Supermarket refrigeration & Living Lab

Tommie Månsson & Christian Marx

Co-authors: Shea Hagy, Madeleine Malmsten, York Ostermeyer, Angela Sasic, Holger Wallbaum

DAT300

2016-09-27

Contents

- Who are we and what do we do, the Sustainable Building Group @ Civil & Environmental Engineering Department?
- What makes supermarket refrigeration interesting?
- How to innovate in the built environment?

The Sustainable Building Group

A brief snapshot.

The group

1 Full Professor

1 Assistant professor

5 Senior researcher and PostDoc

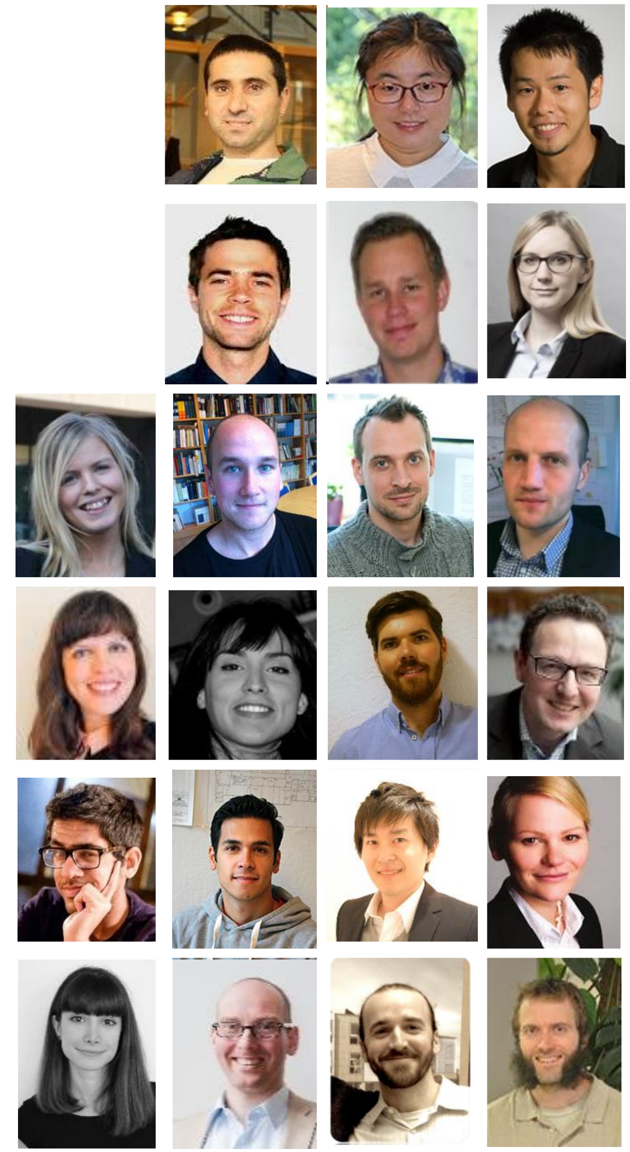
8 PhD students

2 Researcher

1 Project manager

3 Project assistants

9 nationalities
13 disciplines



Research foci

The Sustainable Building Group works on concepts, tools and strategies to enhance the sustainability performance of construction materials, building products, buildings as well as entire cities.

The main research interests are related to

1. The ecological and economic life cycle assessment of construction materials, buildings and infrastructures,
2. sustainability assessment tools for buildings,
3. social-cultural and climate adapted design concepts,
4. the refurbishment of the building stock, and
5. dynamic building stock modeling and its visualization.

Our network

The Sustainable Building Group has a large global network covering world leading research institutes and universities, sustainability driven business partners and change-making transdisciplinary initiatives.

Selected partners:

NTNU
Norwegian University of Science and Technology

TU Delft
Delft University of Technology

wbcsd
business solutions for a sustainable world

EBC
Energy in Buildings and Communities Programme

ETH
Eidgenössische Technische Hochschule Zürich
Swiss Federal Institute of Technology Zurich

Statens vegvesen
Norwegian Public Roads Administration

eit

SIRen
Sustainable Integrated Renovation

Wuppertal Institute
for Climate, Environment and Energy

acciona
Infraestructuras

eit Knowledge & Innovation Community
Climate-KIC

NCC

HILTI FOUNDATION

CIB
International Council for Research and Innovation in Building and Construction
W115 - "Construction Materials Stewardship"

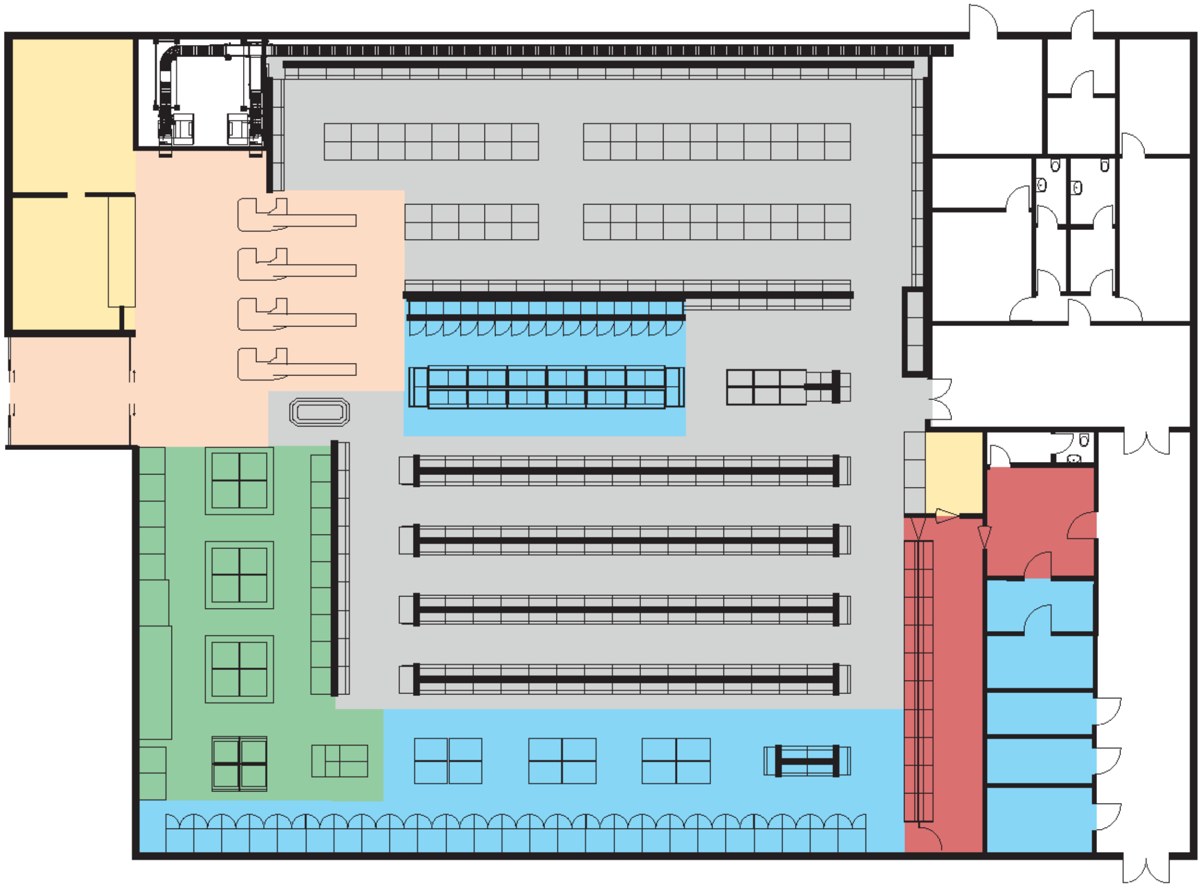
Supermarket Refrigeration

What makes supermarket refrigeration interesting?

Scene I

Floor plan of a typical 1,300 m² retail store

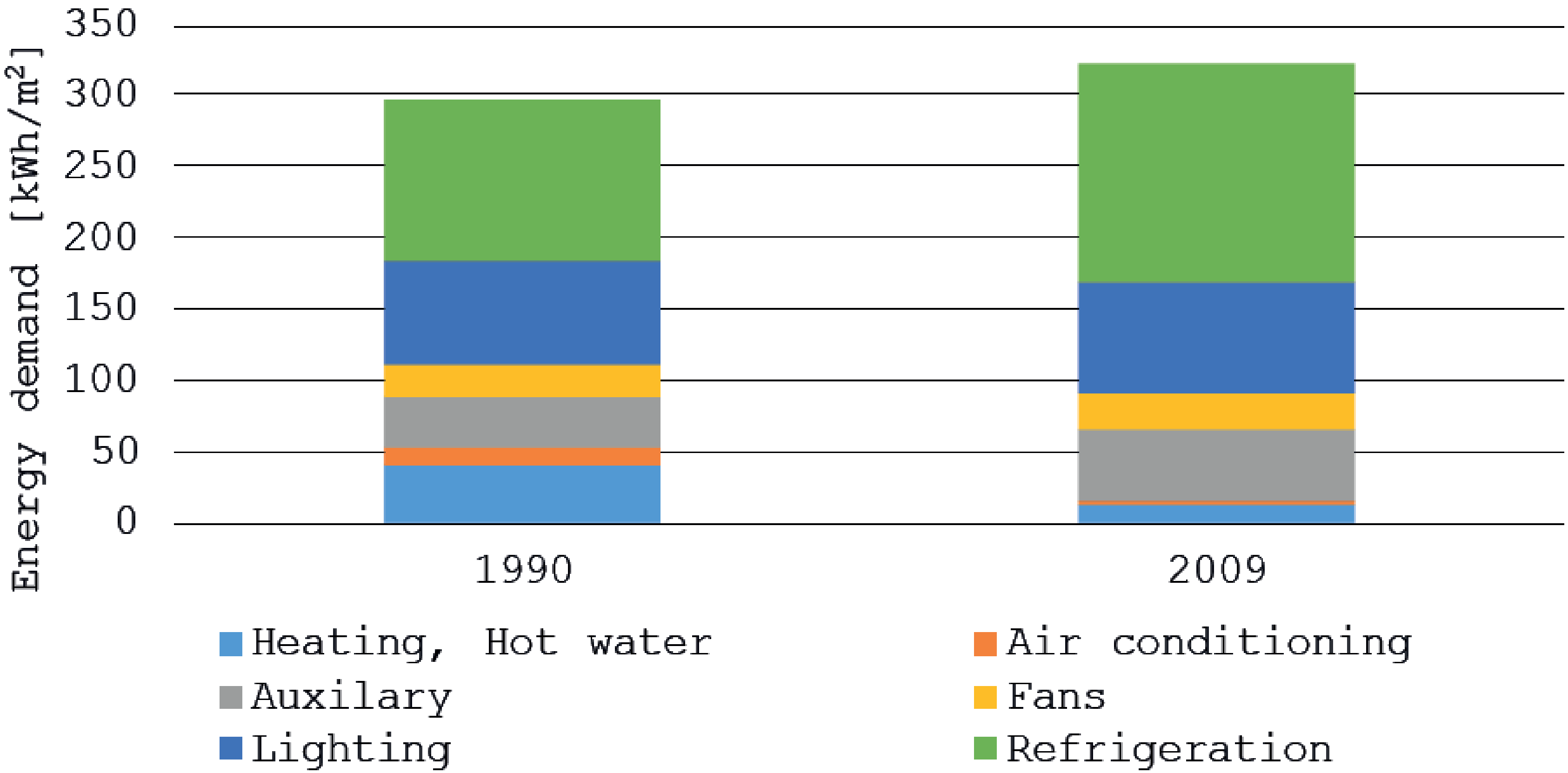
- Check out
- Produce
- Refrigerated / Frozen
- Bakery / Café
- Delicacies
- Drygoods
- Other



source: Tommie Månsson

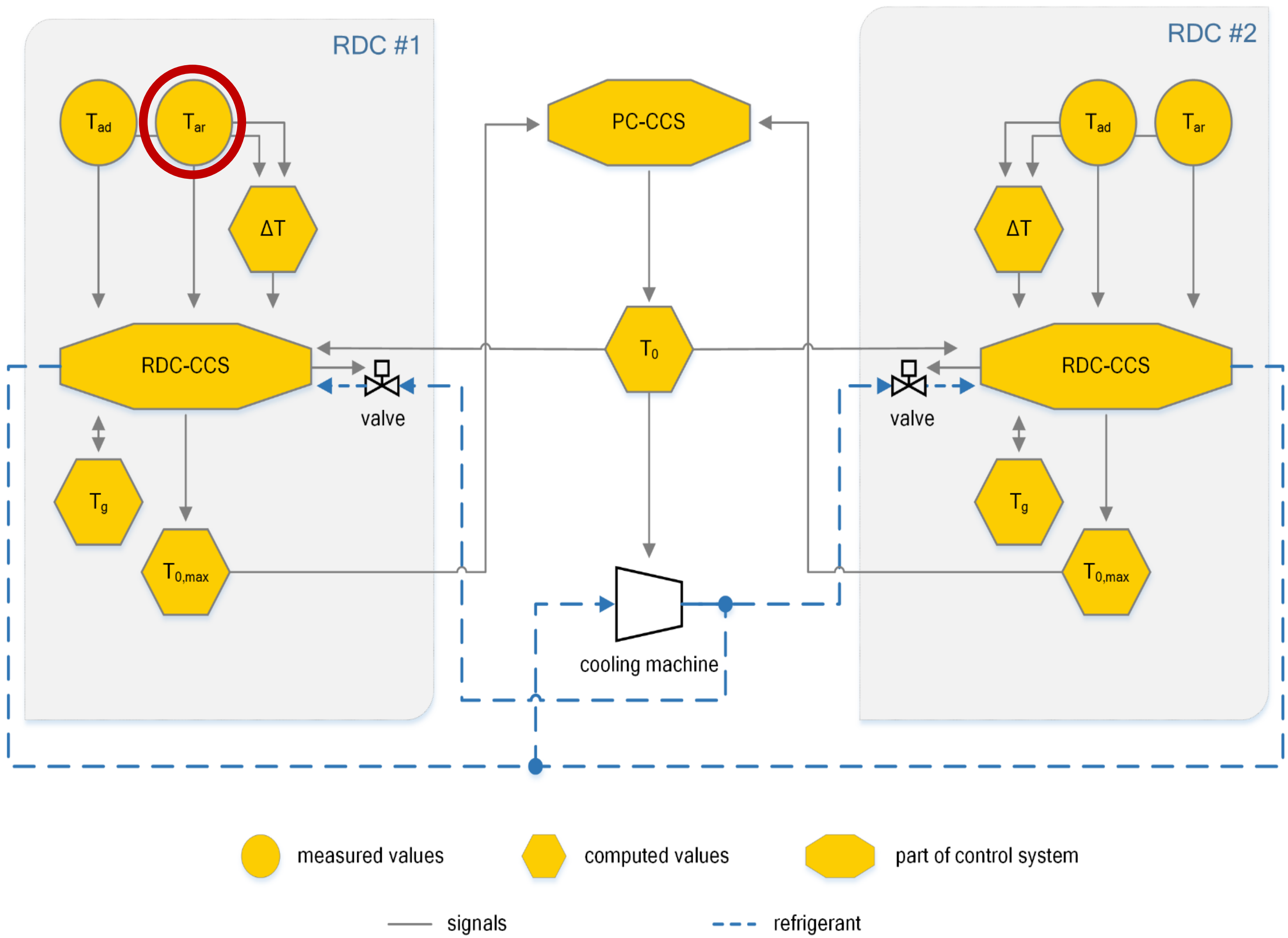
Scene II

Annual energy use of Swedish supermarkets



source: Tommie Månsson

Refrigeration control system

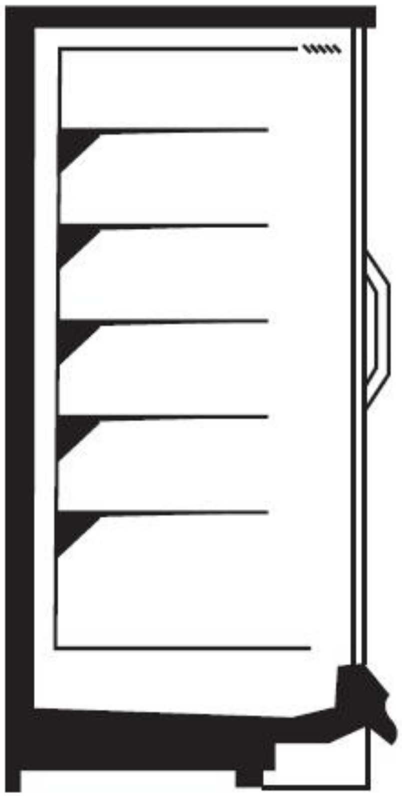


RESEARCH GOALS

1. Identify base level innovation potentials
2. Validate and implement technological solutions
3. Find further potentials on data processing and control side
4. Investigate into thermal storage capabilities of supermarkets
5. Develop suitable technologies to improve the overall flexibility of supermarkets to balance electricity grids
6. Validate and implement technological solutions

Computational Fluid Dynamics

CFD – Model configuration



$$\rho(\bar{u}\nabla)\bar{u} = \nabla\left[-p\bar{I} + (\mu + \mu_T)(\nabla\bar{u} + (\nabla\bar{u}^T))\right]$$

$$\rho\nabla(\bar{u}) = 0$$

$$\rho(\bar{u}\nabla)k = \nabla\left[\left(\mu + \frac{\mu_T}{\sigma_k}\right)\nabla k\right] + P_k - \rho_\epsilon$$

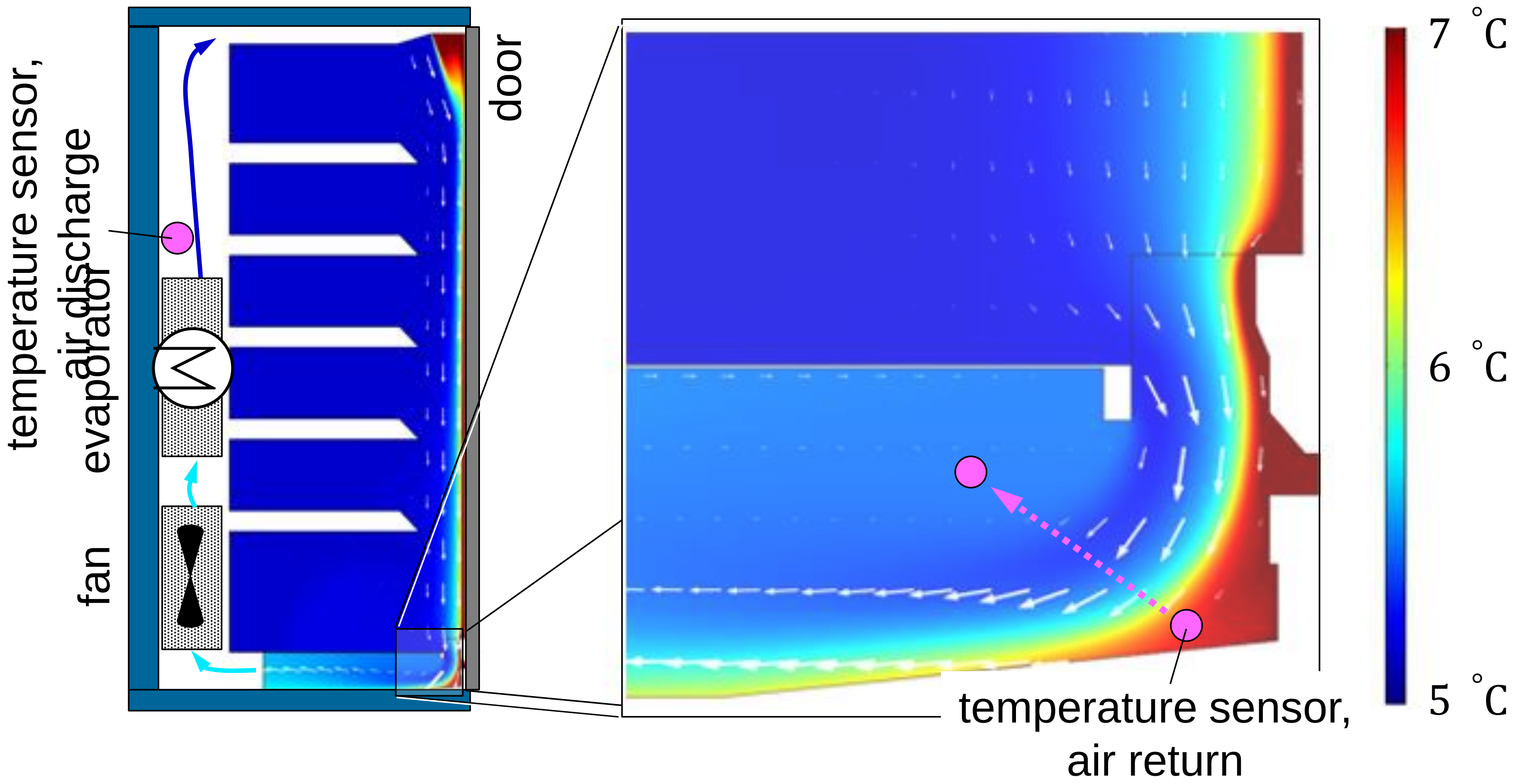
$$\rho(\bar{u}\nabla)\epsilon = \nabla\left[\left(\mu + \frac{\mu_T}{\sigma_\epsilon}\right)\nabla\epsilon\right] + C_{\epsilon 1}\frac{\epsilon}{k}P_k - C_{\epsilon 2}\rho\frac{\epsilon^2}{k}$$

$$\rho C_p\bar{u}\nabla T + \nabla\bar{q} = Q$$

$$\bar{q} = -k\nabla T$$

source: Tommie Månsson

Computational Fluid Dynamics



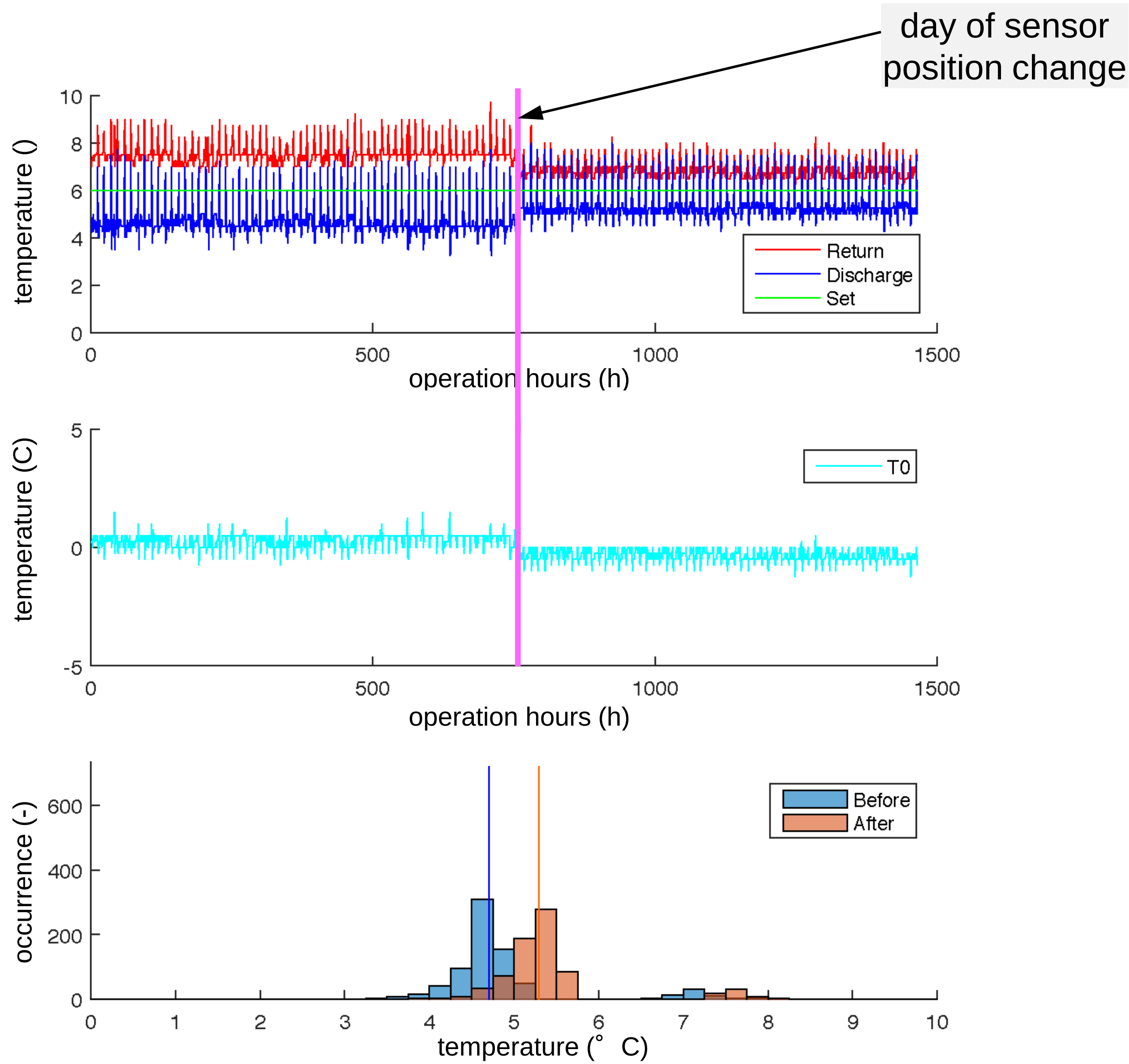
source: Tommie Månsson

Impact on performance

Return & discharge temperature

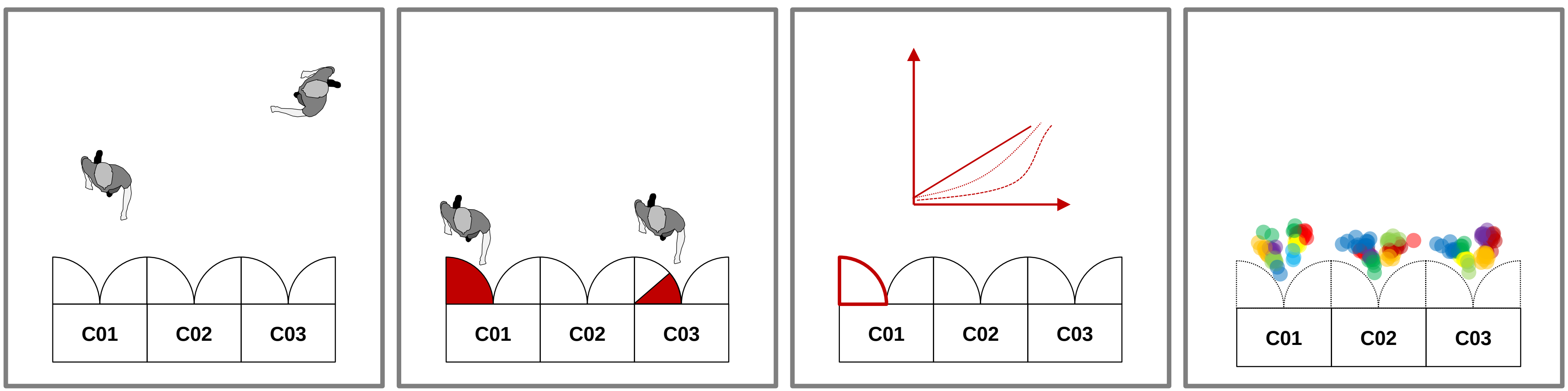
Evaporator temperature

Discharge temperature histogram

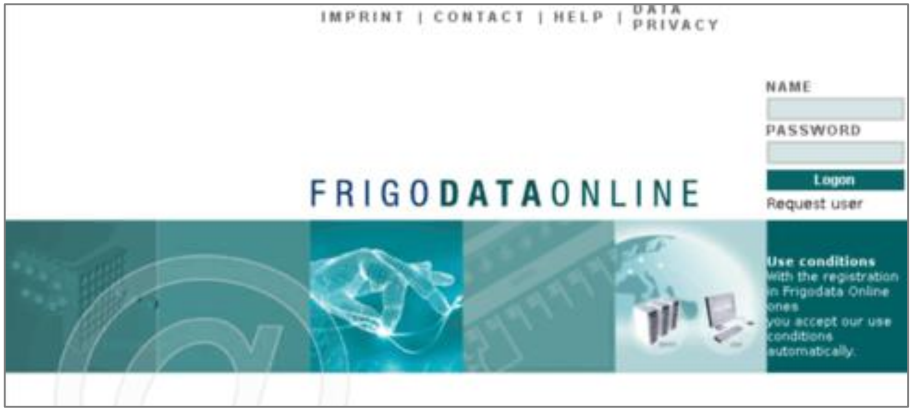


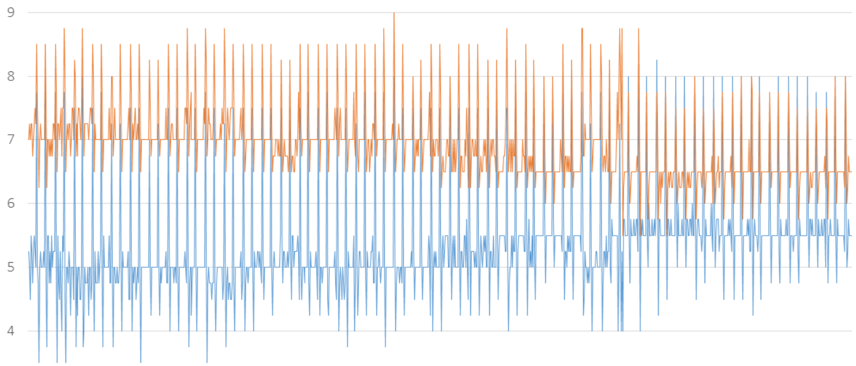
OUTLOOK
User impact

With doors on cabinets the energetic efficiency is improved - and can be improved more - but now the door opening behavior becomes a new factor.



OUTLOOK
Supermarket data basis I

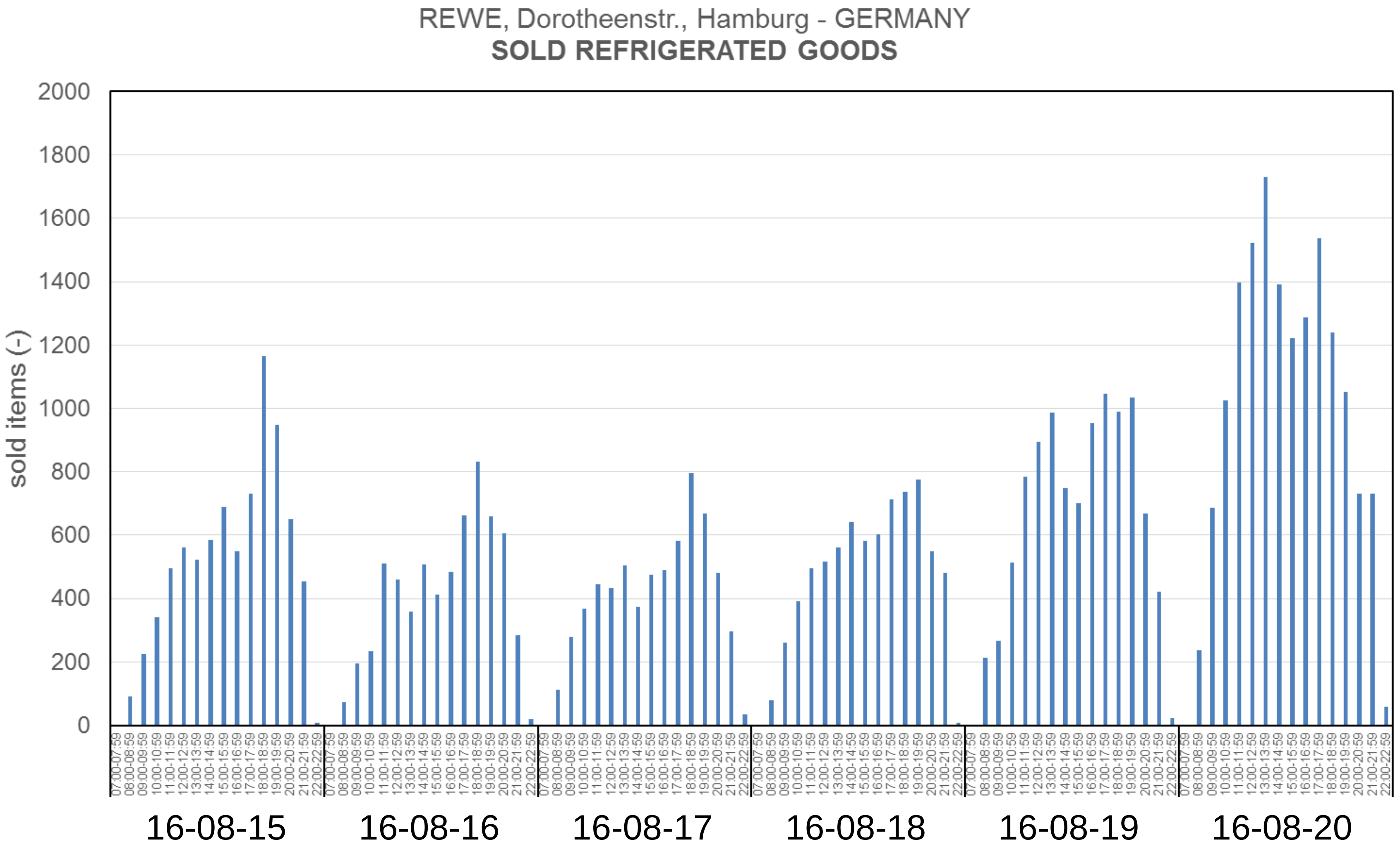




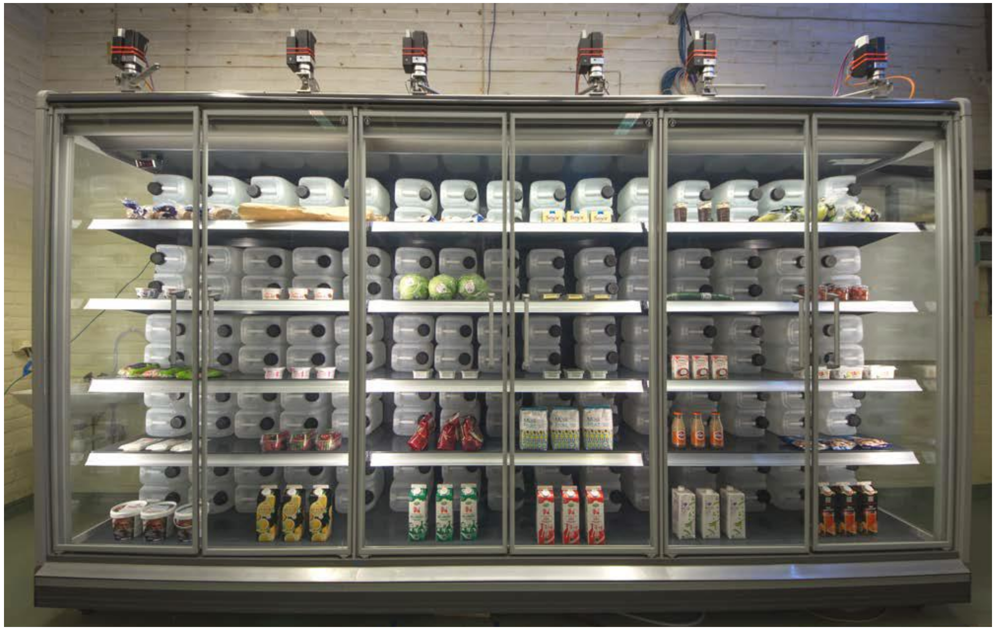
Meta data
- Store location
- RDC IDs
- Indoor environmental quality

Technical data
- spatial resolution: 1 cabinet
- temporal resolution: 5 min
- values:
  - set / actual temperature
  - air discharge / return temp.
  - $T_{0,max}$

OUTLOOK
Supermarket data basis II



OUTLOOK
Validation in RDC lab



Studies

- Door opening impact
- Heat extraction rate

Equipment

- 3.75 m RDC
- direct cooling unit (oversized)
- PLC (Beckhoff)
- parallel door openers
- refrigerant flow meter, pressure and temperature sensors
- air temperature and relative humidity sensors
- condensate meter
- all electricity meters

What makes supermarket refrigeration interesting?

- Low hanging fruits
  (some extremely low hanging)
- Spatial distribution of demands in the electricity grid with energy buffering capabilities
- Complex, versatile human-technology inter-actions with some monitoring in place in the supermarkets

Living Lab Infrastructure

How to innovate in the built environment?

HSB LIVING LAB

HSB – där möjligheterna bor

Johanneberg Science Park

TENGBOM

Electrolux

Göteborg Energi

BENGT DAHLGREN

PEAB
NORDENS SAMHÄLLSBYGGARE

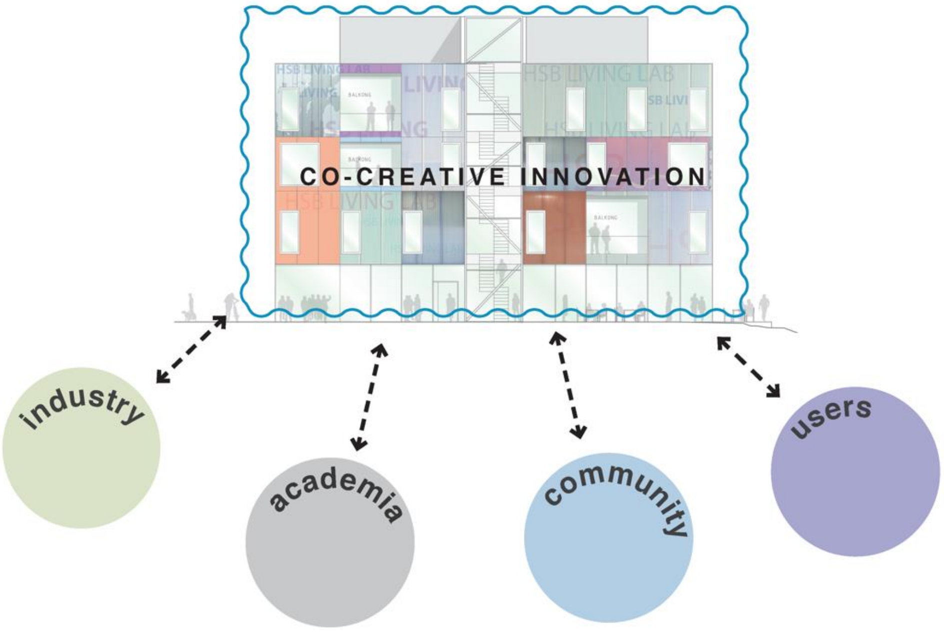
VEDUM

elfa

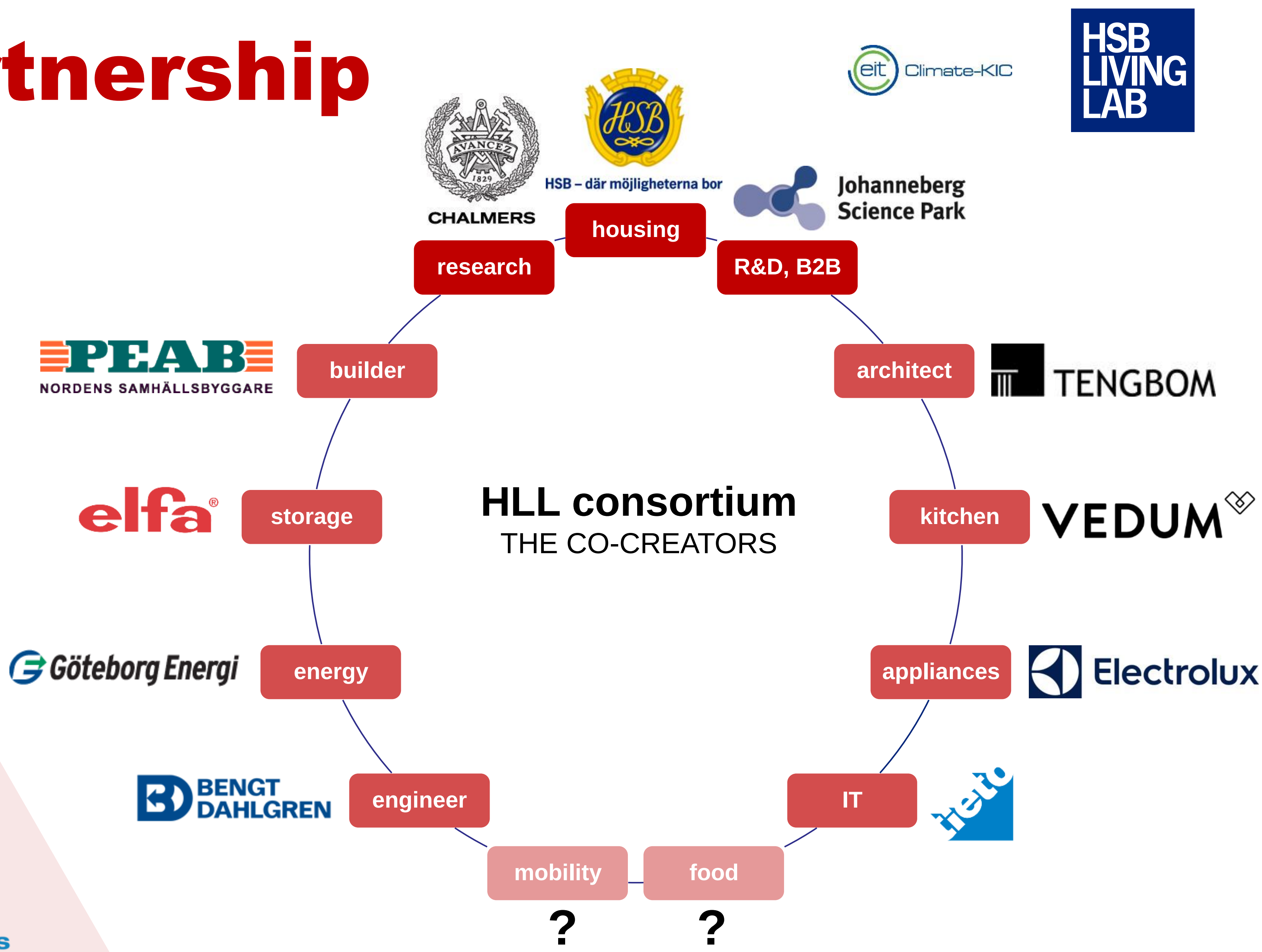
Living Lab infrastructures

A Living Lab

"… aims to turn users into active co-creators of emerging ideas and innovative concepts. A living lab is an experimental environment, physical or virtual, where users are immersed in a creative social space for designing and experiencing their own future."

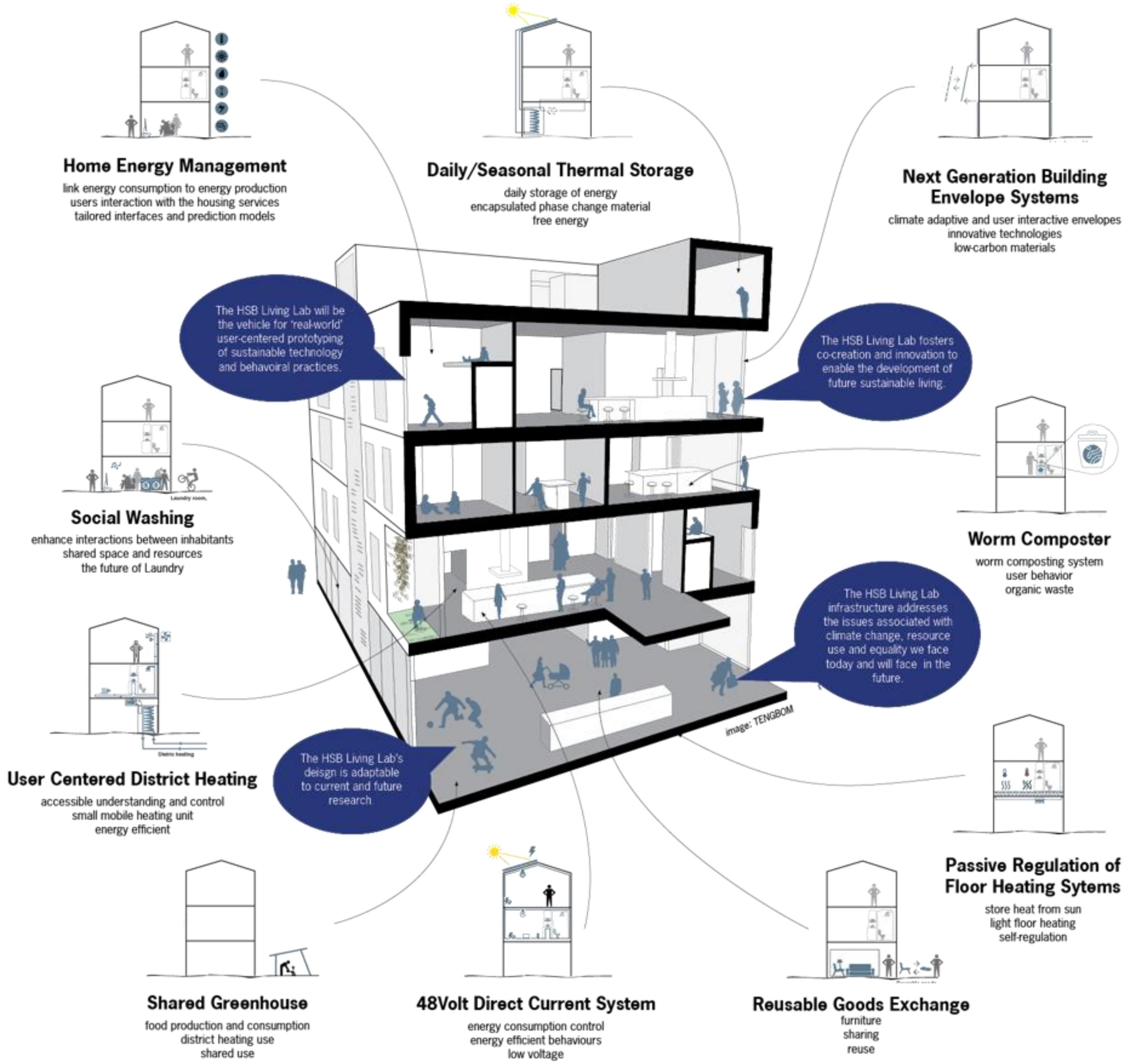


Partnership



SUS LAB NWE
eit Climate-KIC
AKADEMISKA HUS
Chalmers STUDENTBOSTÄDER

Research based Design



HSB Living Lab

- 24 single room apartments (4 clusters)
- 5 more standard apartment
- 34 tenants
- common kitchens
- common laundry
- elevator
- district heating
- FTX-system
- modular construction
- transparent installations

CHALMERS = enabler

Vita Lådan & Dare2Build

Next Generation Building Envelop System

© Angela Sasic @ Chalmers

Sensor and Data Network

HSB Living Lab Sensors I

Indoor environmental quality

Measurements	Accuracy
Temperature	0.6 °C
Relative humidity	2.5 %rH
CO_2 concentration	50 ppm
Number of sensors in the building	80 units

HSB Living Lab Sensors II

Through-wall heat and moisture transfer

Measurements	Accuracy
Reading time and date	1 s
Temperature (in-wall)	0.5 °C
Relative humidity (in-wall)	2.5 %rH
Dewpoint temperature (in-wall)	0.5 °C
Moisture content (in-wall)	1 g/kg air
Wood moisture equivalent (in-wall)	1 %WME
Number of sensors in the building	15 units

HSB Living Lab
Sensors III

Electricity

1-phase meters

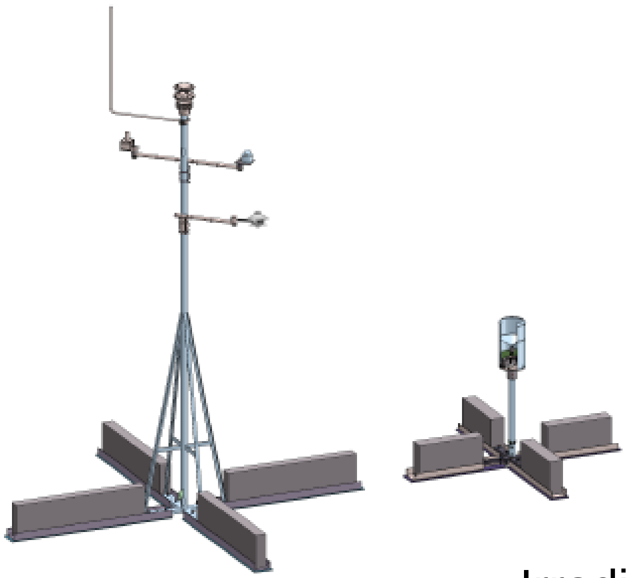
Measurements	Accuracy
Present active power, wattage	1 %
Total energy, accumulated	0.1 kWh
Minimum measurement interval	1 s

Number of sensors in the building	
1-phase meters	490
3-phase meters	40

Also measures present voltage (V), present current (A), present reactive power (var), present apparent power (VA), power factor (-) and frequency (Hz)

HSB Living Lab Sensors IV

Weather



Measurements	Accuracy
Wind direction	1°
Wind speed	1 m/s
Relative humidity	3 %rH
Temperature	0.6 °C
Precipitation	0.1 mm
Precipitation intensity	max. 11 mm/min
CO_2 concentration	3 %
Irradiation, PAR (400-700 nm)	1 µmol/m²/s
Irradiation, global (380-3500 nm)	1 W/m²
Irradiation balance, net albedo (W/m²)	1 %
Brightness & twilight	0.1 klux & 1 lux
Minimum measurement interval	5 s
Number of sensors in the building	1 units on roof, 4 units on façade

HSB Living Lab Sensors V

Water usage

Measurements	Accuracy
Flow	0.2 L/min
Temperature	0.15 °C
Minimum measurement interval	10 s
Number of sensors in the building	207 units

HSB Living Lab Sensors VI

Positioning

Measurements	Accuracy
Acceleration, tag-based	0.01 m/s²
Position x-y-z, tag-based	0.2 m
Minimum measurement interval	0.2 s

Number of sensors in the building	54
Number of positioning tags	300

Senses position with tags, allows triggering, in-zone notifications, IDs etc.

HSB Living Lab
Sensors VII

Heating

Measurements	Accuracy
Heating flow	0.1 L/s
Heating temperature	0.1 °C
Heating energy	10 Wh
Minimum measurement interval	10 s
Number of sensor in the building	47 units

HSB Living Lab Sensors VIII

Ventilation

Measurements	Accuracy
Ventilation air flow	4 %
Ventilation velocity	2 %
Ventilation air temperature	0.15 °C
Ventilation air relative humidity	3 %rH
Minimum measurement interval	10 s
Number of sensor in the building	42 units

HSB Living Lab Sensors IX

Waste water

Measurements	Accuracy
Temperature	0.15 °C
Minimum measurement interval	10 s
Number of sensor in the building	28 units

Ongoing

This is a short presentation of the research projects which are being performed in the HSB Living Lab. Projects which request to use the HSB Living Lab infrastructure are reviewed on criteria concerning sustainability, innovation and user involvement.

design for sustainable behavior change

An exploration on how you can change the living environment to help individuals towards a more sustainable lifestyle. The project explores an interdisciplinary method where behavior challenges for a sustainable lifestyle are defined. The project will design prototypes together with the residents to test in HSB Living Lab and then measure actual behavior change.

Project Lead: Kajsa Lindström - Beteendelabbet

Project Partners: Beteendelabbet

sharing is caring

Implementation of two spaces aimed to create a backbone for a sharing economy withing the Living Lab. The Swap Cube, which is for exchanging things (e.g. clothes and books) and the Share Hub which is a sharing pool (e.g. household appliances and leisure equipment).

Project Lead: Shea Hagy - Chalmers University

Project Partners: additional partners yet to be decided

district heating in a low temperature system

The flow of temperature in district heating pipes of approximately 90-120°C is not necessary for the well insulated buildings of today. The effect needed for heating is also much lower compared to what is used in traditional buildings. The aim of this study is to see the effects of using this type of system in a pilot project.

Project Lead: Claes Sommansson - Göteborg Energi

Project Partners: Göteborg Energi

sustainable changes in apartments

A study on the correlation between the layout of the apartments and the changes which are done over time to adapt the apartment to the changed needs. It also includes calculations on the environmental impact these changes imply. Further, the aim is to define a concept and guidelines for sustainable apartment renovation solutions

Project Lead: Paula Femenias - Chalmers University

Project Partners: TENGBOM, BENGT DAHLGREN

innovative energy management

This project will develop an innovative energy management and protection system for buildings which have multiple energy sources. The project will contribute to improve overall energy efficiency in buildings, reduce the customers' energy bills, reduce buildings' carbon footprints and reduce the demand for grid investment by the distribution network company.

Project Lead: Tuan Le - Chalmers University

Project Partners: Göteborg Energi

development of p.e.t. interface

The goal of this project is to develop a front-end interface, the "Personal Energy Threshold (PET)", for getting users actively engaged to change their energy consumption behavior. The inclusion of ICT in energy networks, homes, and everyday appliances will give new possibilities for energy delivery and consumption and mainly the interface in between.

Project Lead: Ulrike Rahe - Chalmers University

Project Partners: boid, tieto, Göteborg Energi

solar cells on facade

Exploration of the potentials and challenges in mounting solar cells on facade elements. It will be investigated what is the degree of efficiency, methods for mounting the solar cells and potential impact on the facade.

Project Lead: Filippa Borg - Göteborg Energi

Project Partners: Göteborg Energi, SOLAR TEST BED, SP

innovation platform for electricity consumers

The project will build and provide an R&I platform consisting of a micro-grid with solar power and battery storage, where electricity consumers interact through an interface that make it possible to monitor and manage electricity flows. The purpose is knowledge building for designing of electricity consumer interaction.

Project Lead: Jan Kristoffersson - Sustainable Innovation

Project Partners: boid, tieto, Sustainable Innovation

apartment cloud

Investigation on the technological preconditions for creating a virtual cloud which contains all necessary information about the apartment appliances (warranties, manuals). Including an analysis of the current situation, performed together with Living Lab partners and residents.

Project Lead: Linnéa Källgård - Tieto

Project Partners: tieto, Electrolux

refreshment cupboard demonstrators

A study on the usage of a refreshment cupboard, which is to be used to freshen up clothes instead of washing them. The purpose of this study is to investigate whether this could lengthen the time between the washing of garments and avoid unnecessary washing.

Project Lead: Mattias Johansson - Electrolux

Project Partners: Electrolux, BENGT DAHLGREN, TENGBOM, VEDUM

life cycle analysis of the building

Perform a Life Cycle Analysis on the HSB Living Lab. A comparison to other apartment buildings in order to investigate what is the impact of a movable module building compared to a regular building. Develop guide lines for future use of similar analyses.

Project Lead: Henrik Jönsson - Bengt Dahlgren

Project Partners: BENGT DAHLGREN, TENGBOM, PEAB, Göteborg Energi, anavitor

simulation of process flow in textile care

An analysis of the required room and movements in a combined space for social interaction and laundry. The usage of the appliances in the combined meeting and laundry space is investigated in order to create efficient laundry handling in such a space.

Project Lead: Christine Gustavsson - Electrolux

Project Partners: Electrolux, TENGBOM

indoor air quality measuring

Measurements of the air quality inside the apartments will be performed in combination with questionnaires about the perceived indoor air quality. Investigations on what characterizes good air quality and how the measurements relates to the perceived quality will be performed.

Project Lead: Sarka Langer - IVL Svenska Miljöinstitutet

Project Partners: BENGT DAHLGREN, ivl, PEAB

more by less

Project focusing on the energy consumption behavior of end users and the interfaces which have been developed in order to affect end users energy consumption. Further, it will identify knowledge gaps and suggest further research within this field.

Project Lead: Ulrika Rahe - Chalmers University

Project Partners: Göteborg Energi

mycelium acoustics

Development of a solution to reduce noise levels between the common kitchen and living room areas in one of the clusters in the HSB Living Lab using a 100% compostable, mycelium based bio-composite.

Project Lead: Anita Ollár - Chalmers University

Project Partners: TENGBOM

smart storage

Compact living is a highly current topic, this study investigates solutions for smart storage suitable for area efficient homes. Developed solutions will also be tested in the Living Lab.

Project Lead: Peter Elfstrand - Tengbom Arkitekter

Project Partners: TENGBOM, RICE

test bed for storm water management

Investigation of extreme delay and cleaning of storm water in a test bed of two containers. The evaluation in the project will consider economical, societal and environmental aspects.

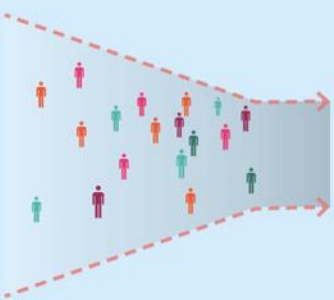
Project Lead: Lena Blom - Göteborg stad, Kretslopp och vatten

Project Partners: Göteborgs Stad Kretslopp och vatten, SP

How to innovate in the built environment?

Step 1

Filtering



Current Market

BTA scans available innovations on an EU scale and selects technologies to be tested in the Living Labs.

Step 2

Testing / Demonstration / Co-Creation

Living Labs

BTA provides unique testing demonstration field facilities with different Living Labs.

Source Image: Tengbom Arkitektur-HSB Living Lab Presentation to SBK-2014.08.26

Step 3

Implementation Network

Finance

BTA provides a unique network of demand side stakeholders in order to introduce the technologies into the market.

Step 4

Market Implementation

Real World

BTA aims at a significant impact on an EU level.

source: Climate-KIC, BTA management

APPENDIX

The Sustainable Building Group

Selected projects.

Transforming campus

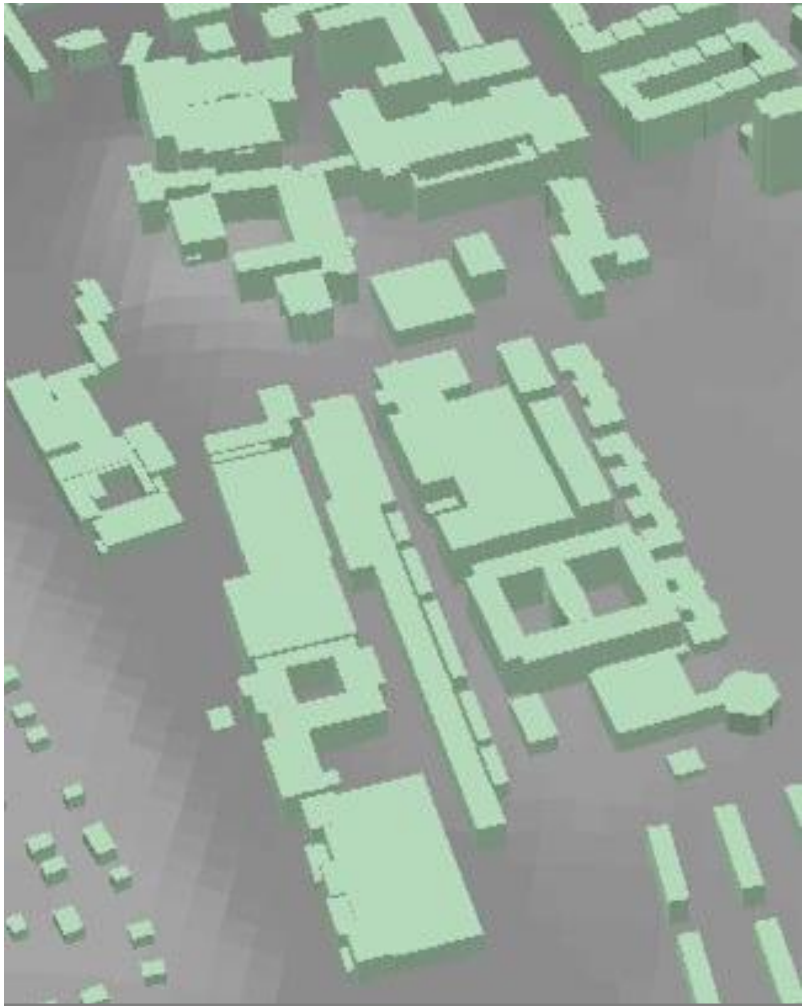
How can the infrastructure of the Johanneberg campus be transformed to drastically reduce the energy and environmental impact and what are innovative pathways to such a conversion?

4 Building owners on campus:

- Akademiska Hus
- Chalmers Fastigheter
- SSPA
- Emils Kårhus AB

Other collaboration:

- Energiteknik, Filip Johnsson
- Data och informationsteknik, Marina Papatriantafilou



Energy consumption: way too high
(> 300 kWh / m^2 / a)

Smart and Sustainable Offices

Guidelines of SSO

- Three climate zones
- Buildings from

- Holistic measures of human responses and physical environments

Business Opportunity

- Targeting various stakeholders
- Covering different processes (design, construction and refurbishment)

Advanced Model

- Human perception driven
- Comfort and health targeted
- Physics and Psychology integrated

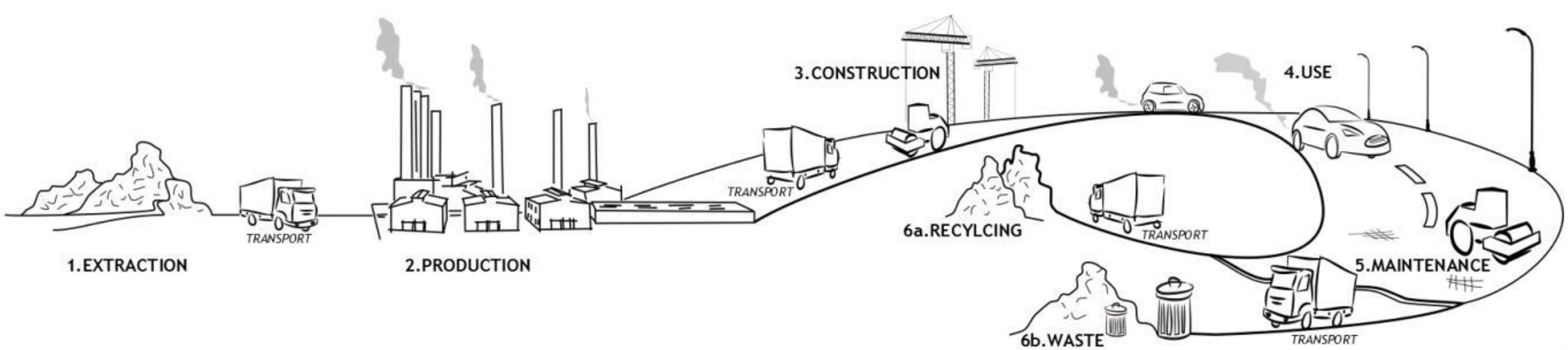
CHALMERS
INSTITUTO VALENCIANO DE LA EDIFICACIÓN
VNIVERSITAT DE VALÈNCIA
eit

Infrastructure Performance

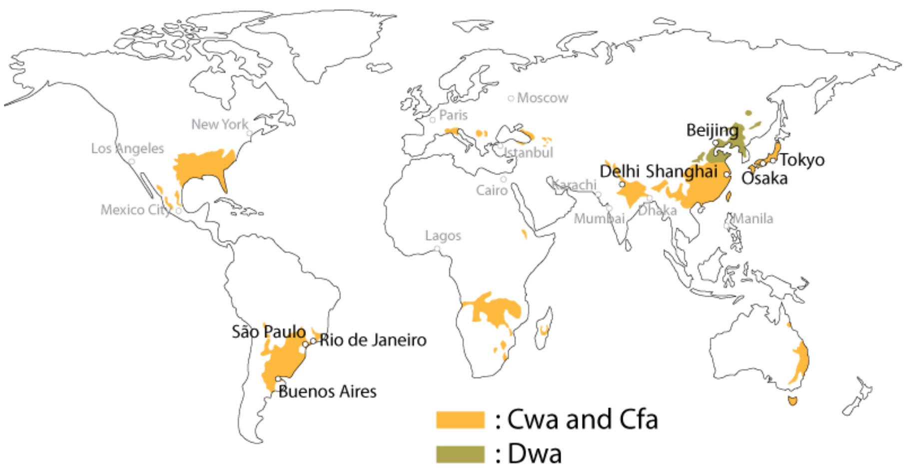
(LCA-LCCA of Norwegian Roads)

Evaluation of **environmental** and **economic** impacts of activities related to the construction and rehabilitation of new and existing Norwegian open roads (excl. bridges and tunnels) by means of:

- Environmental life cycle assessment (LCA) and
- Economic life cycle cost analysis (LCCA).

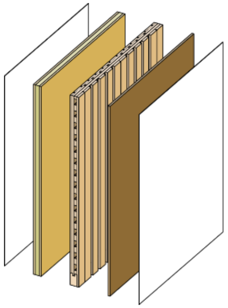


Sustainable wooden building envelope concept for subtropical regions



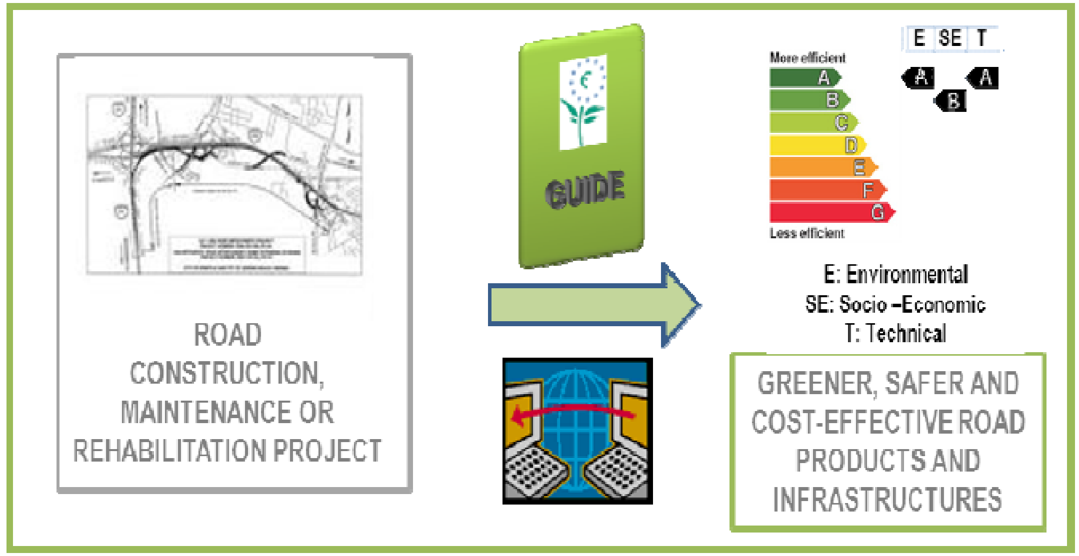
The goal of the project is to develop a sustainable wooden building envelope system for the regions with subtropical climate.

The project emphasizes the socio-cultural and climate adapted technologies applying an interdisciplinary approach (building physics, LCA and LCCA).



ECOLABAL roads

Development of a novel ECO-LABELing EU-harmonized methodology for cost-effective, safer and greener road products and infrastructures

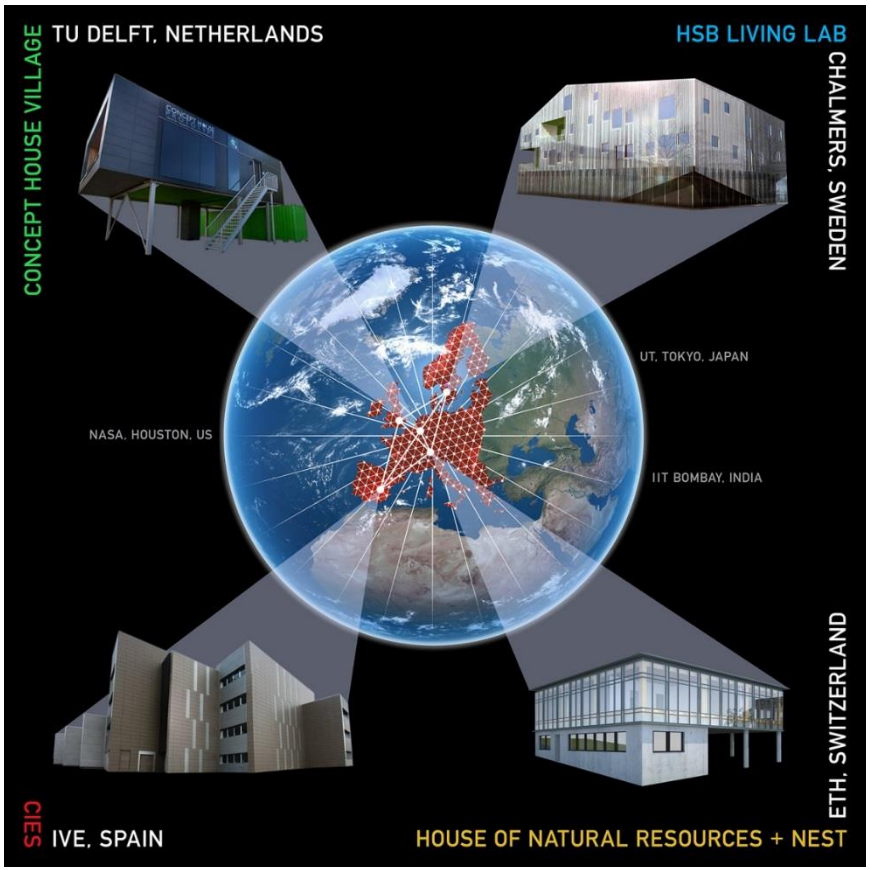


FP7-SST-2013-RTD-1

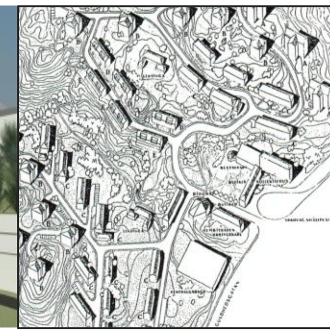
Climate-KIC

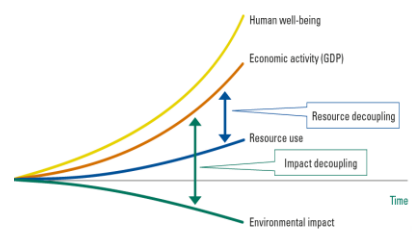
(European Network to foster Entrepreneurship and Innovation on Climate)

HSB Living Lab



Johanneberg District Factor 10





CHALMERS
UNIVERSITY OF TECHNOLOGY

RENEW SCHOOL

Project goals

Promote and increase high-energy performance and prefabricated timber-based renovation of school buildings in Europe

Asplan Viak AS (Asplan), **Norway**; Autonomous public company City Education Antwerpen (AGSO), **Belgium**; Chalmers tekniska högskola AB, **Sweden**; Fraunhofer-Gesellschaft zur Förderung der angewandten Forschung e.V., IBP, **Germany**;Informest – Service and Documentation Centre for International Economic Cooperation, **Italy**; National Energy Conservation Agency (NAPE), **Poland**; Passiefhuis-Platform vzw (PHP), **Belgium**; Politecnico di Milano, Dipartimento di Energia (eERG-PoliMi), **Italy**; Technical University of Denmark (DTU), **Denmark**; Wood Cluster Styria Ltd. (HCS), **Austria**;Wood Industry Cluster (WIC), **Slovenia**

CHALMERS

for a sustainable future