scale LHTES system at KTH that will be further developed and designed, and *RIGHT*: conceptual designs of this developed LHTES for combined operation with HPs (Air-source and Ground-source) → **PCM Heating Solution**

KTH Live-in-Lab

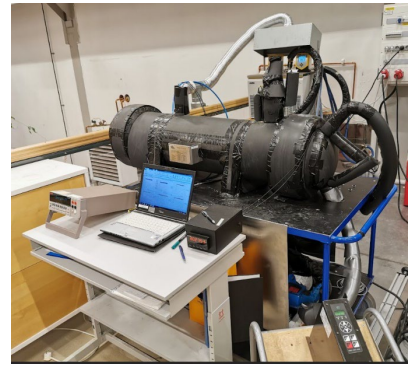
The demo site: where **PCM Heating Solution** will be run for optimized operation &contr

Bench-scale LHTES material testing)

LHTES with a shell-and-tube HEX for supercooling & hysteresis analysis

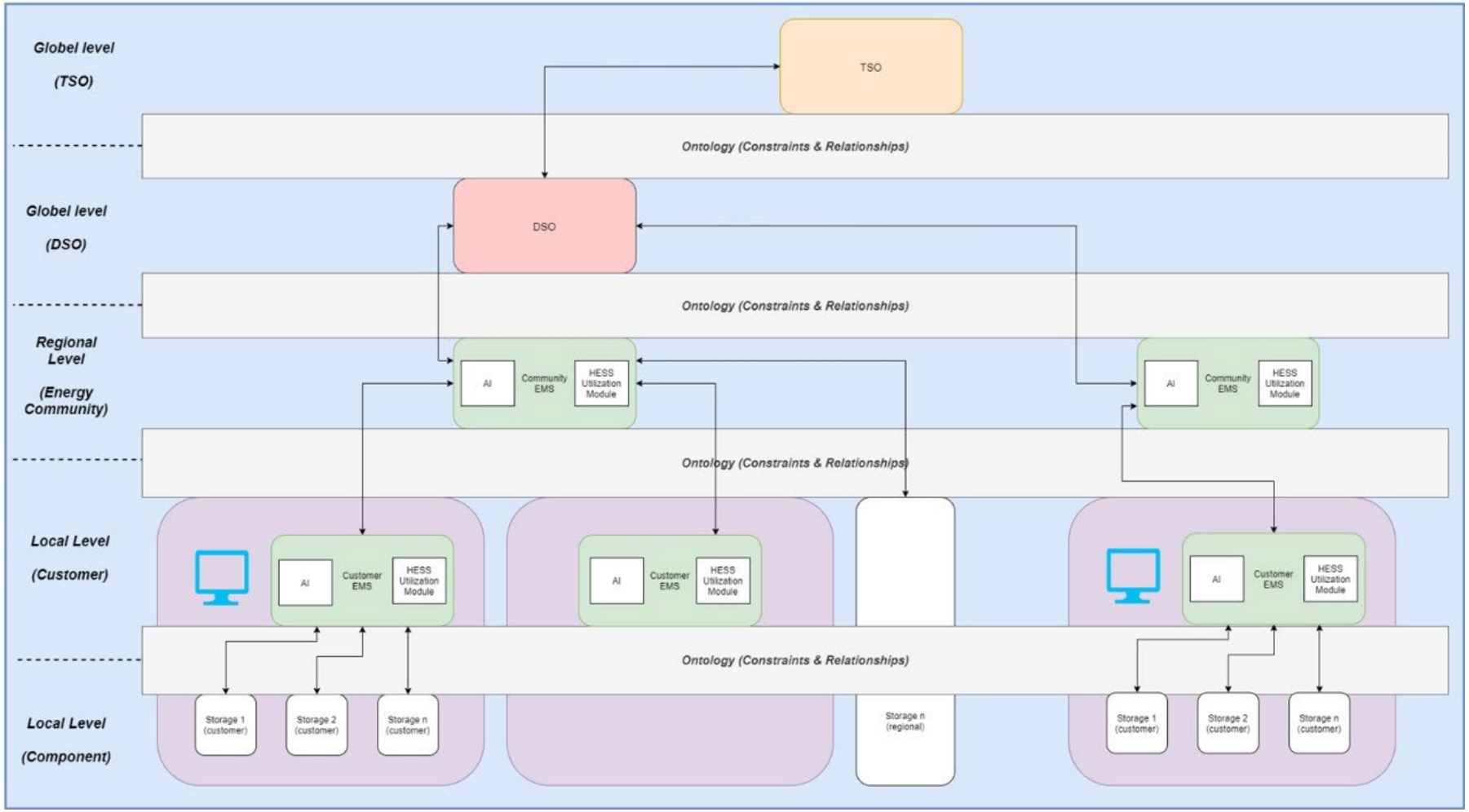


BMS, Internet of Things (IoT) & Techno-economic optimization



PARMENIDES

Plug & plAy EneRgy ManagEmeNt for hybriD Energy Storage



PARMENIDES aims to develop an interoperable and secure ontology-based **Energy Management System for HESS** (EMS4HESS) suited for ECs with energy **storage** technologies, with a focus on the electricity and heating domain, so they can offer **flexibility services to the grid**, while finding a **balance between stakeholders' individual and collective objectives**.

Turnkey solutions with PV and energy storage

Goals

- Enhance access in the housing sector to solar electricity by identifying sustainable PV-ESS business models.
- Develop and demonstrate two key PV-ESS related innovations that increase the flexibility and resiliency of solar PV systems towards an integrated operation in buildings.

A demonstration test-bed.

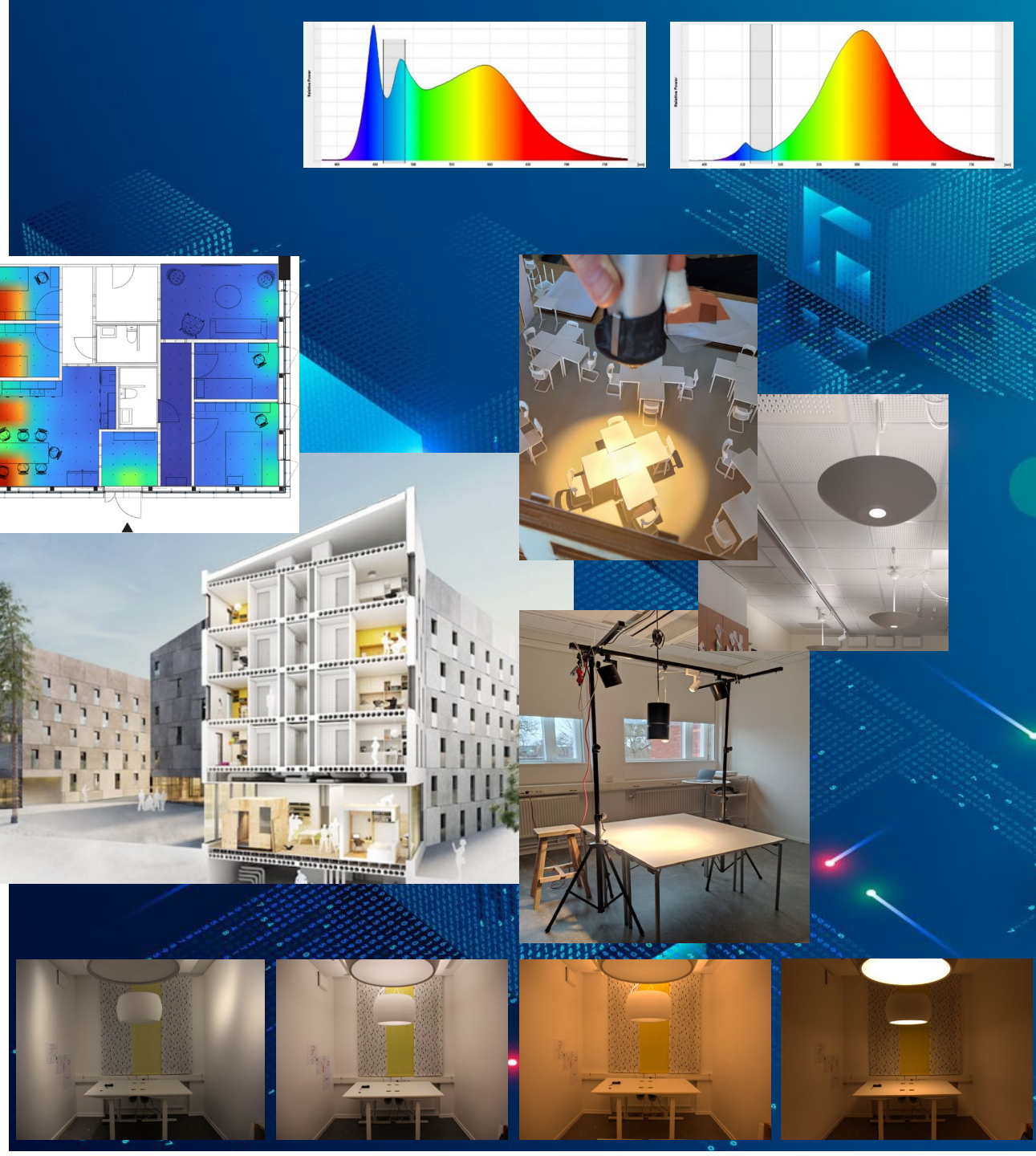
- 150kW solar PV installation, a 300kWh target battery system and an optimized management of the integrated solution.
- First of a kind Li-ion battery installation made of prismatic-cell packaging design manufactured and assembled in Sweden with a depth of discharge of 80% and lifetime of 5,000 cycles.

PLEXE

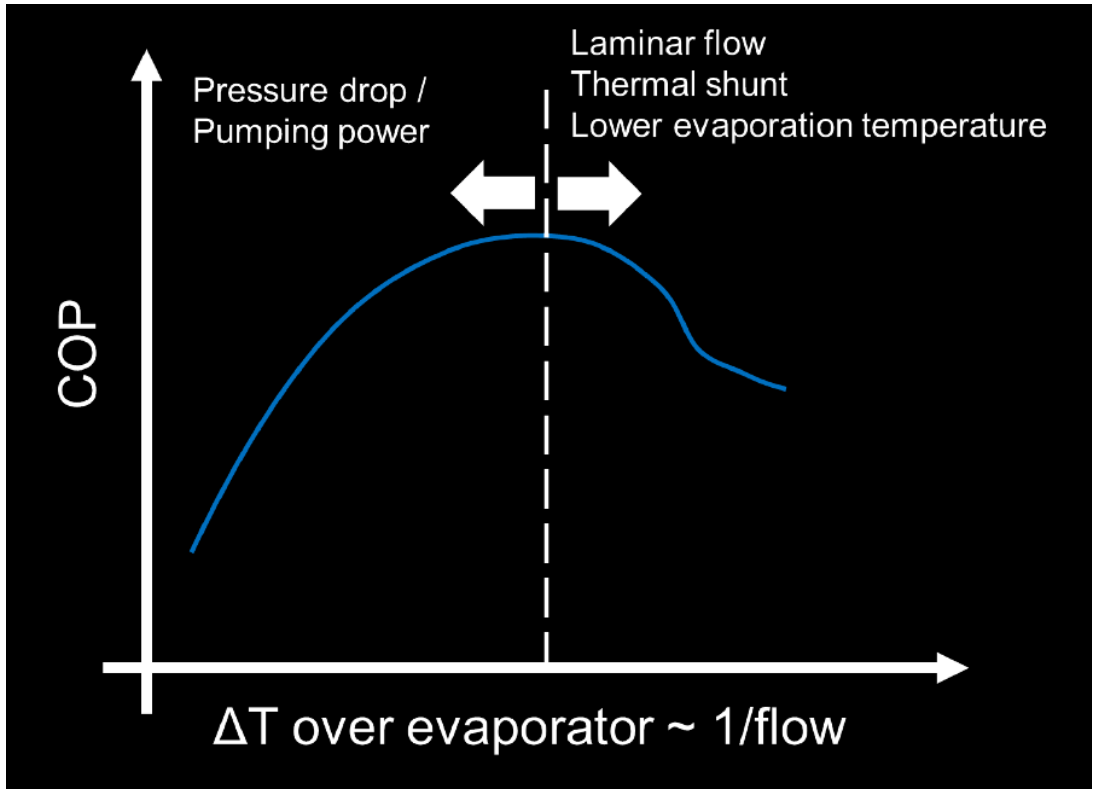
Platform for Lighting Effects Experimentation Environments Background

Lighting Effects Experimentation Environment **Design**

- **Lighting Design**:
  - Placement of spectrally-tuneable lighting systems.
  - Consideration of light distribution, retinal impact, and control usability.
- **Sensors Design**:
  - Strategic positioning of activity and spectral sensors.
- **Data System Design**:
  - Secure, privacy-sensitive, and sensor-accessible IT infrastructure.



Optimal flow for maximum performance of geothermal heat pumps



Geothermal heat pumps already have good performance today, but it could be 10 to 40 percent higher if the optimal flow was used in the borehole circuit.

- How does the optimal flow change with different depths and thermal short-circuiting in borehole heat exchangers?
- How does the optimal flow change, for example, with two 500-meter deep boreholes instead of five 200-meter deep boreholes?
- Does the optimal flow shift (and if so, by how much) as the temperature decreases, such as due to the transition between laminar and turbulent flow?
- Does the optimal flow change when coaxial heat exchangers are used instead of U-tubes in the boreholes?

Cost- and Energy-Efficient Control Systems for Buildings

Swedish Energy Agency

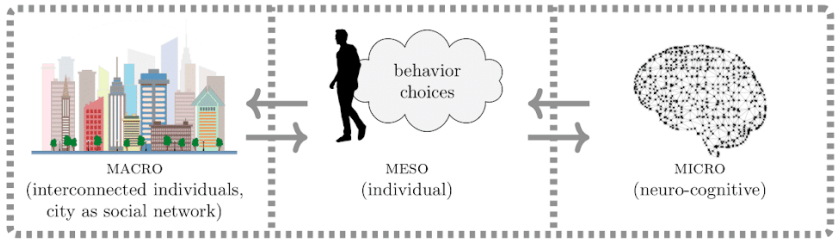
Are smart buildings so smart?

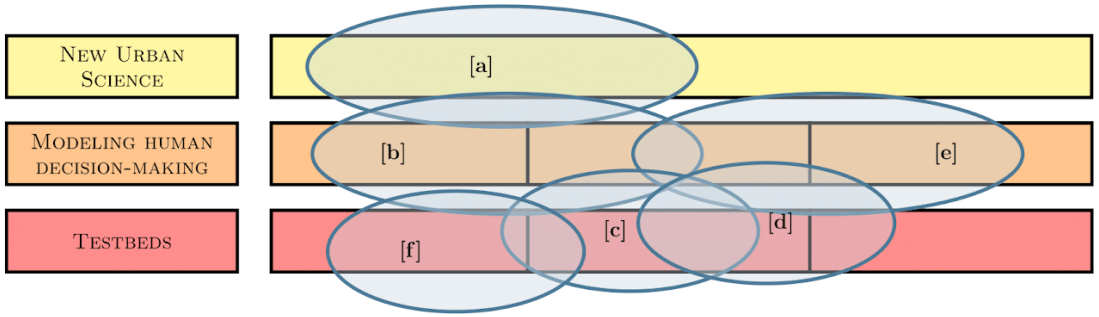
- assess the quality of data from advanced monitoring systems
- enhance existing features and improve the exploitation potential of existing databases
- detect and identify the most common faulty settings in the heating and ventilation that are causing the systems to underperform and estimate the related energy waste;
- test and implement of advanced and self-tuning control strategies;
- showcase the feasibility and cost-effectiveness of ICT solutions to increase the efficient energy use in buildings and improve comfort

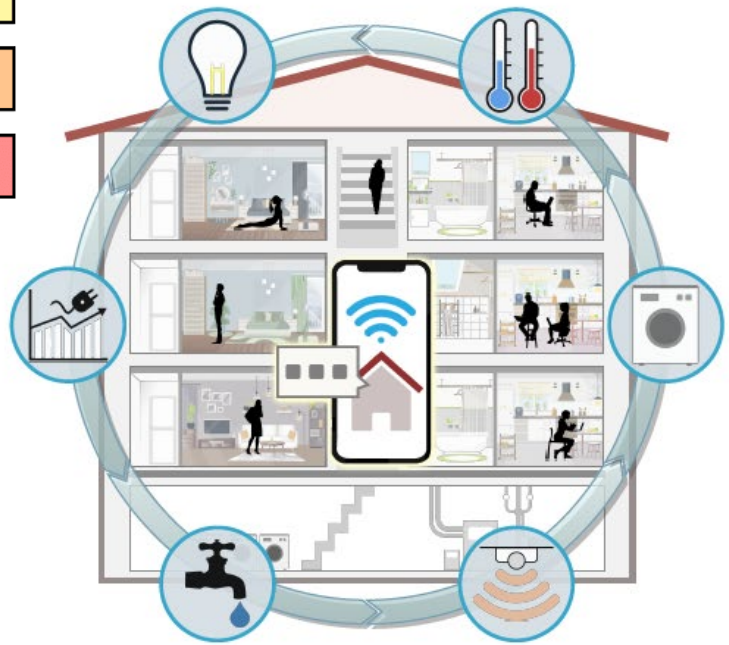
HiSS

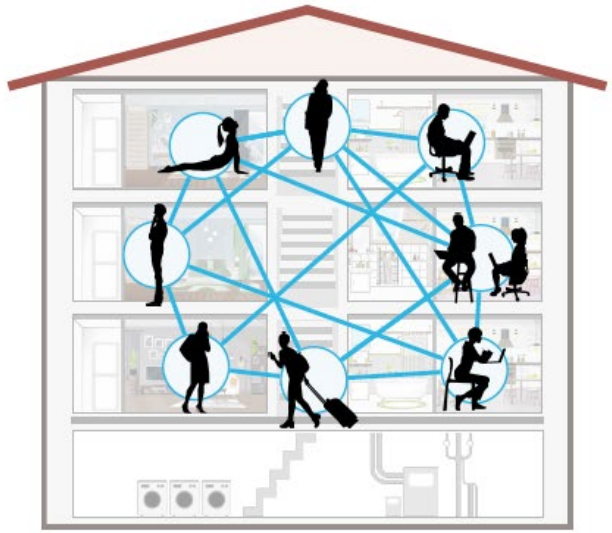
Humanizing the Sustainable Smart city

digital futures



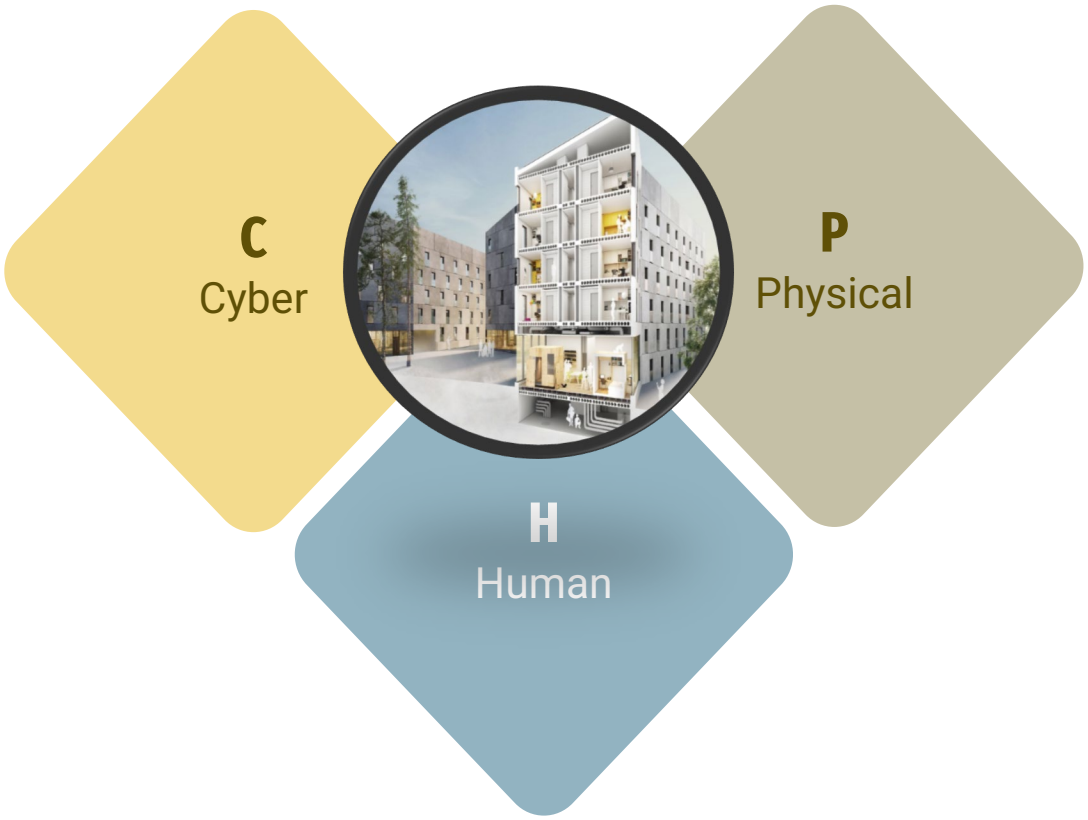






DOCENT

Development of Occupant-centric Control for ENergy efficienT buildings

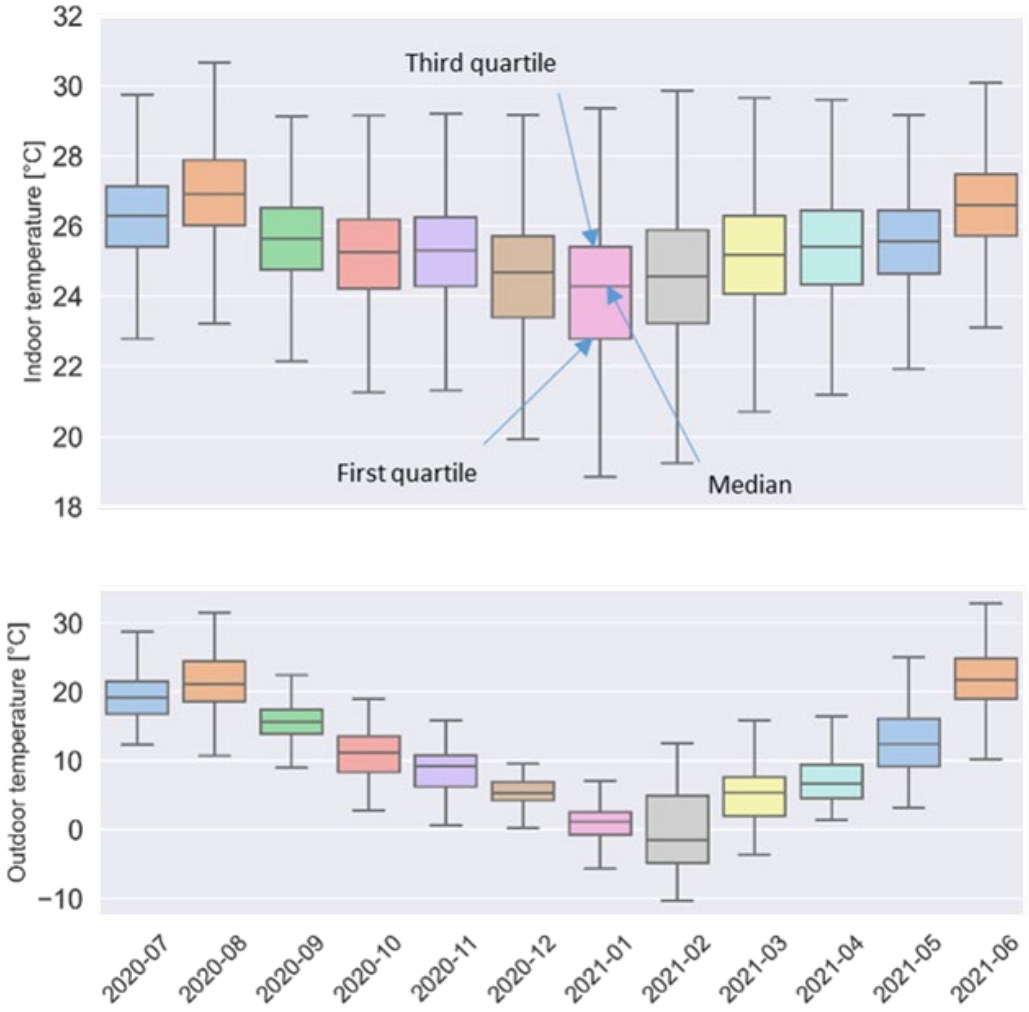


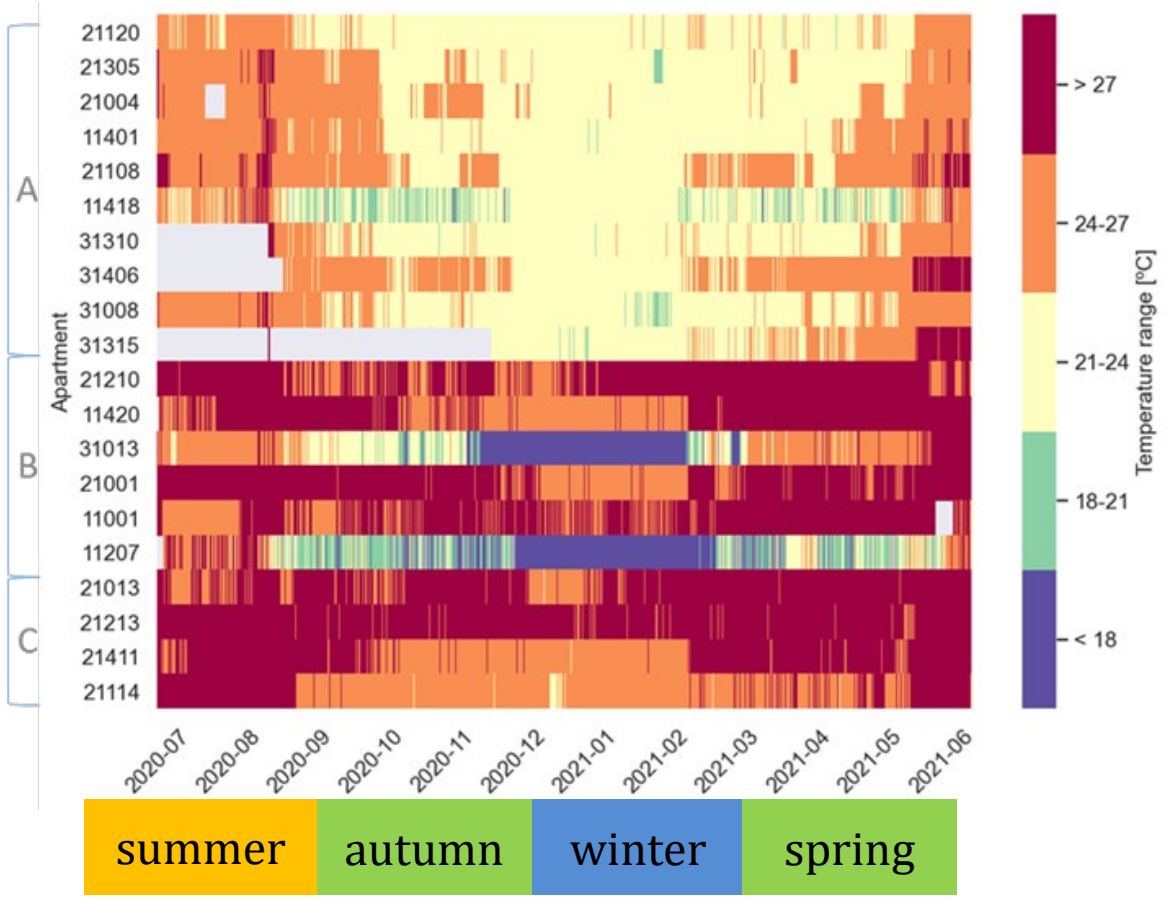
Behavior of building occupant

- **Occupants** are no longer seen as mere recipients of the indoor climate but as **active agents in the optimal operation of buildings** to achieve better indoor climate and improved energy efficiency.
- **Digitalization** enables a **better understanding of occupancy** and **behavioral patterns** and their impact on energy use, but many challenges are still unsolved.
- This project will develop **occupant-centric control systems** through an innovative hybrid research approach, using data-driven tools and digital twins.

Results from projects (selection)

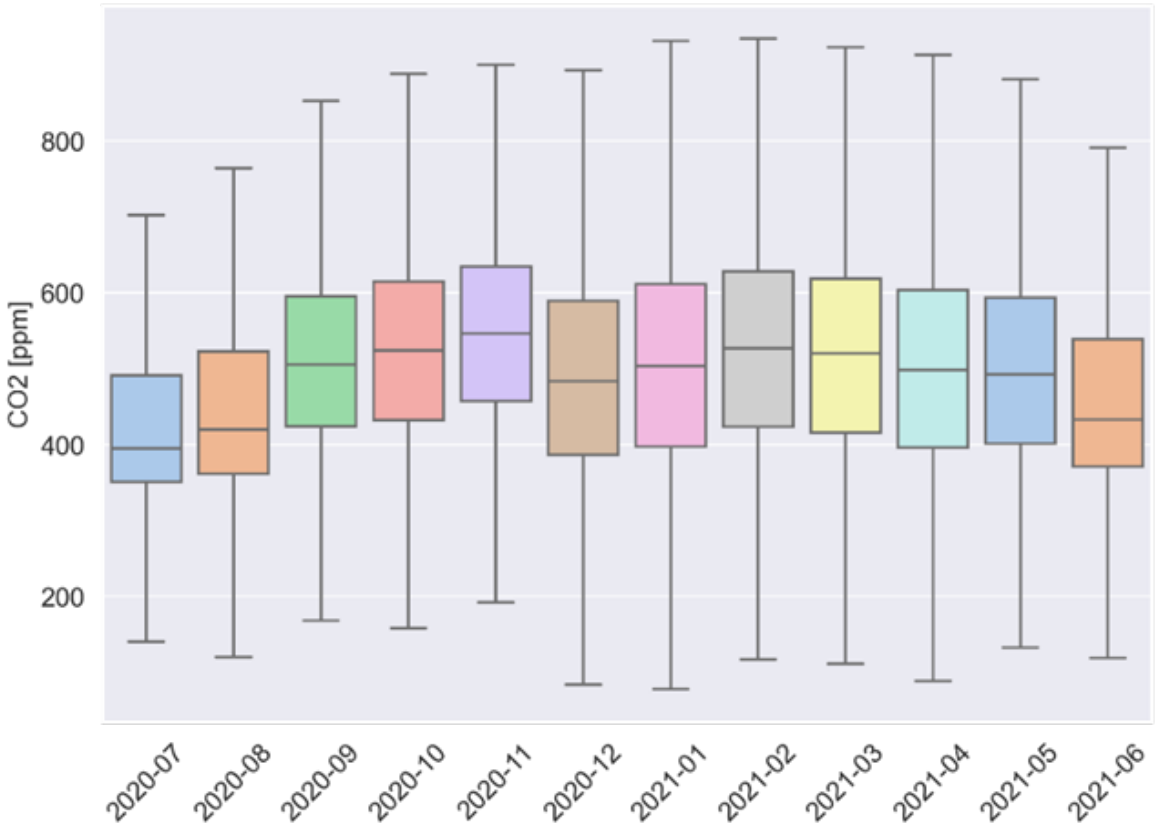
Faults: thermal comfort

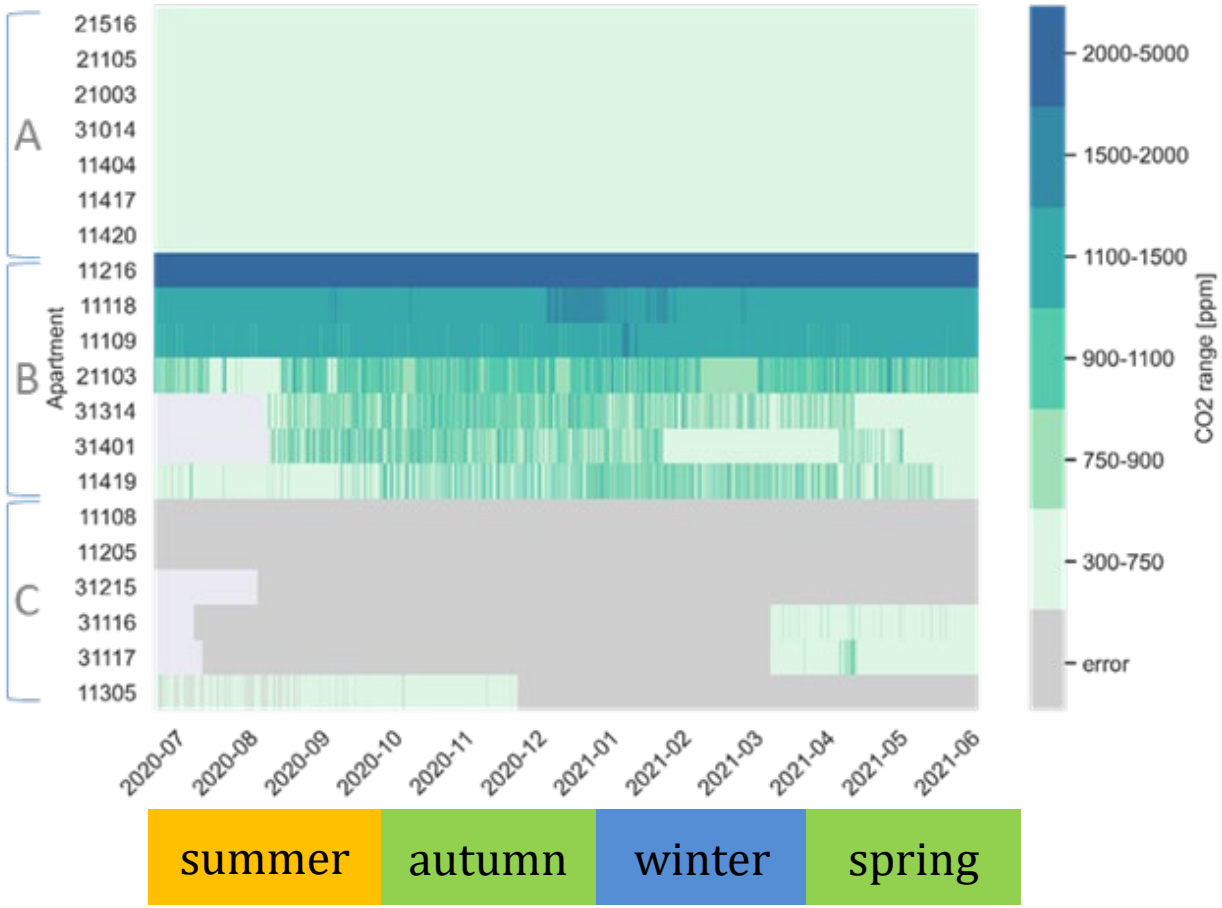




D. Rolando, W. Mazzotti and M. Molinari, "Long-Term Evaluation of Comfort, Indoor Air Quality and Energy Performance in Buildings: The Case of the KTH Live-In Lab Testbeds," Energies, vol. 15, no. 14, pp. 4955, 2022.

Testbed EM: indoor air quality – CO2





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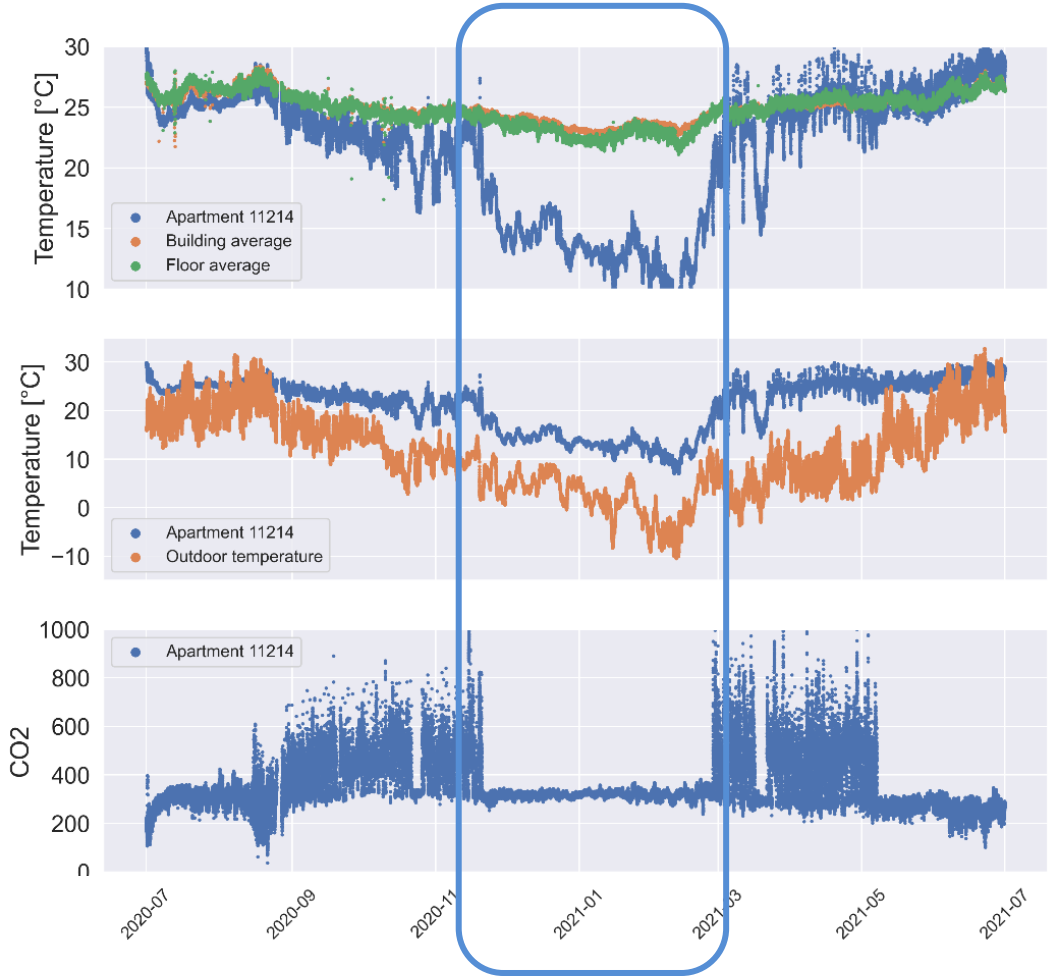
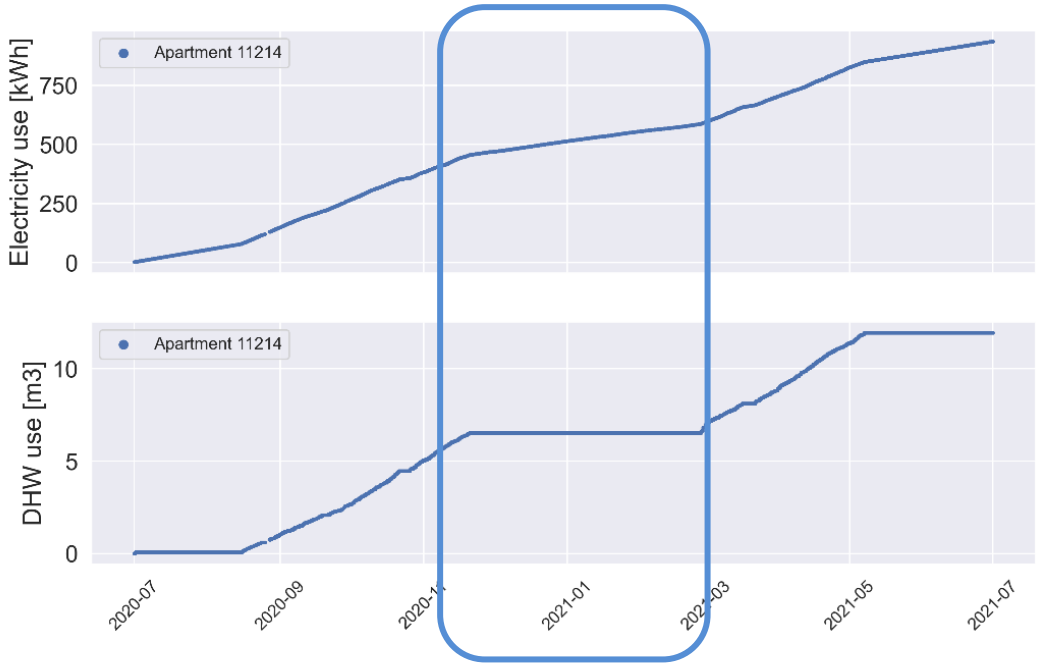
Impact of user behavior in buildings





Windows open with no occupants

D. Rolando, W. Mazzotti and M. Molinari, "Long-Term Evaluation of Comfort, Indoor Air Quality and Energy Performance in Buildings: The Case of the KTH Live-In Lab Testbeds," Energies, vol. 15, no. 14, pp. 4955, 2022.

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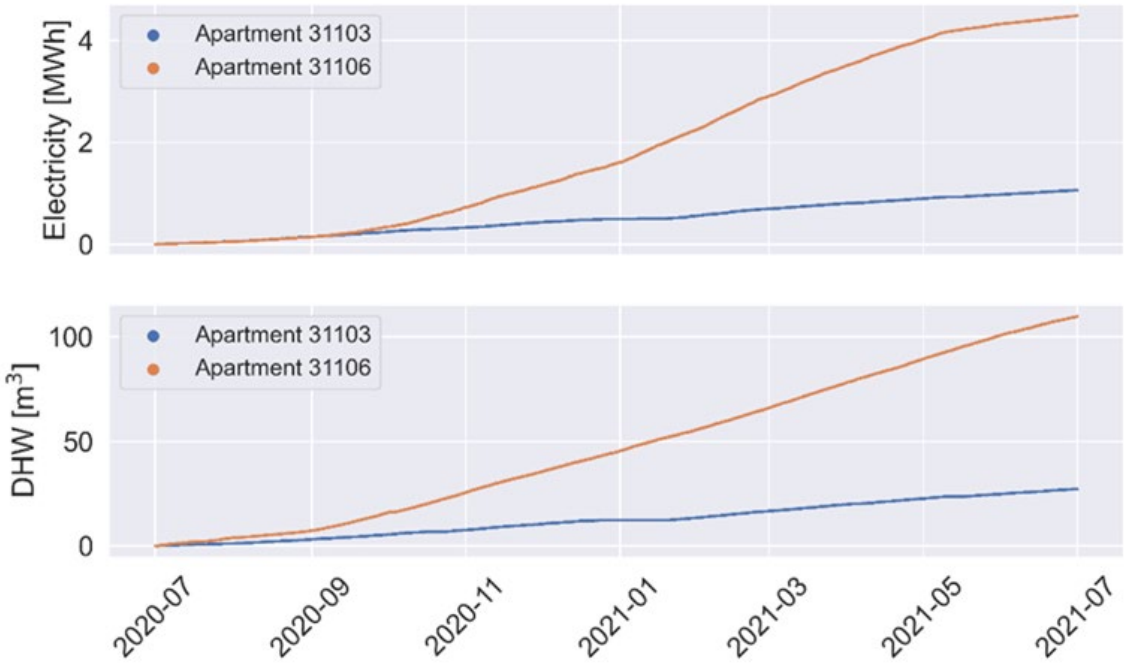
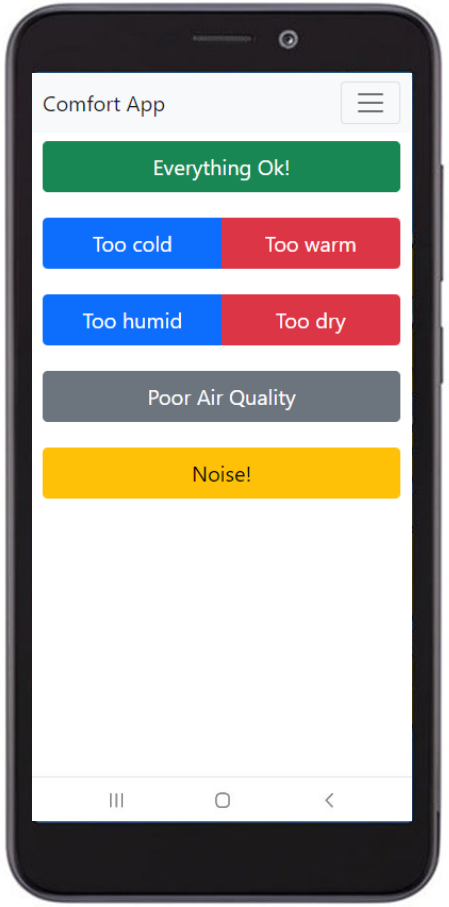
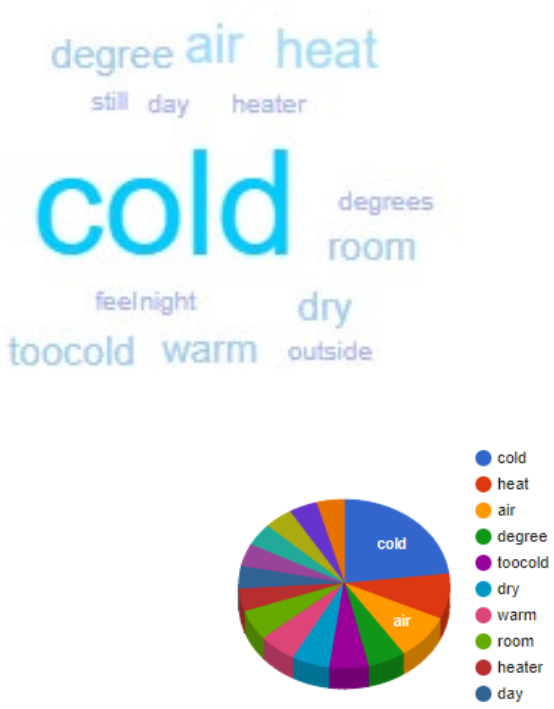


Neighbors with different habits

D. Rolando, W. Mazzotti and M. Molinari, "Long-Term Evaluation of Comfort, Indoor Air Quality and Energy Performance in Buildings: The Case of the KTH Live-In Lab Testbeds," Energies, vol. 15, no. 14, pp. 4955, 2022.

Feedback platform – Comfort App

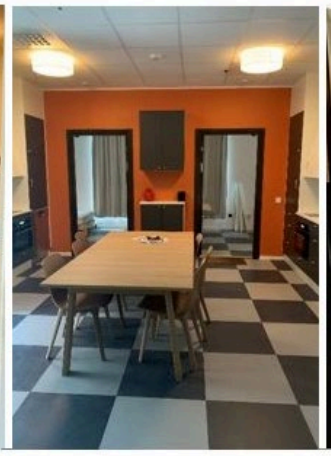


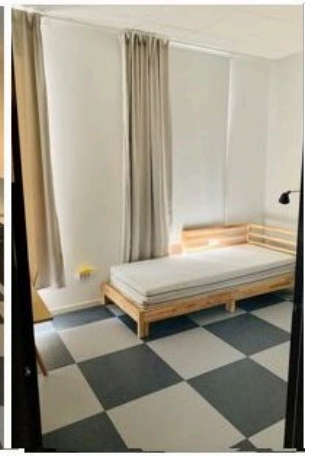


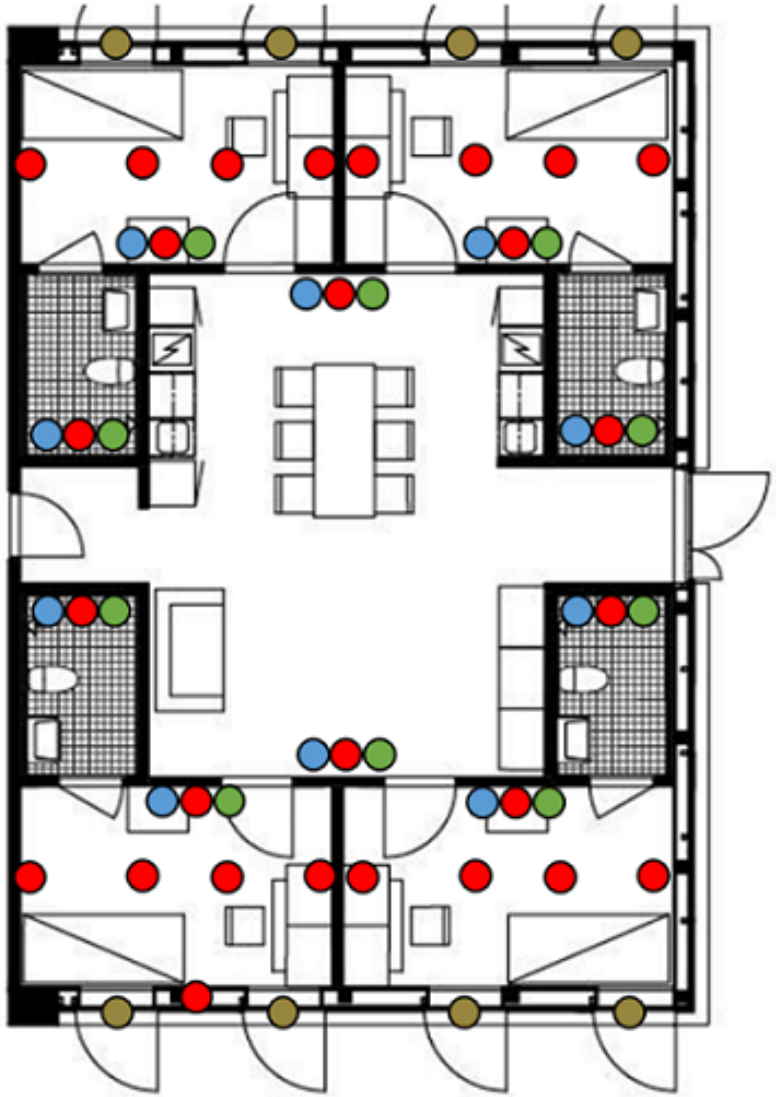
- **Comfort feedbacks**
- **Comfort visualization**

D. Rolando and M. Molinari, "Development of a comfort platform for user feedback : the experience of the KTH Live-In Lab," in *12th International Conference on Applied Energy, (ICAE2020)*, 2020

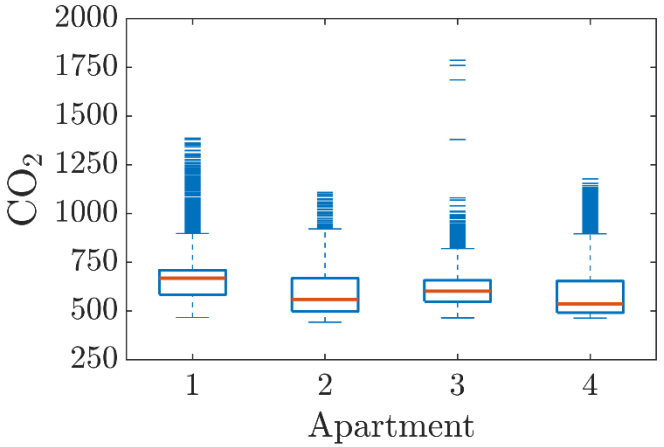
Behavior, control and energy use

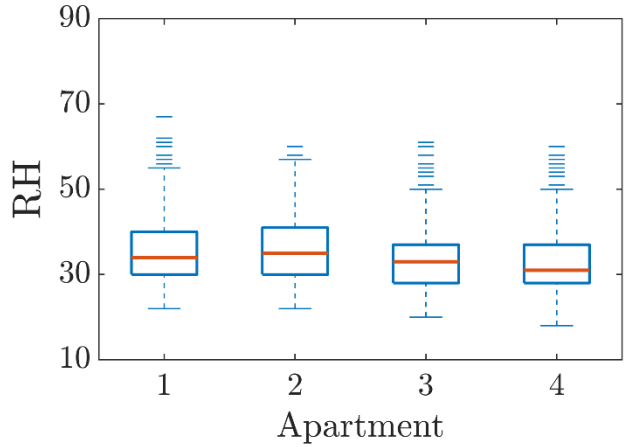


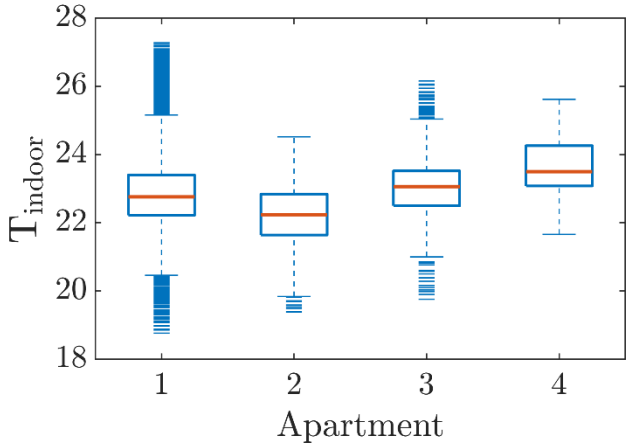


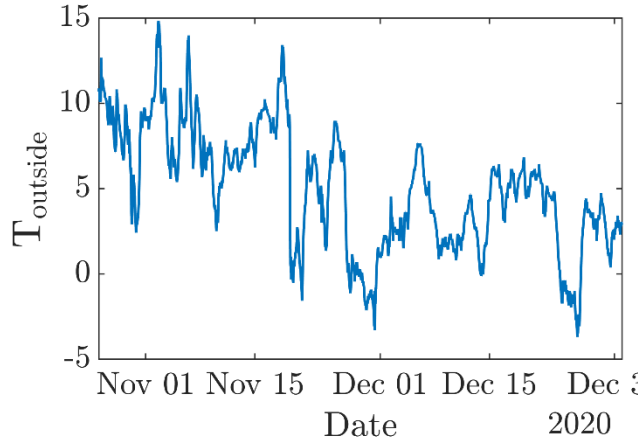


Behavior, control and energy use

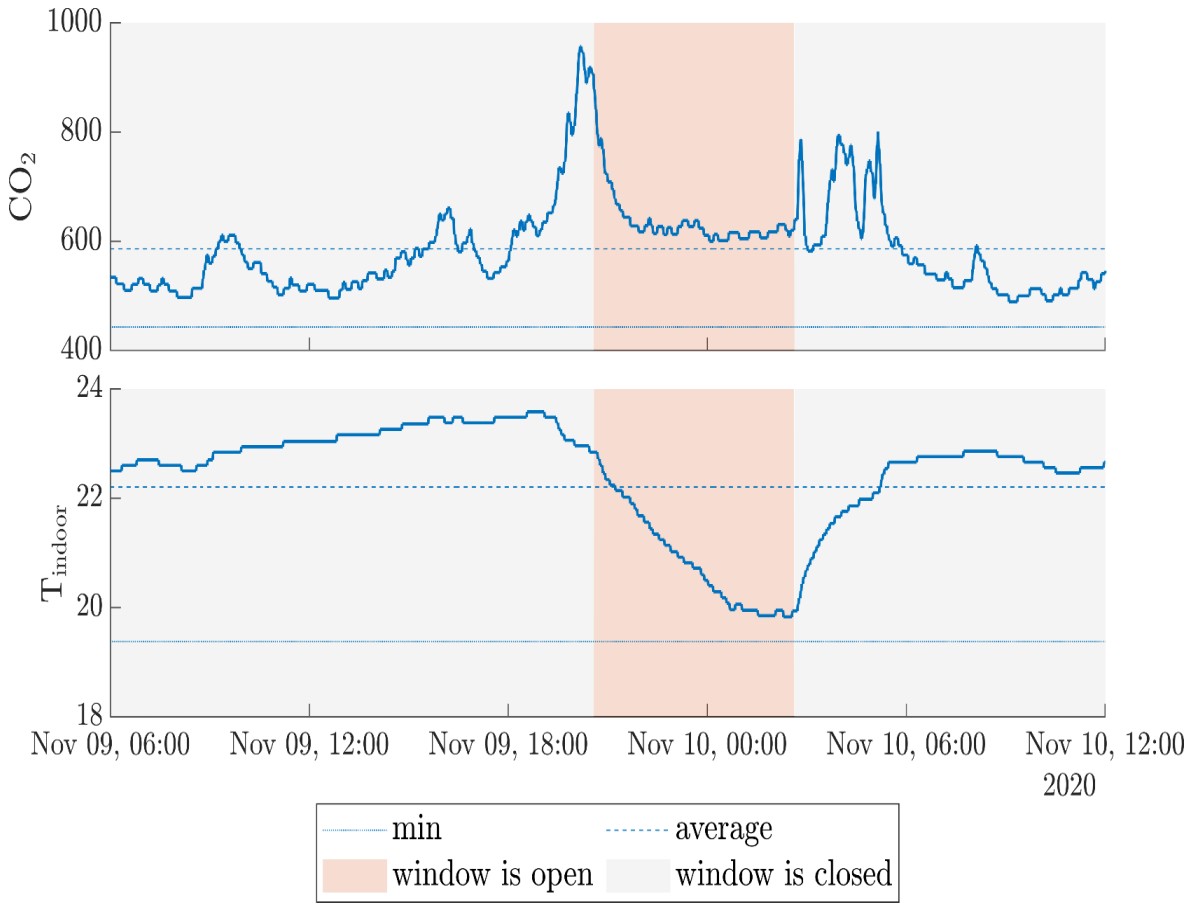


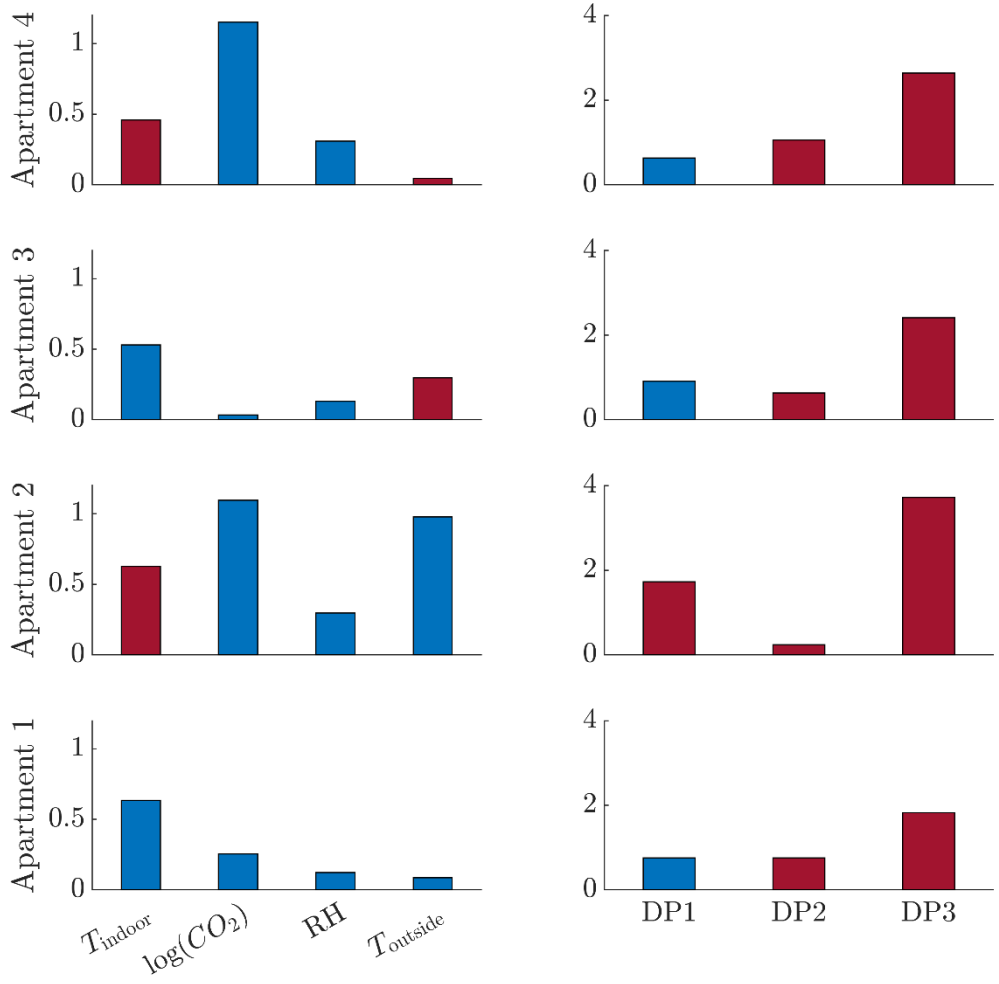






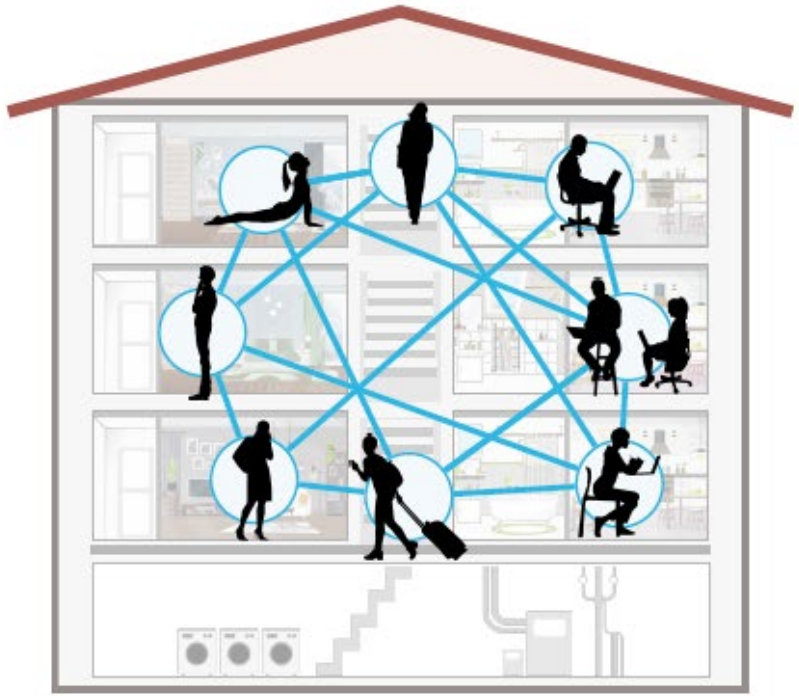
Behavior, control and energy use





Data from the apartment sensors is the basis for tailored control to minimize Energy Performance Gap

Social interactions for a sustainable lifestyle: an experimental case study



digital futures

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Social interactions for a sustainable lifestyle: performance indicators

Sustainability indicators		Measurability
Conservation or Resources	Q1. Turn off the lights, or switch off electronic devices when leaving a room Q2. Use the microwave or stove to warm up food instead of using the oven Q3. Cut down on heating/decrease the temperature of the room to limit energy use Q4. Limit the time in the shower in order to conserve energy Q5. Wait until full load to use the washing machine or dishwasher Q6. Wash clothes at temperatures $< 40°C$ (compared to temperatures $\geq 40°C$) Q7. Open the windows to ventilate the rooms during cold days	Weekly Surveys, to compare with data collected at KTH Live-in Lab, see Section 2.1
Consumption	Q8. Recycle the (home) waste Q9. Buy second hand items (e.g., clothes, electronic devices) instead of new ones Q10. Decide to repair an item instead of buying it new	Weekly Surveys
Food	Q11. Consume non-meat options (vegetarian/vegan/fish) compared to meat options Q12. Consume non dairy options compared to dairy options	Weekly Surveys
Transportation or Mobility	Q13. Use public transportation instead of driving Q14. Walk, cycle, and/or use electric scooters instead of driving	Weekly Surveys
Environmental citizenship	Q15. Watch TV programs, movies, and/or internet/social media videos about environmental issues Q16. Discuss with others outside the household about their environmental behavior (Note: discuss = interact/talk, referring also to social media posts) Q17. Interact with/talk to neighbors about their environmental behavior	Weekly Surveys

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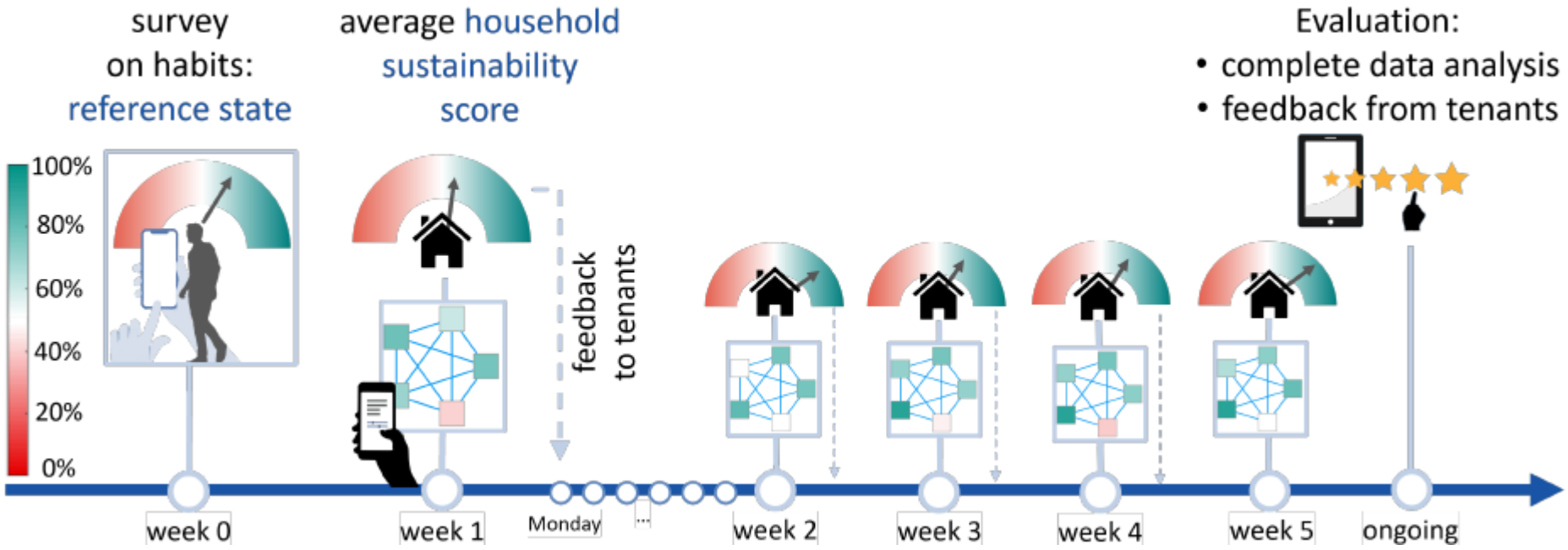
Social interactions for a sustainable lifestyle: timeline of the experiments



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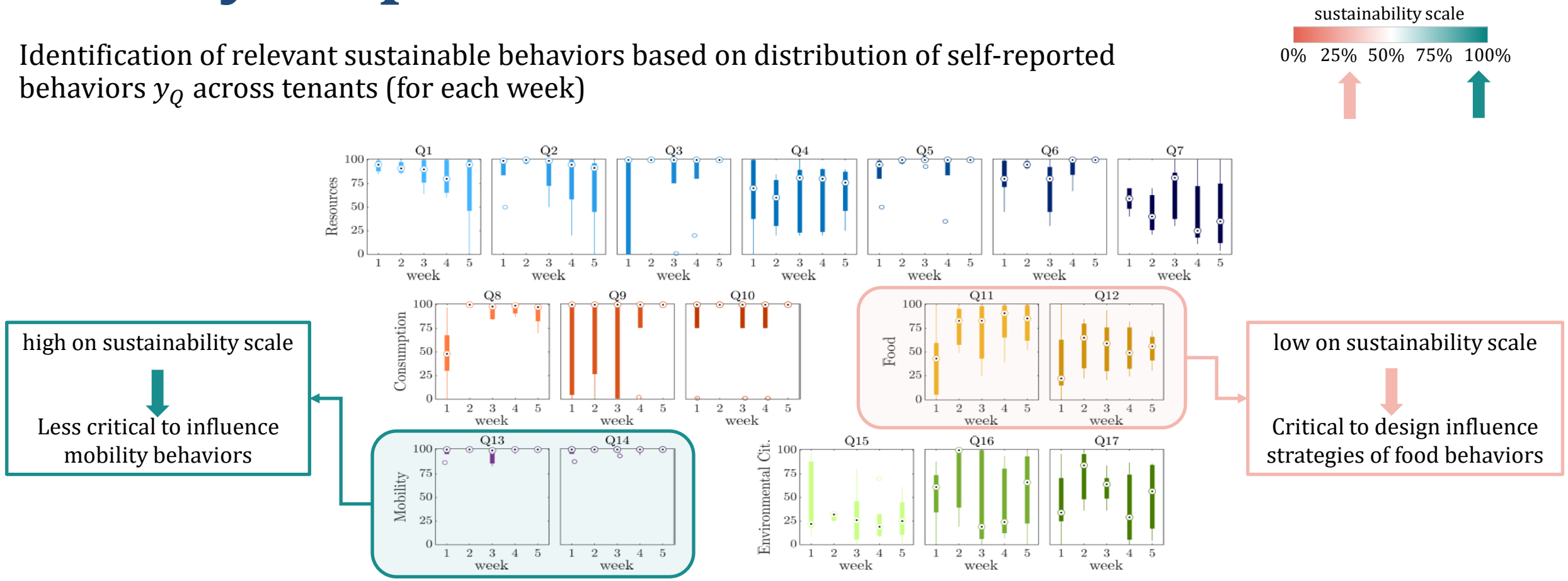
Social interactions for a sustainable lifestyle: performance indicators

Identification of relevant sustainable behaviors based on distribution of self-reported behaviors y_Q across tenants (for each week)



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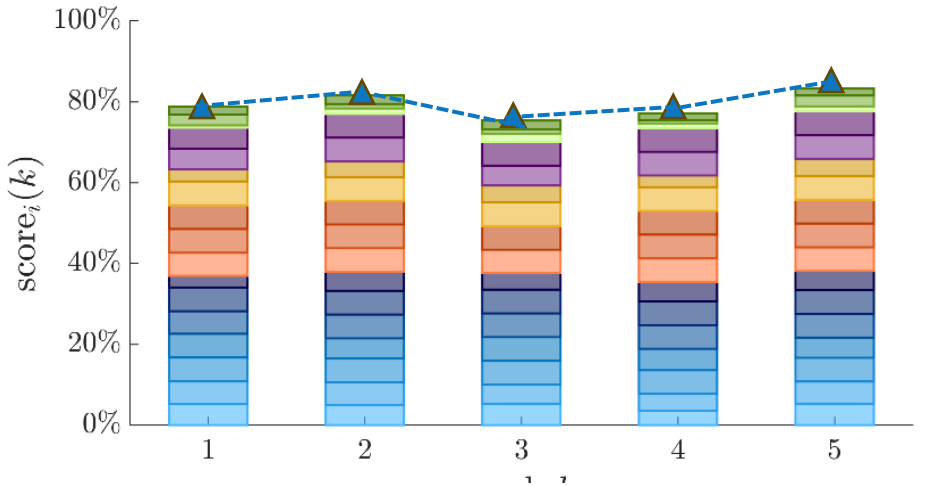
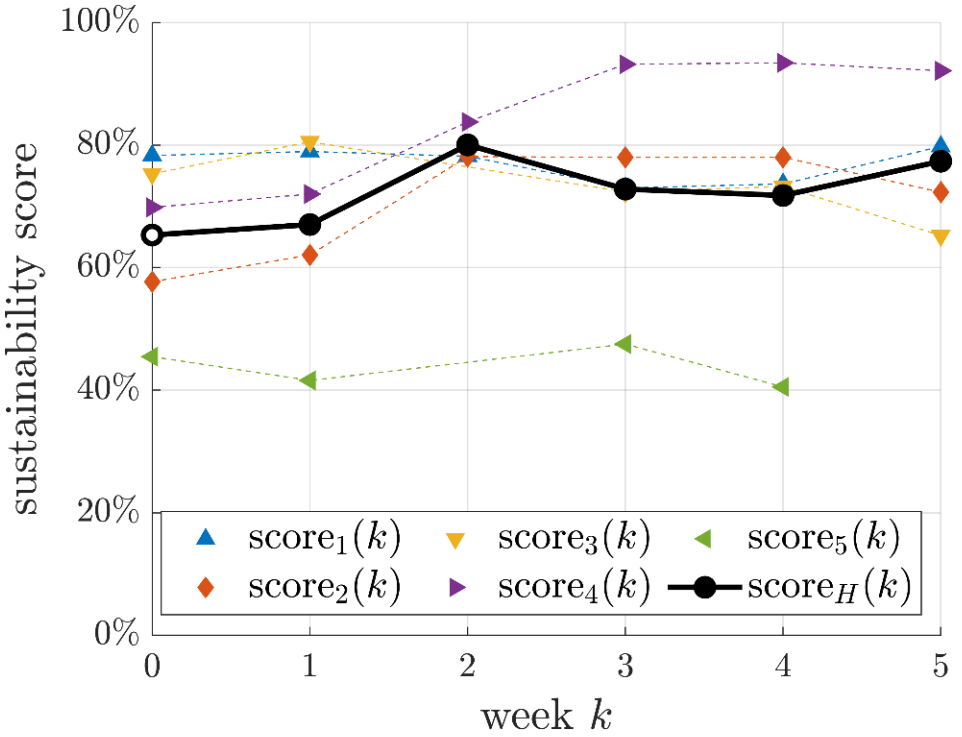
Social interactions for a sustainable lifestyle: performance indicators



$y_{i,Q1}$,.., $y_{i,Q7}$: Resources (Q1-Q7)
$y_{i,Q8}$,.., $y_{i,Q10}$: Consumption (Q8-Q10)
$y_{i,Q11}$, $y_{i,Q12}$: Food (Q11-Q12)
$y_{i,Q13}$, $y_{i,Q14}$: Mobility (Q13-Q14)
$y_{i,Q15}$, .., $y_{i,Q17}$: Environmental citizenship (Q15-Q17)



Household: From 65% to 78% in 5 weeks

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Live-In Lab overall evaluation

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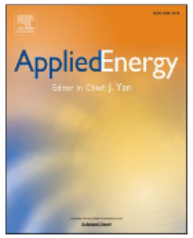

Check for updates

Using living labs to tackle innovation bottlenecks: the KTH Live-In Lab case study

Marco Molinari [a,b,*], Jonas Anund Vogel [a], Davide Rolando [a], Per Lundqvist [a]

[a] Department of Energy Technology, KTH, Stockholm, Sweden
[b] Digital Futures, KTH, Stockholm, Sweden

HIGHLIGHTS

- Living Lab Triangle implemented in the KTH Live-In Lab building innovation platform.
- A SWOT analysis underpins current strengths and weaknesses of the KTH Live-In Lab.
- Empirical data shows that smart building living labs can be financially sustainable.
- Identification of critical conditions to enact smart building demonstrators.
- Thorough analysis, measurable results and transparent evaluation of a Living Lab.