

Social interactions for a sustainable lifestyle: The design of an experimental case study

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In collaboration with:

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digital futures



Outline

- ▶ Background and motivation
- ▶ Introduction to the experimental campaign: Smart homes as social networks
- ▶ Experimental setup: KTH Live In Lab as a CPHS
- ▶ Design of the case study
- ▶ Preliminary results
- ▶ Conclusions

Background

- ▶ A new urban science focused on sustainable lifestyle in smart cities
- ▶ Key aspects include consumption, food, mobility, energy use in buildings, etc.
- ▶ Example: Building sector, with focus on **residential buildings**



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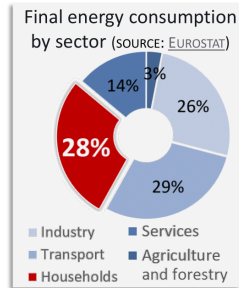
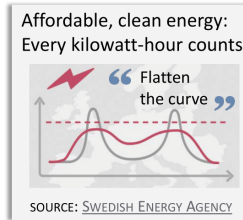
SOURCE: [UNITED NATIONS](#)

Transforming our world: the 2030 Agenda for Sustainable Development

“ Make **cities** and human settlements inclusive, safe, resilient, and **sustainable** ”

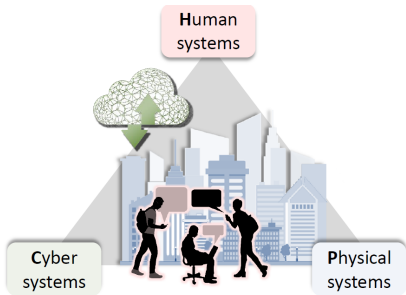


11 SUSTAINABLE CITIES AND COMMUNITIES

Motivation

- ▶ Building automation and energy-efficient smart homes
- ▶ Key site of application: KTH Live-In Lab
 - Integrated real-life trial system
 - Cyber-physical-human system (CPHS)
Ch 4.D in [Control for Societal Scale Challenges: Road Map 2030, Eds. Annaswamy, Johansson, Pappas, 2023], to be presented at IFAC 2023 (semi-plenary panel, July 10, 18:15-19:00)

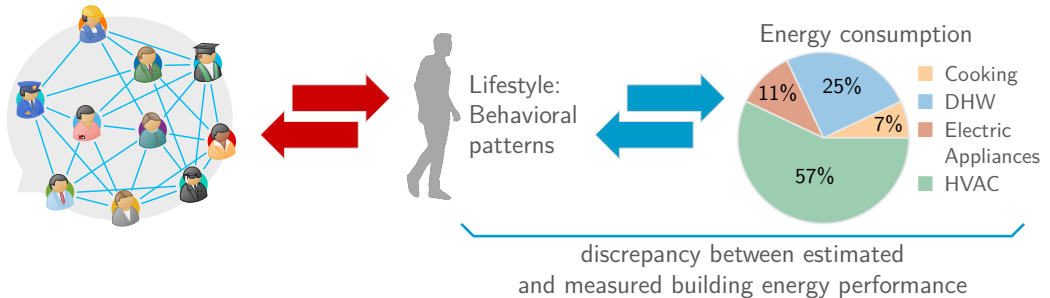


Motivation

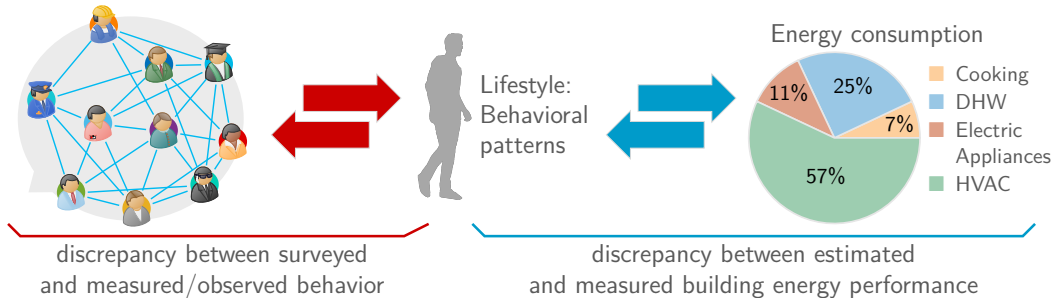
- ▶ **Challenge:** The behavior of occupants have large effects on building energy use
 - Bidirectional interactions between tenants and environmental conditions
[M. Farjadnia et al., to be presented at 7th IEEE CCTA, August 16–18, 2023]
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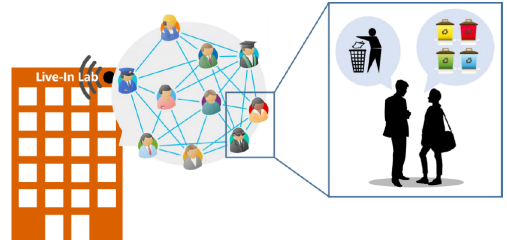


Problem formulation

Design longitudinal experimental study of **social influence** in behavioral changes towards sustainability, to be implemented in the KTH Live-In Lab

Combining several factors..

- ▶ Modeling household and energy use behavior [Wilson and Dowlatabadi (2007), Peng et al. (2012);..]
- ▶ Planning ad hoc social interventions on habits [Steg and Vlek (2009); Frederiks et al. (2015);..]
- ▶ Designing new technologies and infrastructures (flexible Live-In Laboratories) [Intille et al. (2006); Das et al. (2020);..]



..and proposing a social network perspective:

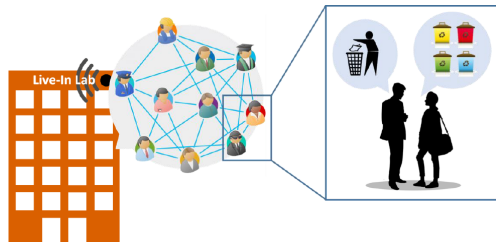
Experimental design as collective (household) decision-making process with interconnected tenants of KTH Live-In Lab as the decision-makers

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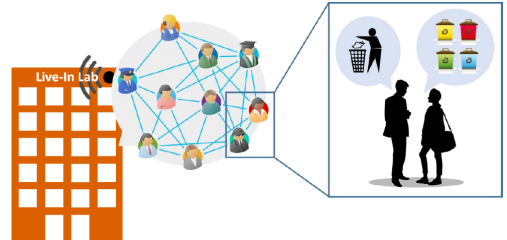
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Exploring diffusion of sustainable behaviors: Smart homes as social networks

Approach: Observe **how tenants' sustainability scores change over time** given that:

- ▶ Tenants are encouraged to exchange opinions with their neighbors
- ▶ Tenants can observe the average household sustainability score

Experimental campaign based on the interpretation:

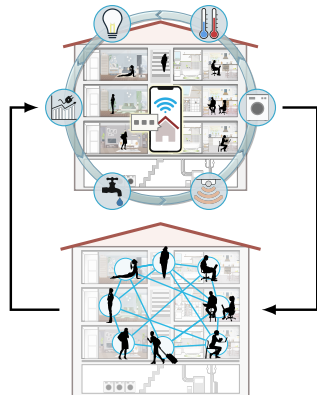
- ▶ Smart home: Social network of interacting tenants
- ▶ Lifestyle choices: Decisions
(based on opinions on environmental responsibility)

Opinion dynamics: [Proskurnikov, Tempo (2017); Anderson, Ye (2019);..]

..on real-world social networks: [Fontan, Altafini (2021); Bernardo et al. (2021)]

Diverse challenges in experimental design:

- ▶ Define building, data, and tenants infrastructure
- ▶ Define significant behaviors to derive sustainability scores
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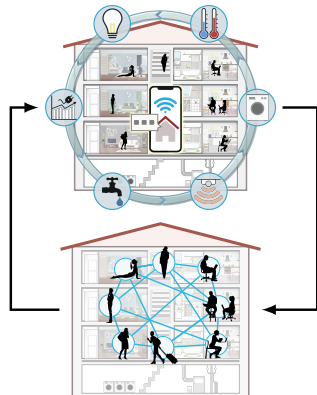
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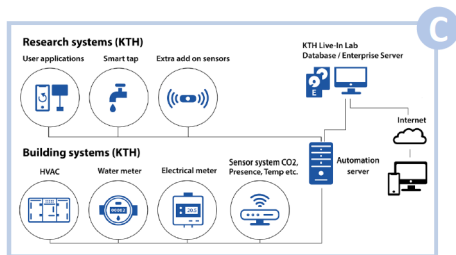
Campaign run at the KTH Live-In Lab, state-of-the-art platform of building testbeds

- ▶ Datapool with extended sensor network
- ▶ Customizable layout (combining private apartments and shared spaces)
- ▶ Interaction capability with and between occupants

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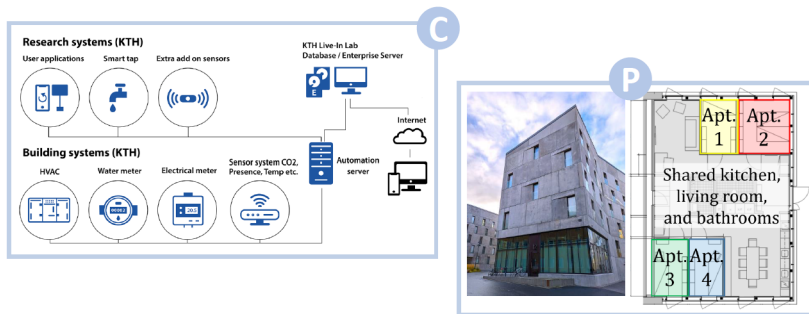
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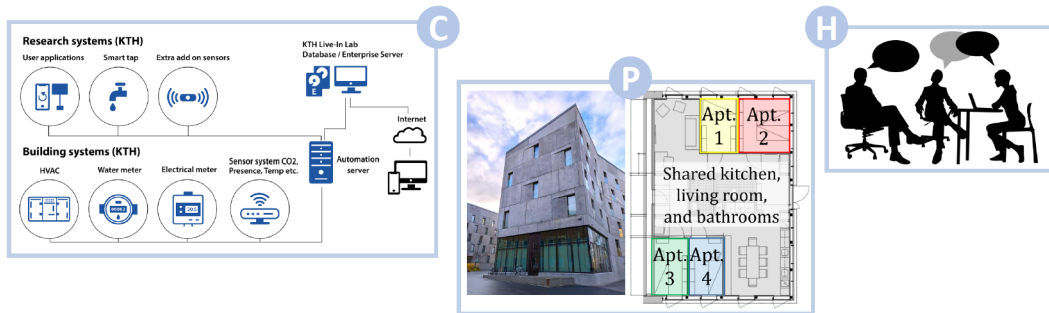
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Preparatory phase of the project (winter 2022-spring 2023)

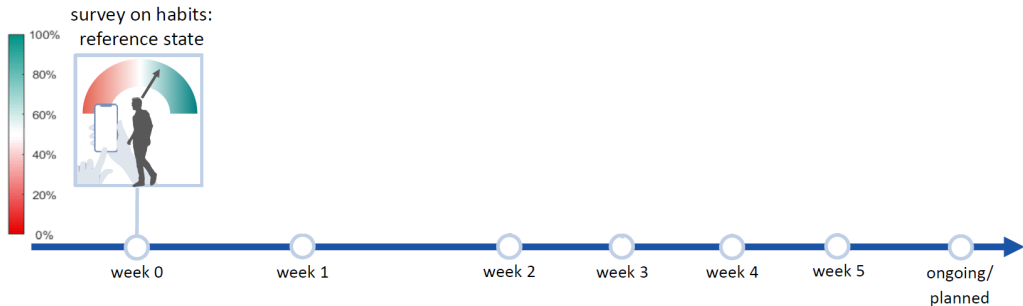
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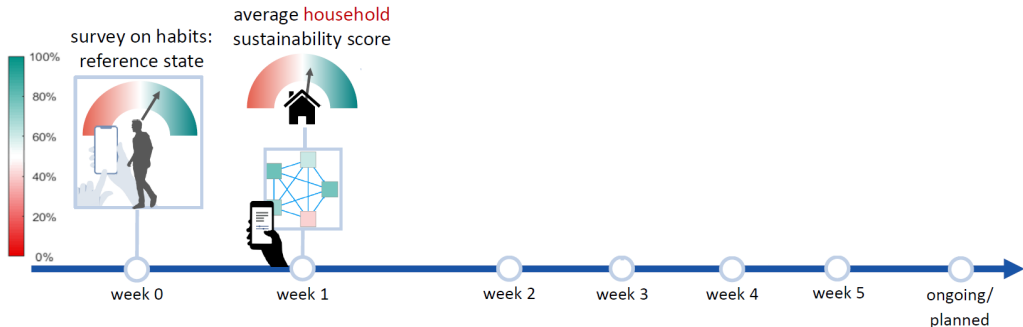
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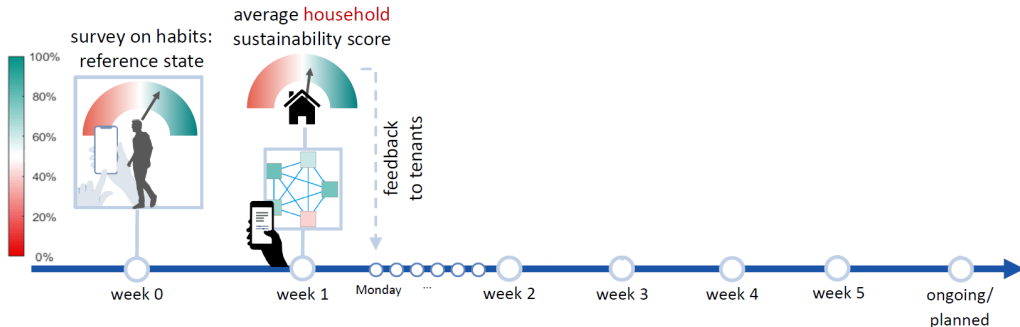
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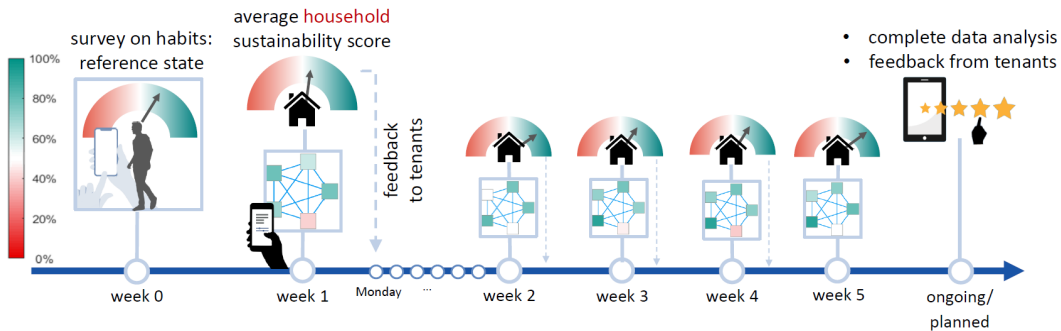
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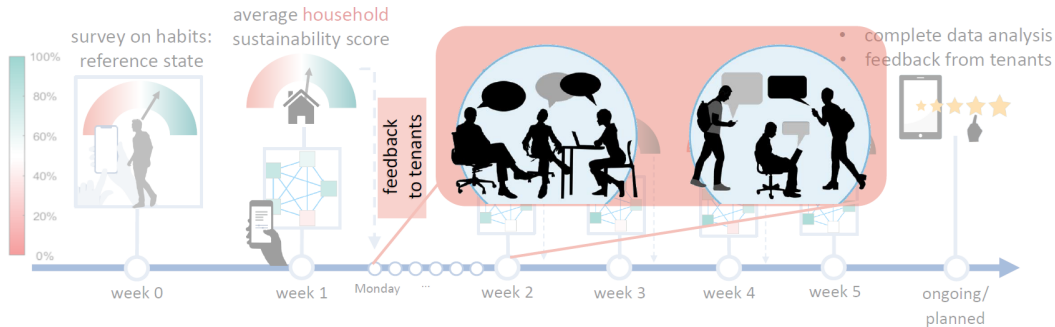
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Sustainability scores (I/II)

Environmentally significant behaviors of tenants:

- ▶ Definition: Activities for which correlation with environmental impact is established (based on [Stern, 2000; Markle, 2013])
- ▶ Approach: Weekly surveys, questionnaire designed around 17 sustainability practices

How often do you?

How often do you?		Measurability
Resources	Q1. Switch off electronic devices when leaving a room Q2. Use the stove to warm up food instead of using the oven Q3. Decrease temperature in 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 $< 40^{\circ}C$ Q7. Open the windows to ventilate the rooms during cold days	Weekly Surveys, to compare with data collected at KTH Live-in Lab
Consumption	Q8. Recycle the (home) waste Q9. Buy second hand items (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/fish) compared to meat options Q12. Consume non dairy options compared to dairy options	Weekly Surveys
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 or social media videos about environmental issues Q16. Discuss with others outside the household about environmental behavior Q17. Interact with/talk to neighbors about environmental behavior	Weekly Surveys



Sustainability scores (II/II)

At the end of week k :

- ▶ Each tenant i ($i = 1, \dots, 5$) reports past week's actions..

$$y_{i,q}(k) \in [0, 100], q = 1, \dots, 17$$

- ▶ ..from which we can calculate the **sustainability score of each tenant..**

$$\text{score}_i(k) = \frac{1}{17} \sum_{q=1}^{17} y_{i,q}(k) \in [0, 100]$$

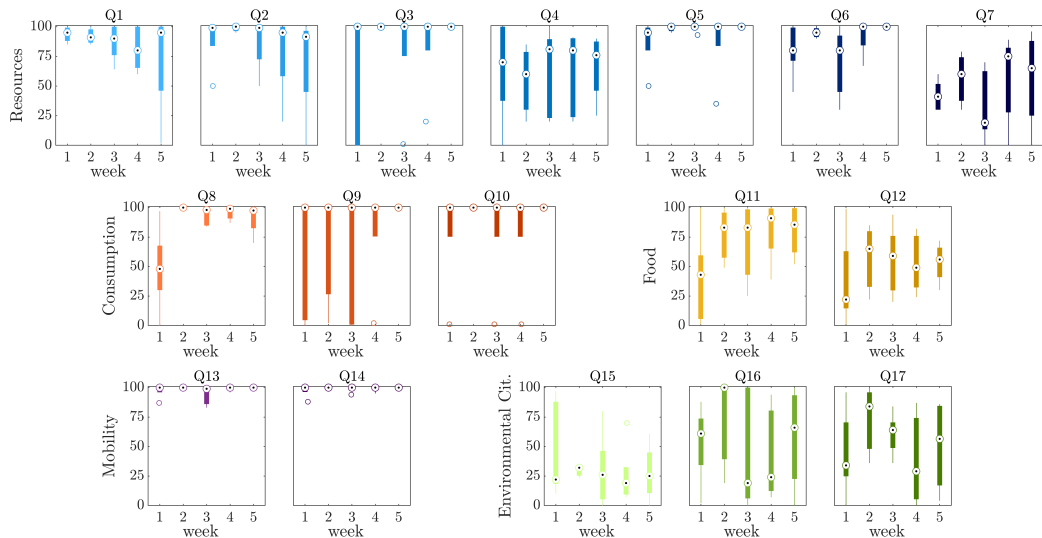
- ▶ ..and the **average household sustainability score**

$$\text{score}_H(k) = \frac{1}{5} \sum_{i=1}^5 \text{score}_i(k) \in [0, 100]$$

Preliminary results (I/II)

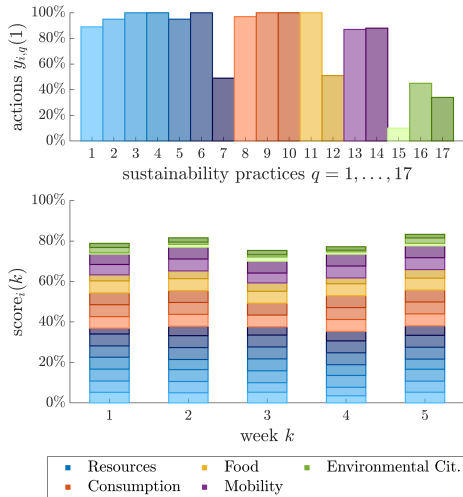
Summary of actions on sustainability practices $y_{i,q}(k)$, $q = 1, \dots, 17$

- ▶ Across all tenants, $i = 1, \dots, 5$
- ▶ In a 5-week period, $k = 1, \dots, 5$

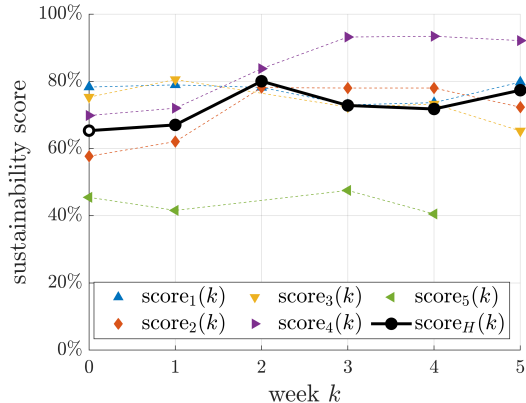


Preliminary results (II/II)

Actions $y_{i,q}(k)$ and sustainability score of tenant i of the KTH Live-In Lab



Sustainability scores of all tenants and average household sustainability score



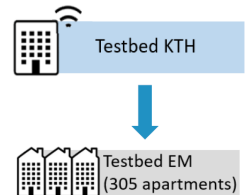
Conclusions

In this work:

- ▶ Introduction of the preparatory phase of an experimental study on the effect of social influence in behavioral changes towards sustainability
- ▶ Design based on interpretation of smart home (KTH Live-In Lab) as social network, investigating the dynamics of sustainability scores of tenants

Ongoing/future directions:

- ▶ Move from preparatory to execution phase:
Large group of participants
- ▶ Compare surveys' data with sensor data collected at KTH Live-In Lab (byproduct: Evaluation of awareness of tenants regarding their behavior related to resources)



Thank you for your attention!

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