University of California, Berkeley
Peder Sather Workshop of Building Efficiency
September 15, 2014, 3110 Etcheverry Hall

Using Commissioning of Building Services as a Tool to Pinpoint Research Topics Significant for Improving Energy Efficiency

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Outline

- Commissioning (Cx) of Buildings and Building services
  - What is Cx and why Cx is necessary?
  - Functional Requirements vs Real Life
  - Initial vs Life-time Commissioning
  - Two Examples for Real Life Commissioning

- Influence of occupant’s behavior on the performance of Net-Zero Emission Buildings

- Life Cycle Assessment as a tool for comparison of building services systems

Desired Functional Requirements

- All serious industry players involved in procurement, planning, construction and operation of buildings have good intentions regarding meeting requirements.
- This include safe and efficient operation, a healthy indoor air climate, rational use of energy, minimal impact on the outdoor environment, and decent economy.
- Practical experience, however, tell that in numerous cases there are serious discrepancies between goals and reality.

Actual Functional Performance

- Many buildings show significant deviations between design requirements and actual performance.
- The problems may be related to errors made
  - during the design phase,
  - during the construction of the building,
  - during the (initial) commissioning process,
- or they may be caused by
  - incorrect operation of the technical systems,
  - lack of maintenance or
  - altered use of the building.

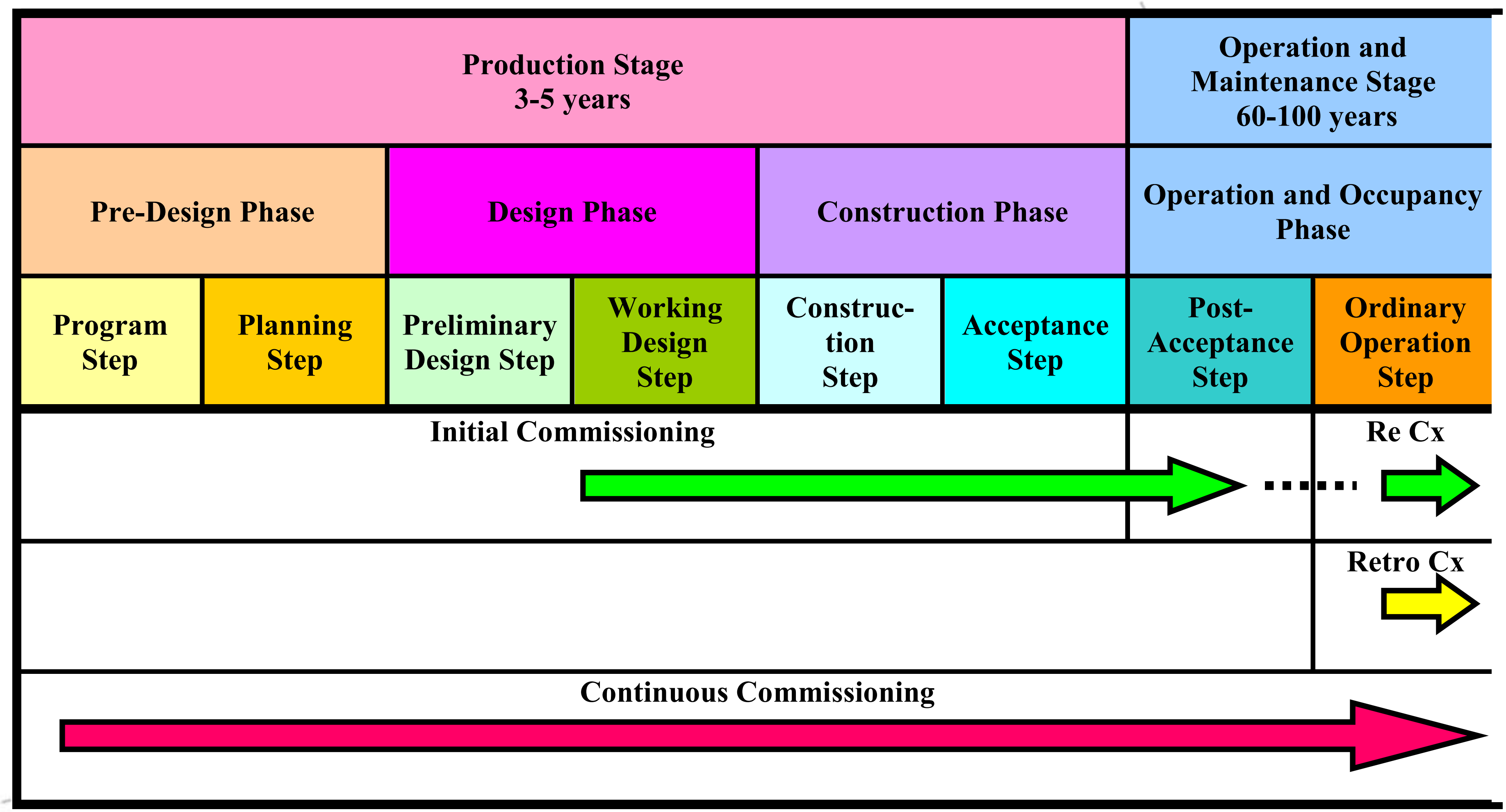
Commissioning

- Commissioning has lately been internationally recognized as a promising tool to solve the challenge of buildings that do not function properly.
- Commissioning has earlier solely been understood as a process at the end of the construction of a building, also called taking-over or initial commissioning.
- The new understanding is that commissioning is a continuous process that spans from the early design phase throughout the operational phase.

Commissioning

- Commissioning is the process of ensuring that systems are:
  - designed,
  - installed,
  - functionally tested and
  - capable of being operated and maintained,
- to perform in conformity with the intent and
- to keep building in optimal conditions throughout the entire lifetime.

Schematic of Commissioning Process, Phases and Types



International projects on the Building Commissioning

- **The International Energy Agency (IEA) has thorough the Energy Conservation in Buildings and Community System Programme (ECBCS) recognized the necessity of proper commissioning of buildings to avoid faulty operation.**

- **Two collaborative project with brad international participation was conducted:**
- **Annex 40: "Commissioning of Building HVAC Systems for Improved Energy Performance" (2001-04)**
- **Annex 47: "Cost-Effective Commissioning for Existing and Low Energy Buildings" (2005-09)**

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Norwegian Project for Life-Time Commissioning and Energy Efficient Operation of Buildings

- **The overall objective was to contribute to the implementation of life-long commissioning of building HVAC systems, so that this becomes a standardized way of building, operating and maintaining the HVAC systems.**

- **The main goal was to develop, verify, document and implement suitable tools for function control of energy and indoor environment conditions in buildings under continuous operation during the entire operational life of the building.**

Norwegian Project for Life-Time Commissioning and Energy Efficient Operation of Buildings

- Two examples for use of commissioning for improvement of energy performance of buildings:
- Using building energy monitoring data to verify building energy performance
- Data fusion for improved performance estimation

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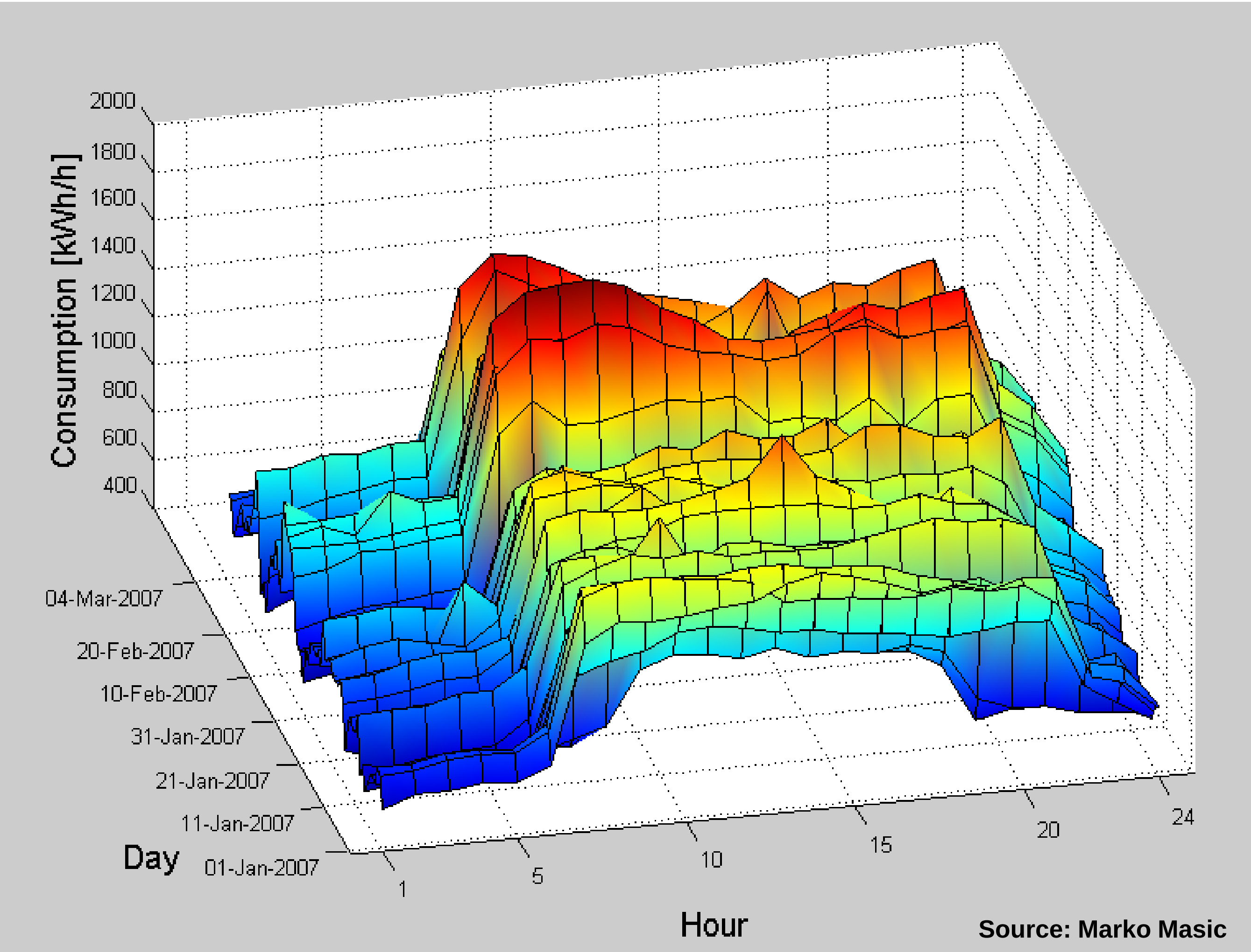
Using building energy monitoring data to verify energy performance



Energy consumption for space heating

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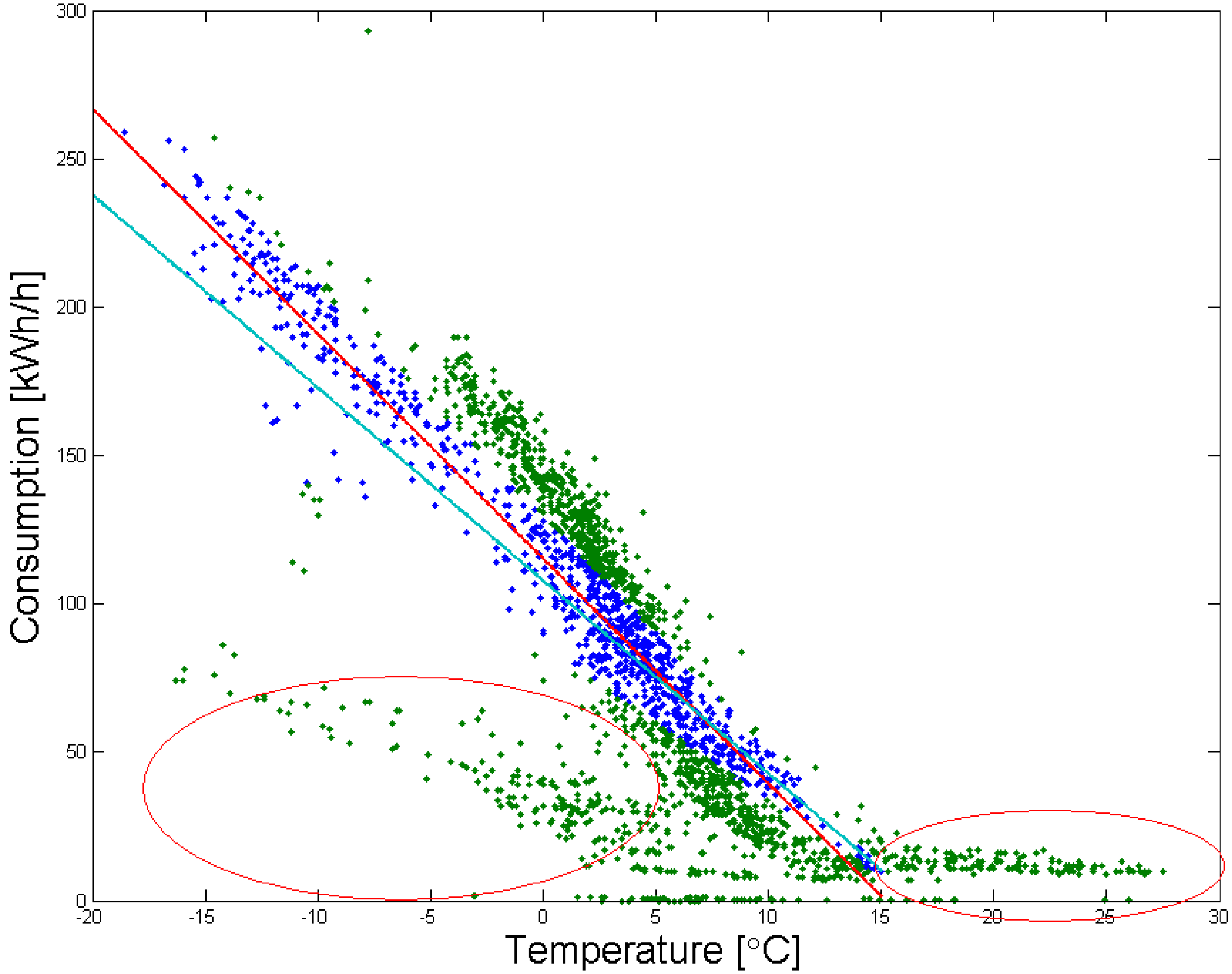
Building Energy Signature



Source: Marko Masic

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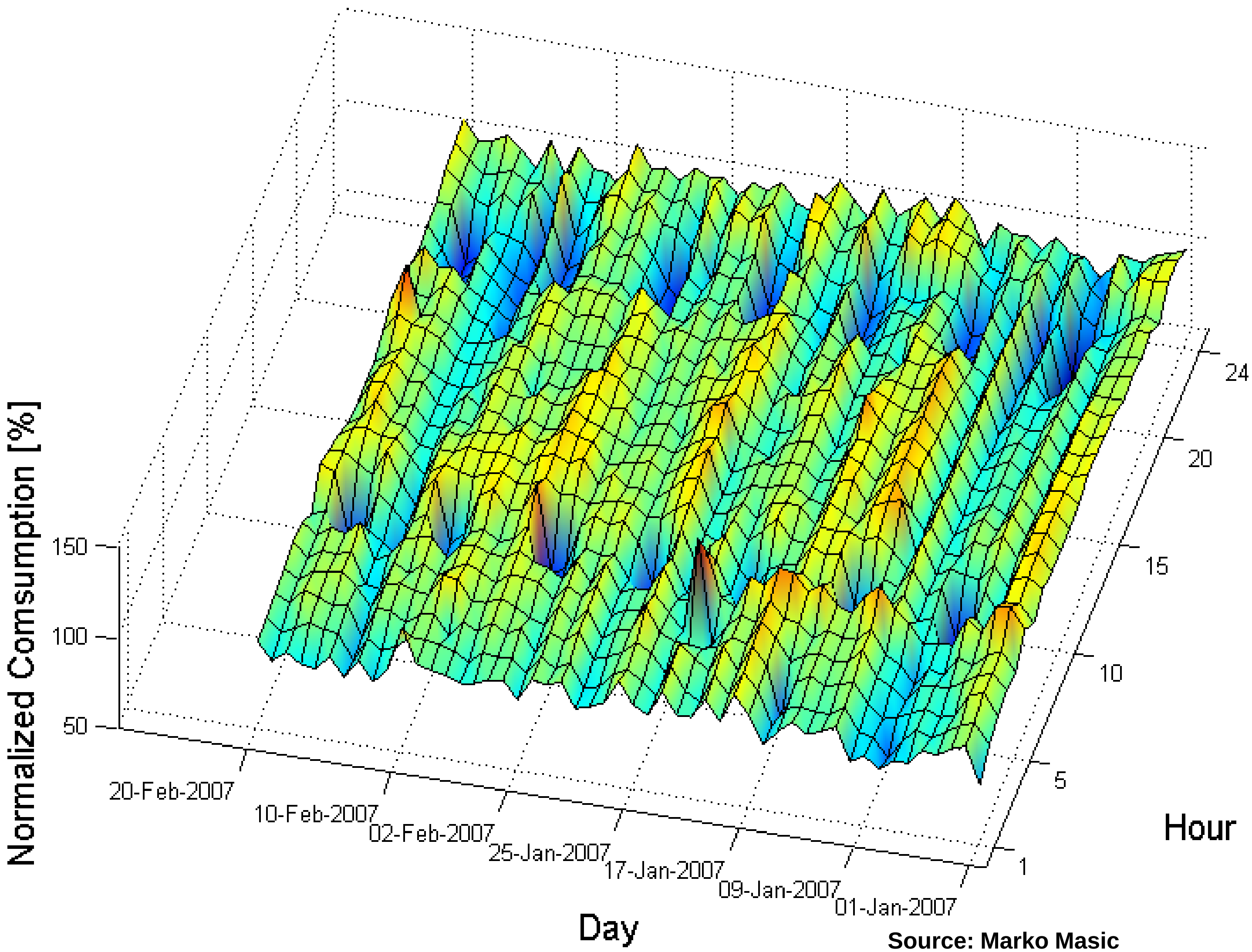
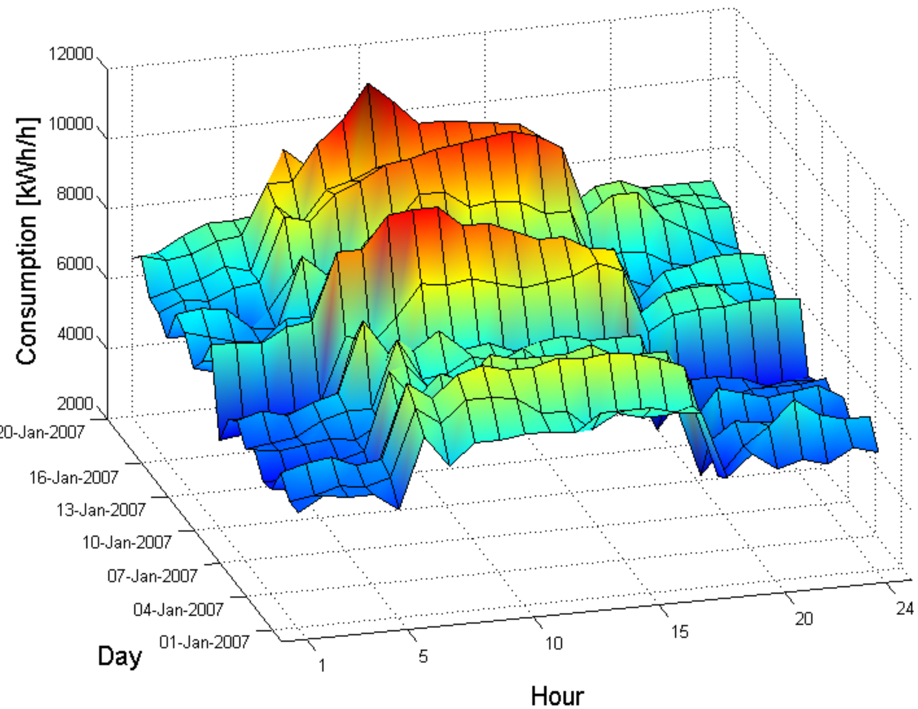
Identifying weekend regime

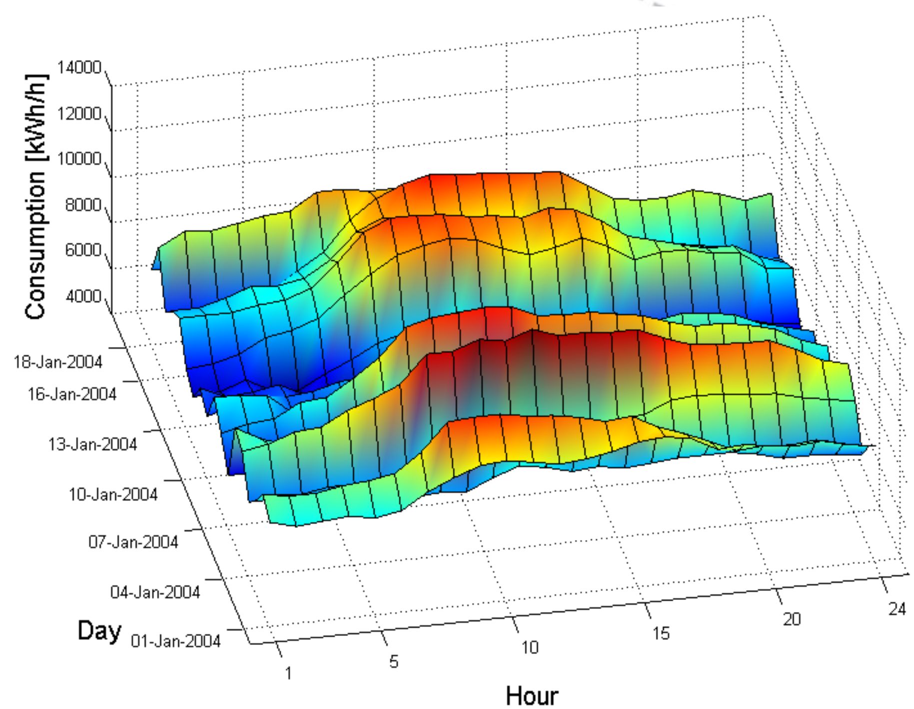


Source: Marko Masic

Overall consumption of Gloshaugen campus

- Monitoring period 01.01.2003 – 17.06.2007
- Control regimes were changed after 10.01.2006





Source: Marko Masic

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Overall consumption of Gloshaugen campus

- 3 regimes are recognized:
  - Monday– Friday 6-17h
  - Saturday – Sunday 6-17h
  - Night regime
- Regime schedule corresponds to control regimes of many buildings on campus

Energy signature line coefficients for 5 heating seasons

Linear coefficients	01.01.2003-30.03.2003	01.10.2003-30.03.2004	01.10.2004-30.03.2005	01.10.2005-30.03.2006	01.10.2006-30.03.2007
Regime 1	8186	8229	8240	8481	8263
Regime 2	7350	7030	6897	7229	7064
Regime 3	7054	6848	6896	6225	6363

Close values of linear coefficient for control regime 2 and 3

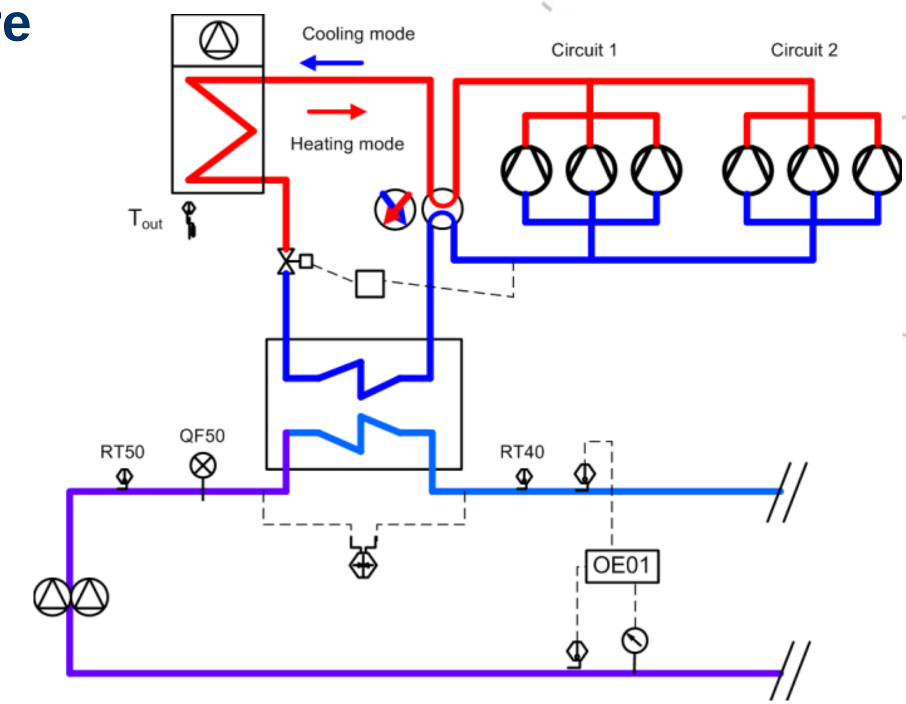
Different regimes

Source: Marko Masic

Data fusion for heat pump performance estimation

- **Data fusion means that data from different information sources are combined to achieve better resulting information**

- **Measured compressor power was several times higher than the condenser heat**
- **Theoretically, this ration should be opposite.**
- **“Improved measurements” on heat pump performance were developed.**



Source: Natasa Djuric Nord

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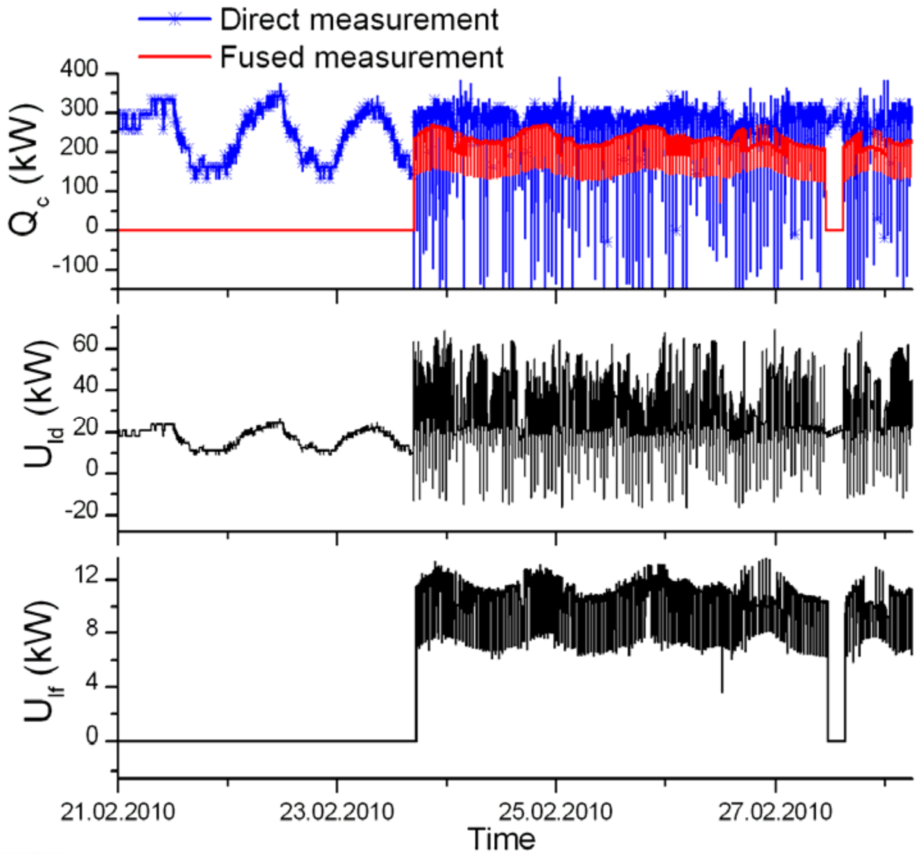
Data fusion for heat pump performance estimation



- **Direct measurements obtained using the temperature and pressure measurements**

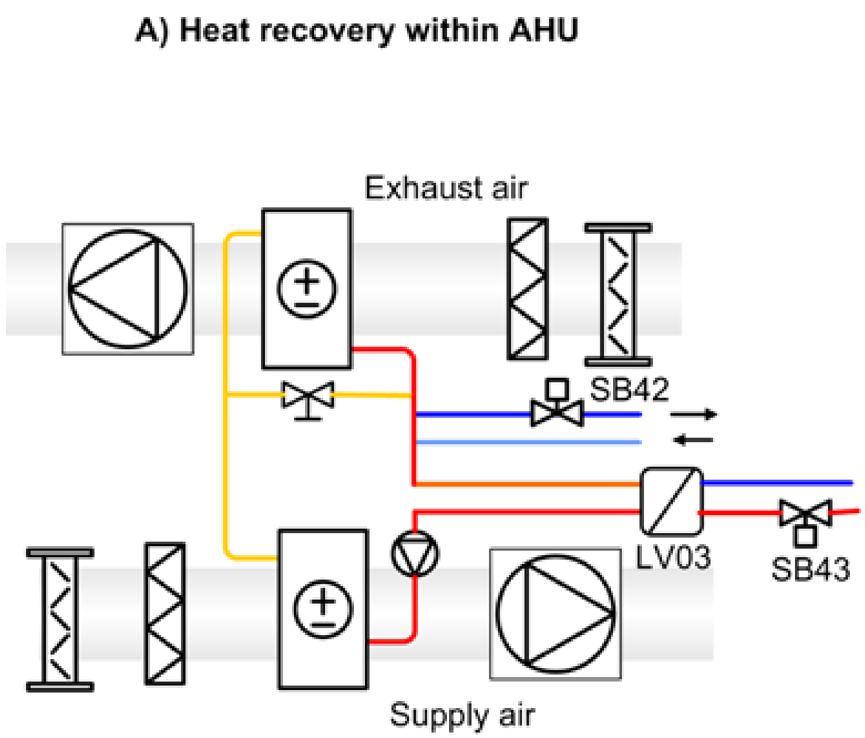
- **Indirect measurements obtained using the electrical signal of the heat pump part load**

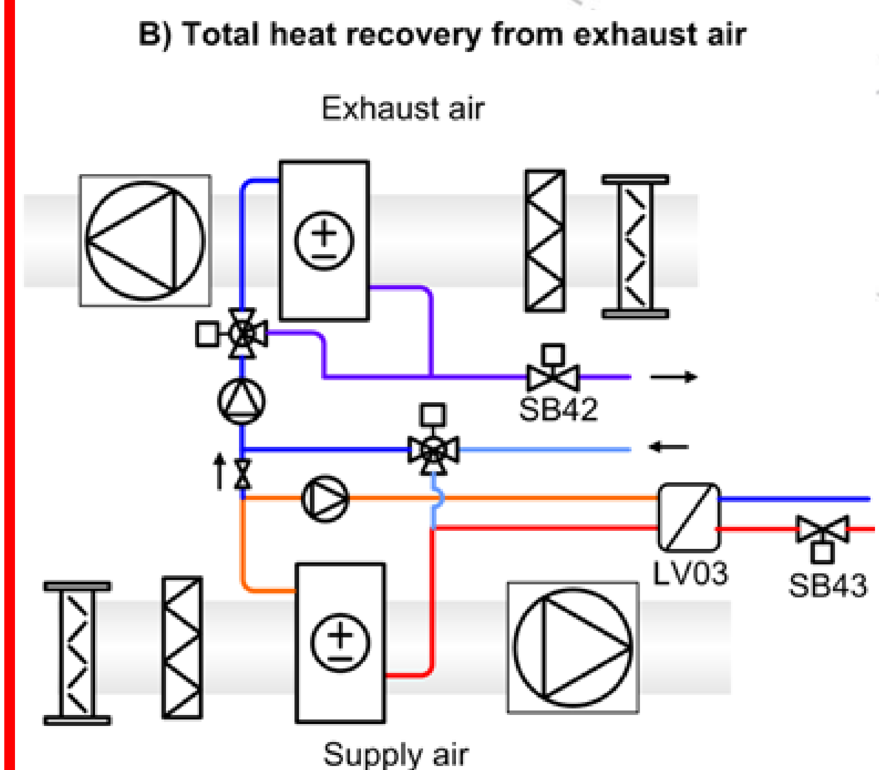
Source: Natasa Djuric Nord

Data fusion for heat recovery performance estimation

Solution from design phase

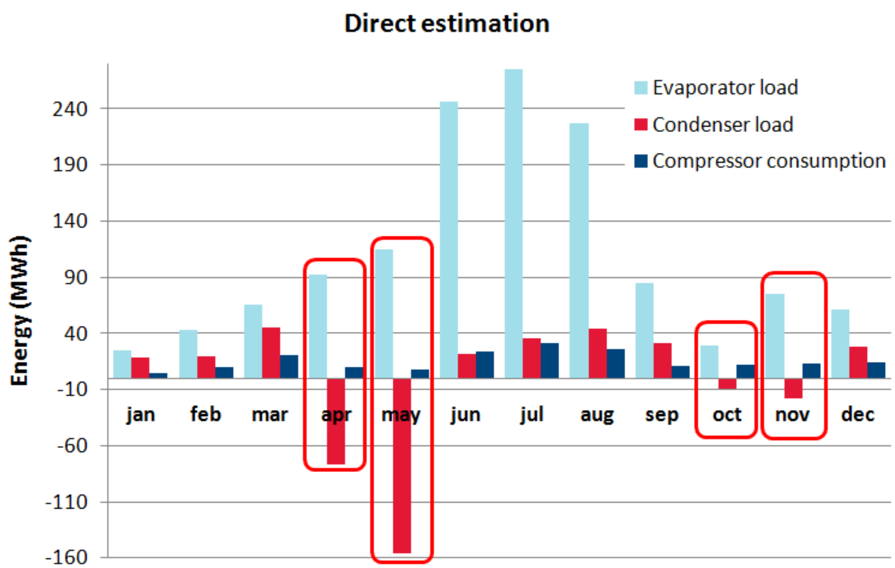
Installed

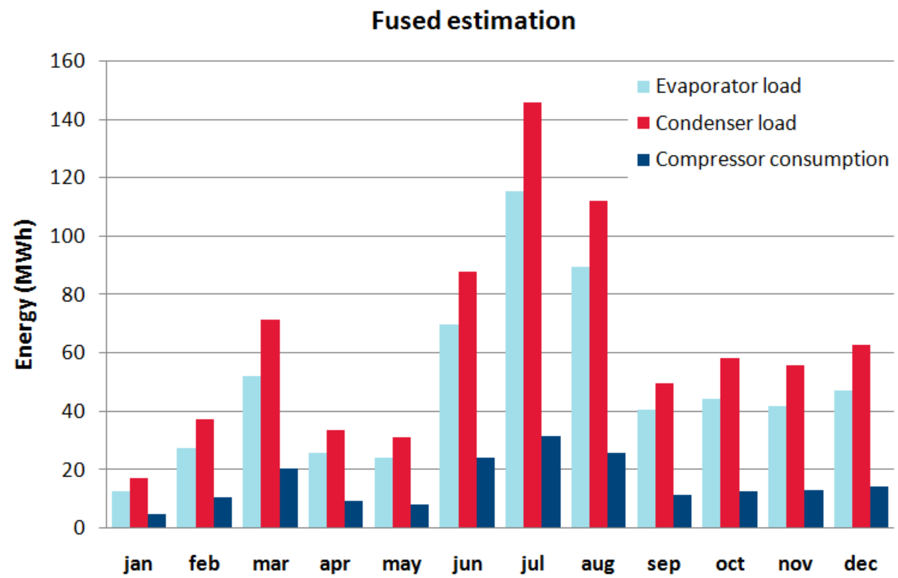




Source: Natasa Djuric Nord

Data fusion for heat recovery performance estimation





- Sensors for the evaporator includes also the free cooling
- Temperature difference over the condenser was to small

- Data fusion estimation combines "direct" and "indirect" measurements

Source: Natasa Djuric Nord

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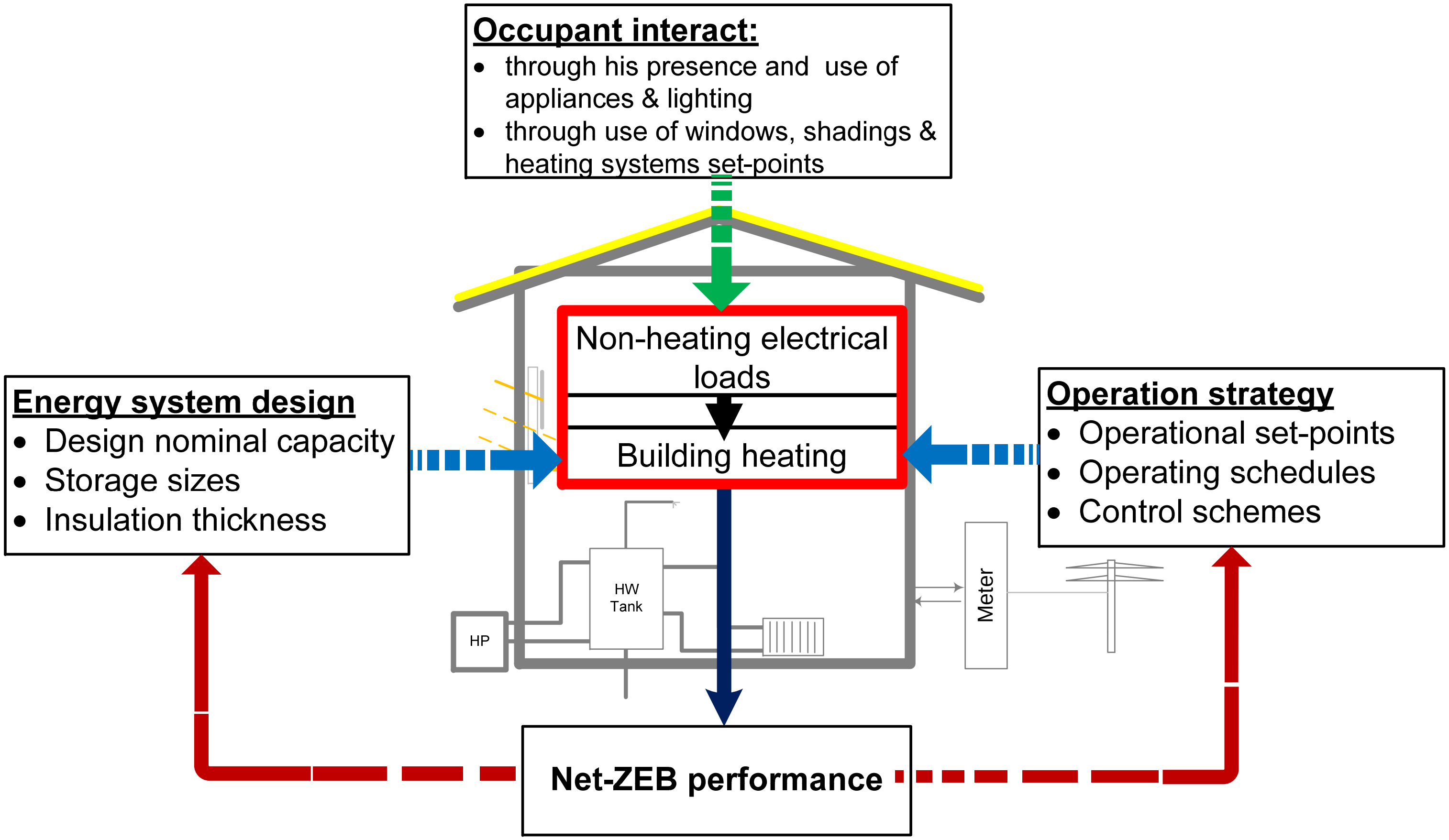
Role of occupant

- Gap between (model) predicted and actual energy use
  - Physical representation
  - Input parameters
  - Boundary Conditions
    - Climate file
    - Occupant interaction with the building
- Progress in Building simulation science
- Better industrial practices
- Better climate data
- Internal boundary conditions related to **occupant interaction** with the building are still oversimplified
- Thus, occupants' behavior is a major cause of this gap!

Hypothesis



Better understanding about influence of occupant interaction with the building can contribute to better design of energy system

Methodology

Step 1: Define a case study building with the heating system

↓

Step 2: Generate a sample of behavior profiles for case study building

↓

Step 3: Dintinguish the profiles according to cases

↓

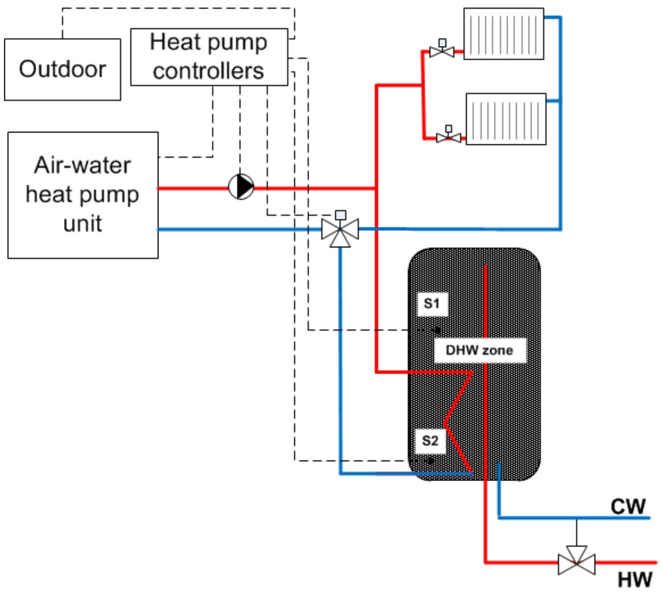
Step 4: Simulate the cases and post-process

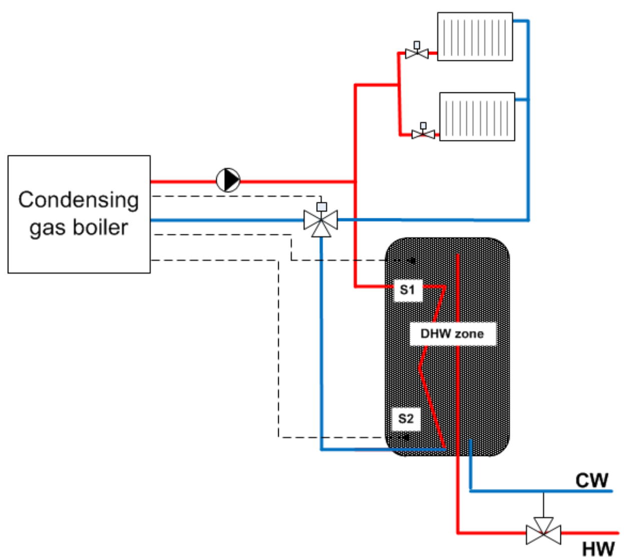
↓

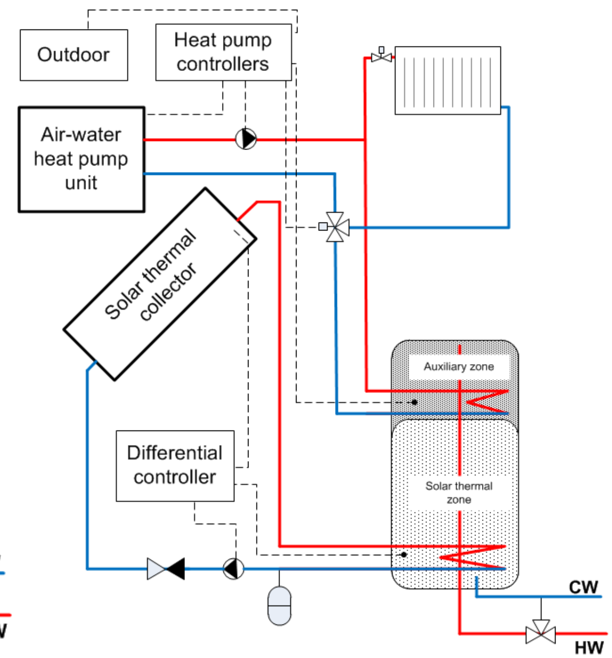
Step 5: Conclusion and recommendation

Building and heating system (1)

- A study of detached house in the climate of Oslo
- Two insulation cases (Norwegian standard)
  - A moderate-insulated case using LEH: class 2
  - A well-insulated case using PH
- Three cases of heating systems







Source: Usman Dar

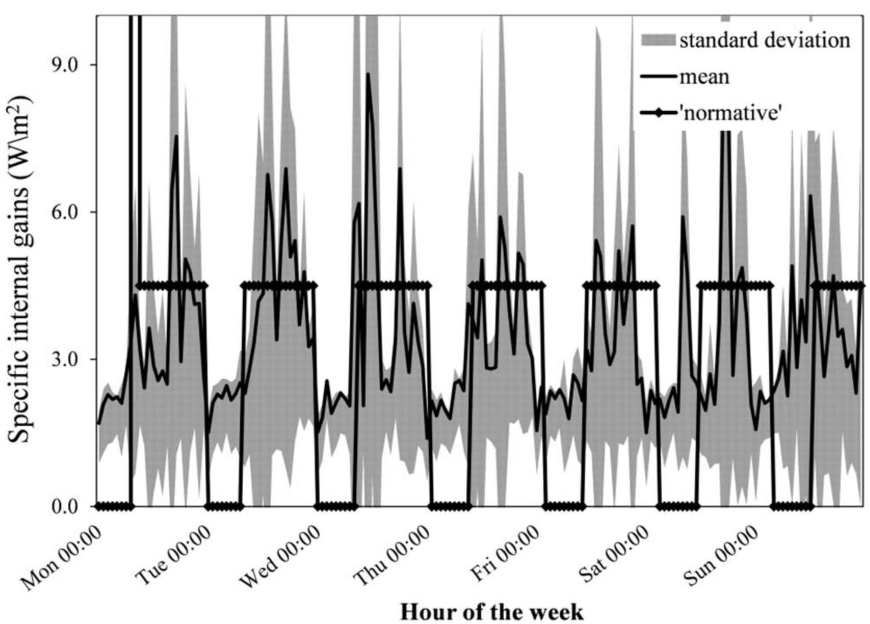
Occupant Behavior

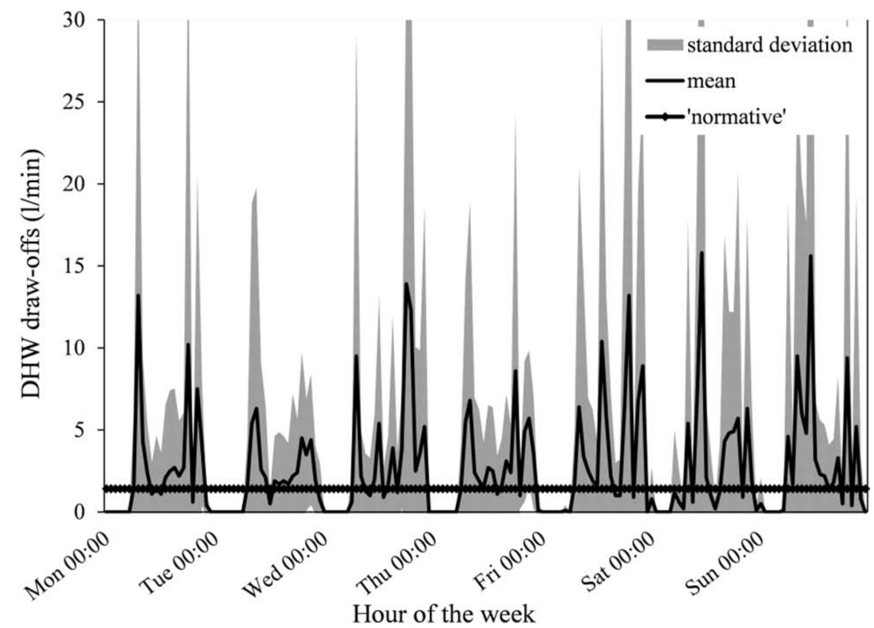
- Occupants' interactions are categorized into actions:
  - Relatively independent of environmental stimuli
  - Dependent on environmental stimuli (Adaptive actions)
- This research focuses only on first domain and considers the variation in electrical loads and DHW draw-offs
- The behavior model reproduces the household profiles considering different occupants- and household-related parameters such as:
  - Number of occupants in a house
  - Household's appliance ownership
  - Occupants' working schedule

Source: Usman Dar

Behavior model(1)

- **The behavior model reproduces profile of individual household that is very different from another**





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Source: Usman Dar

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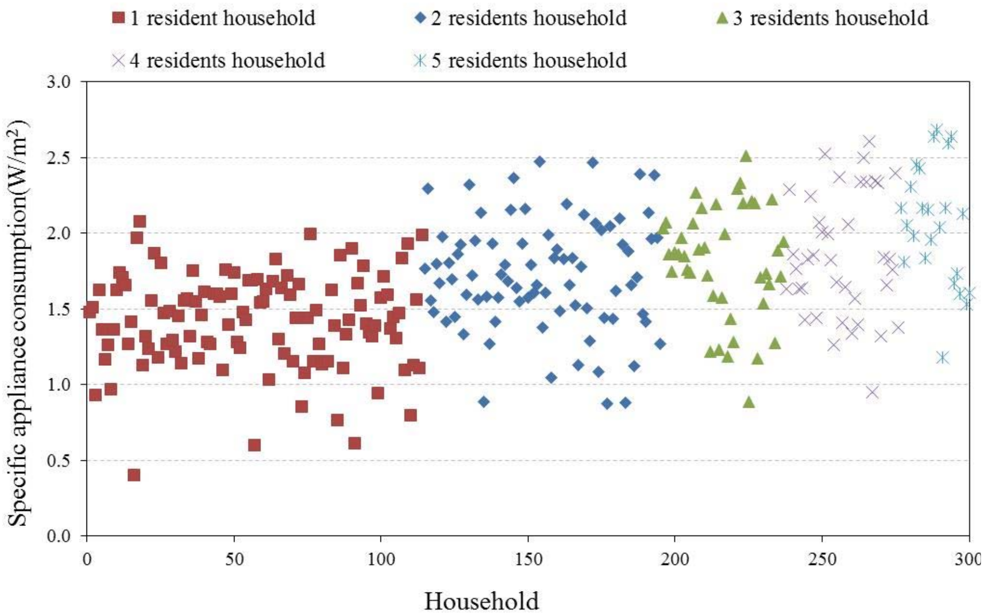
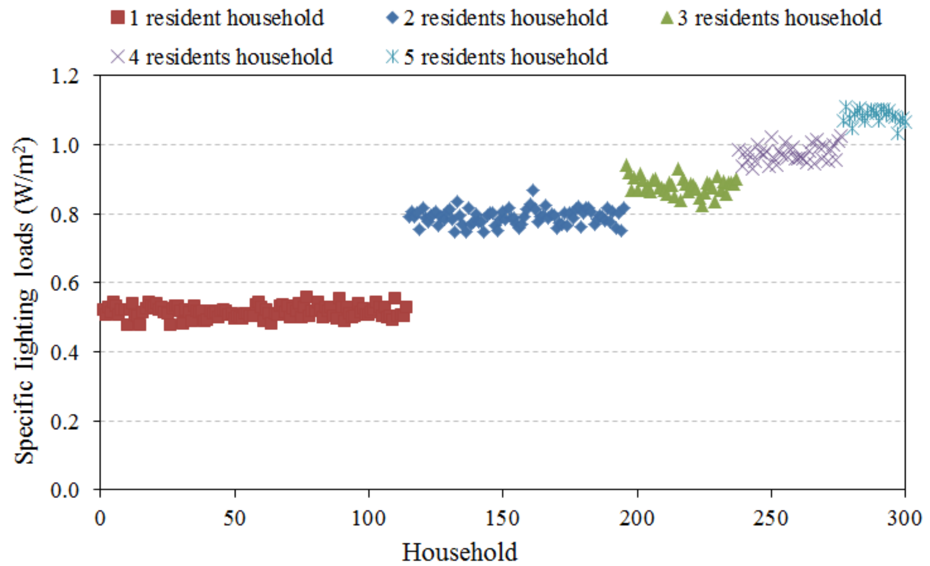
Behavior model (2)

- **Model reproduces the diversity in households's electrical consumptions**





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Source: Usman Dar

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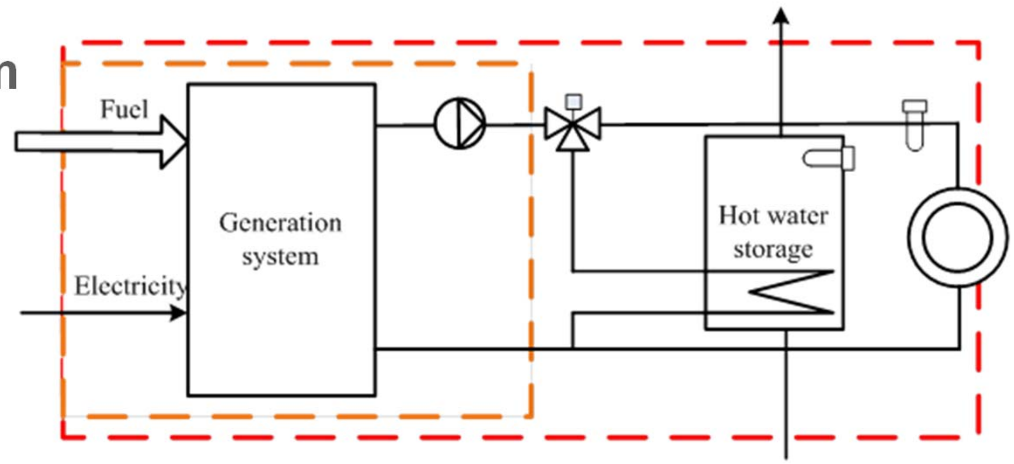
Evaluation method

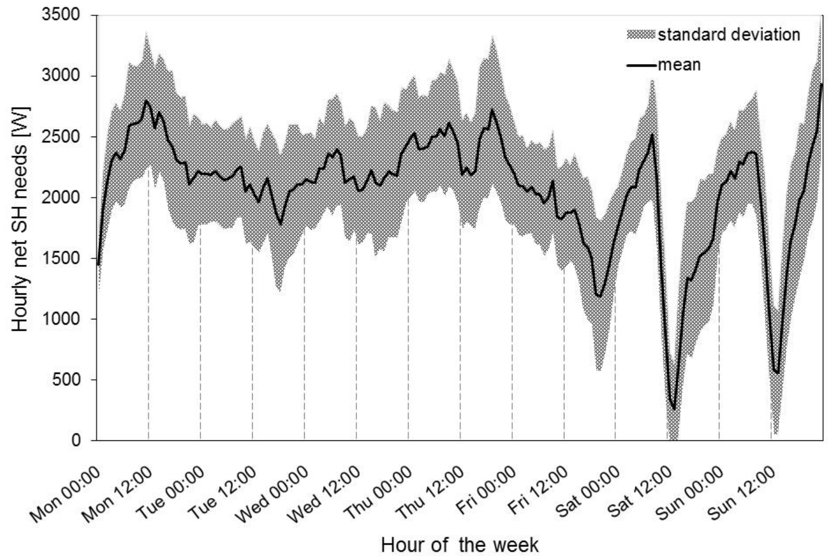
- Seasonal performance factor/seasonal efficiency using two system boundaries
  - Generation system
  - Complete heating system



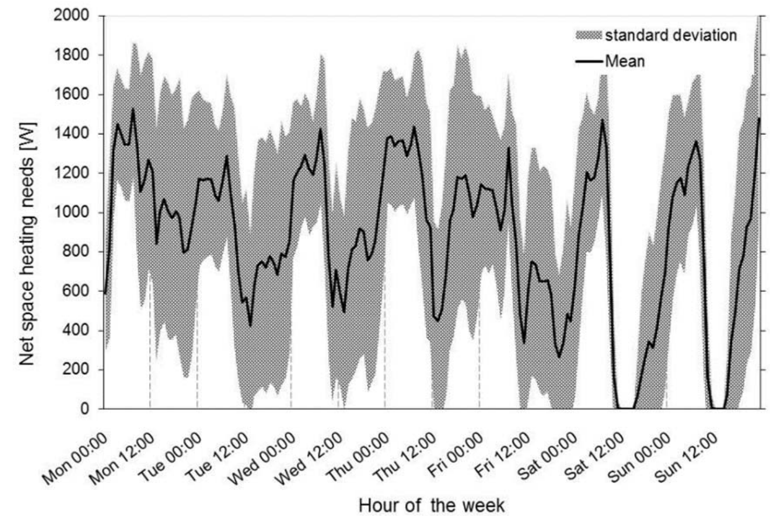
- Building exchange with the grid using different indicators such as
  - Self sustenance factor (SSF)
  - Exchange above given threshold ($E_{>xlim}$)
  - Relative import bill (RIB)

Source: Usman Dar

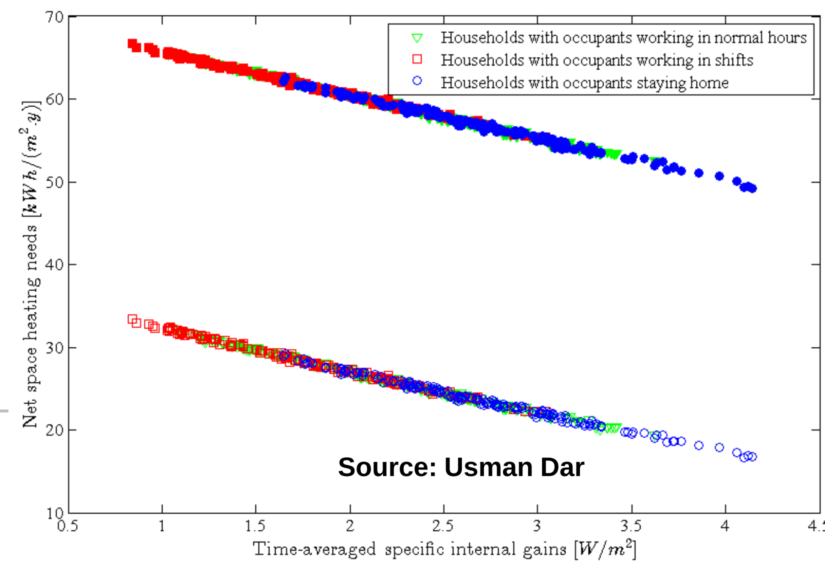
Influence on space heating needs



Moderately-insulated case

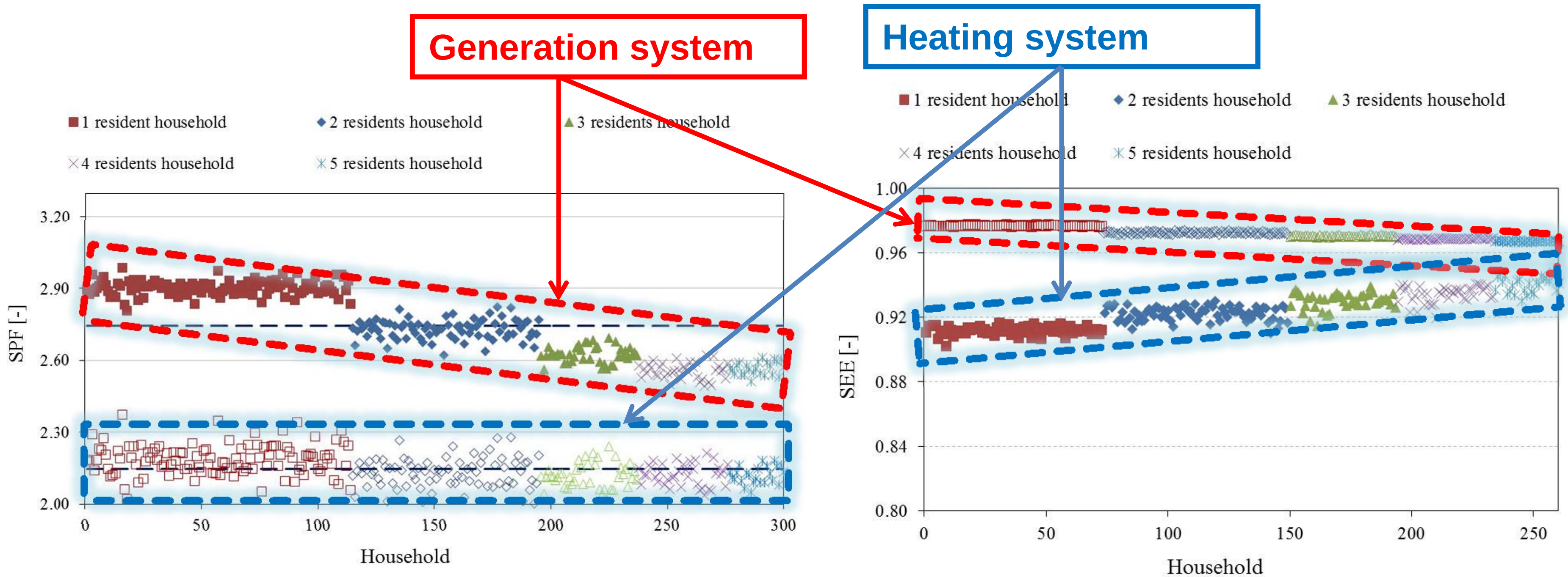


Well-insulated case



Source: Usman Dar

Influence on system performance(1)



Air-to-water HP

Combustion Boiler

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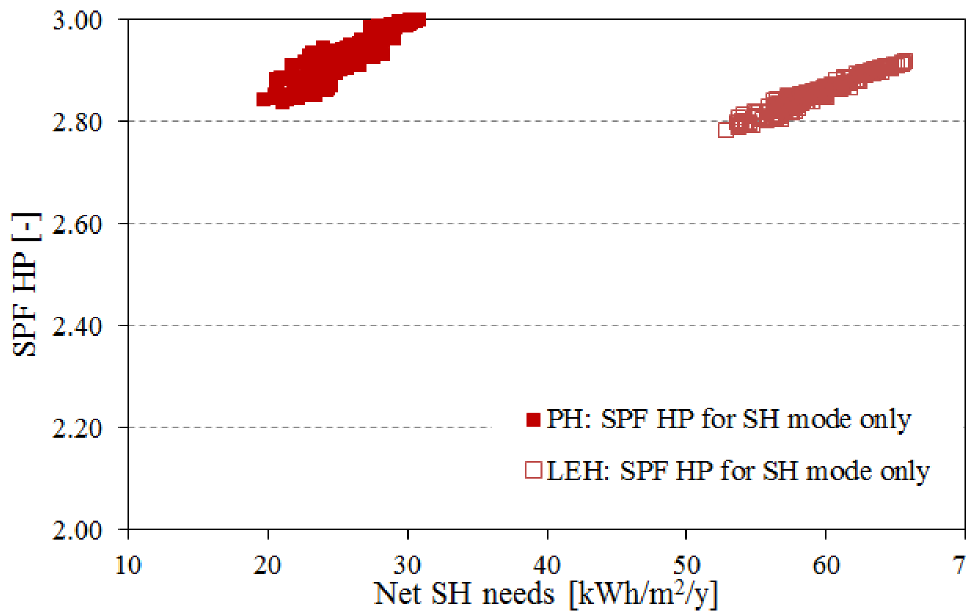
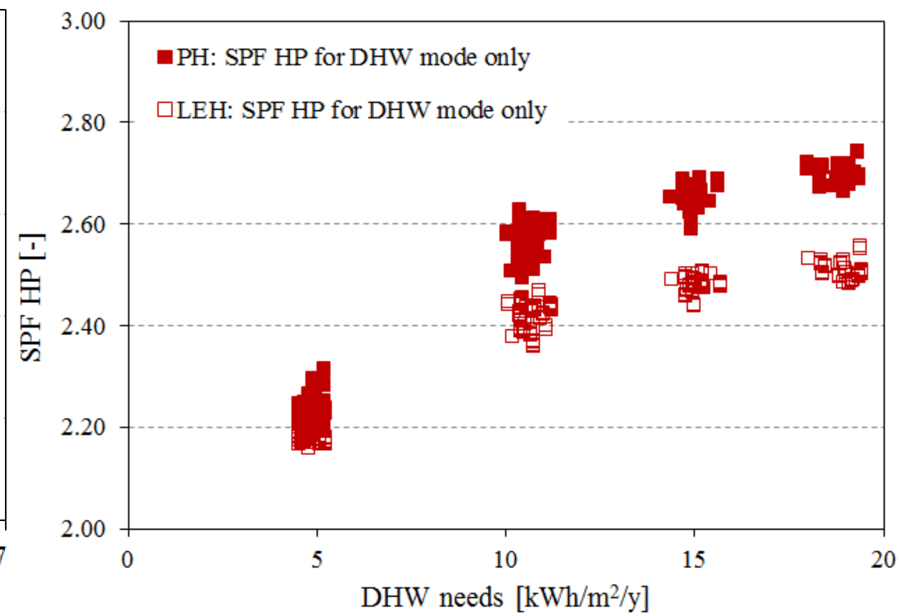
Source: Usman Dar

Influence on system performance(2)

SPF for SH mode only

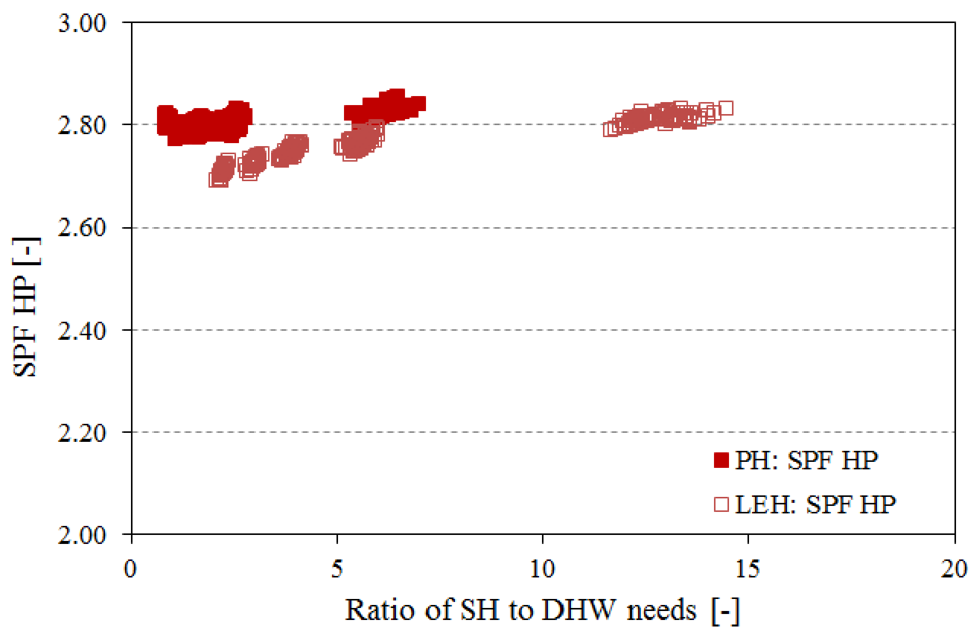


SPF for DHW mode only

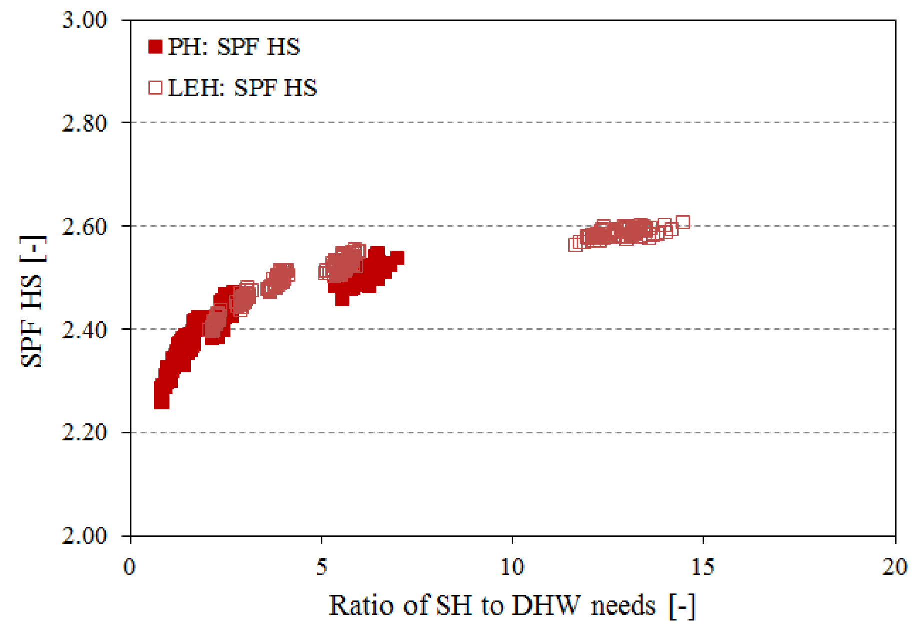


Influence on system performance(3)

SPF for HP for combined modes



SPF for complete heating system



Designers should particularly focus to reduce the system losses through system reduction

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Source: Usman Dar

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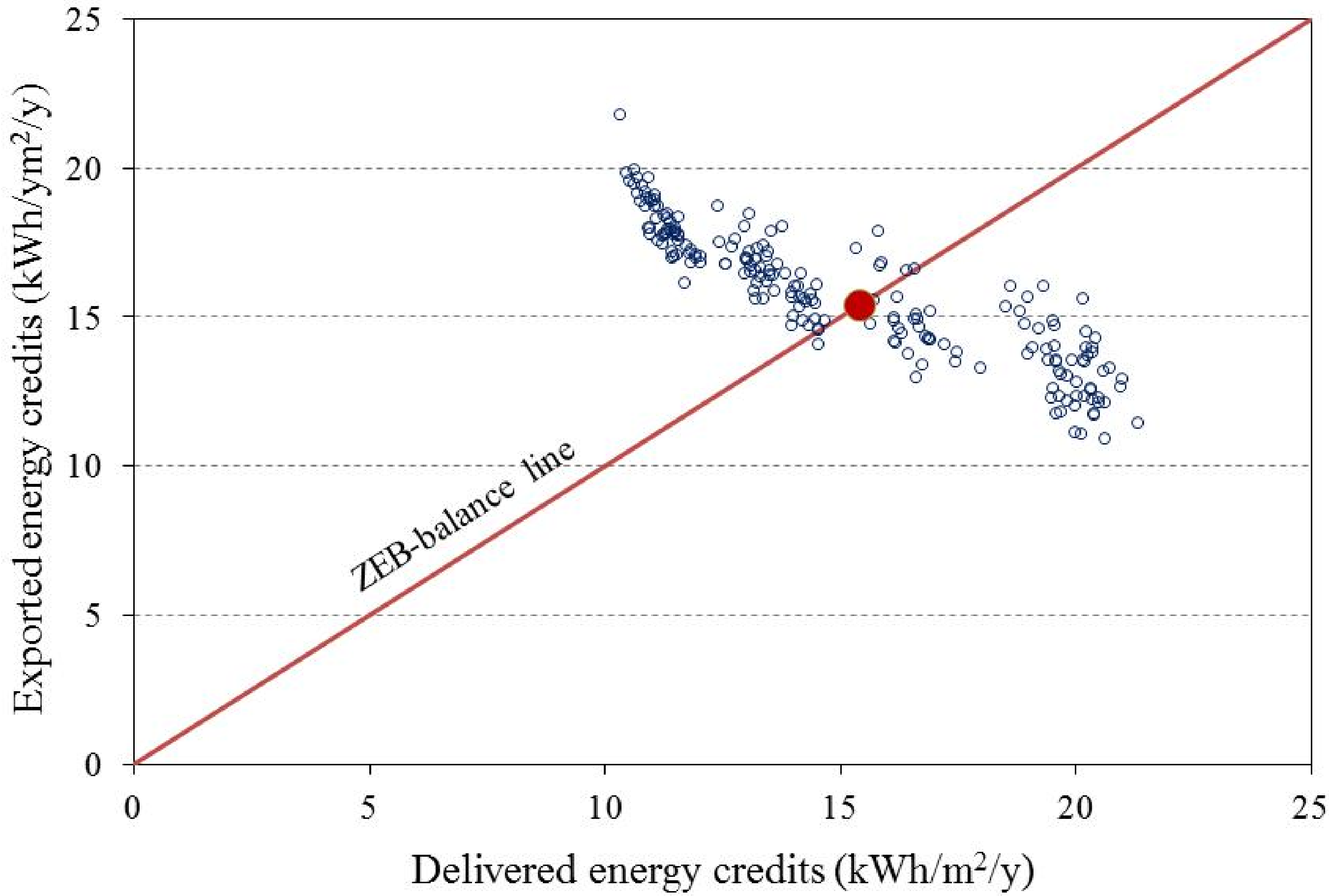
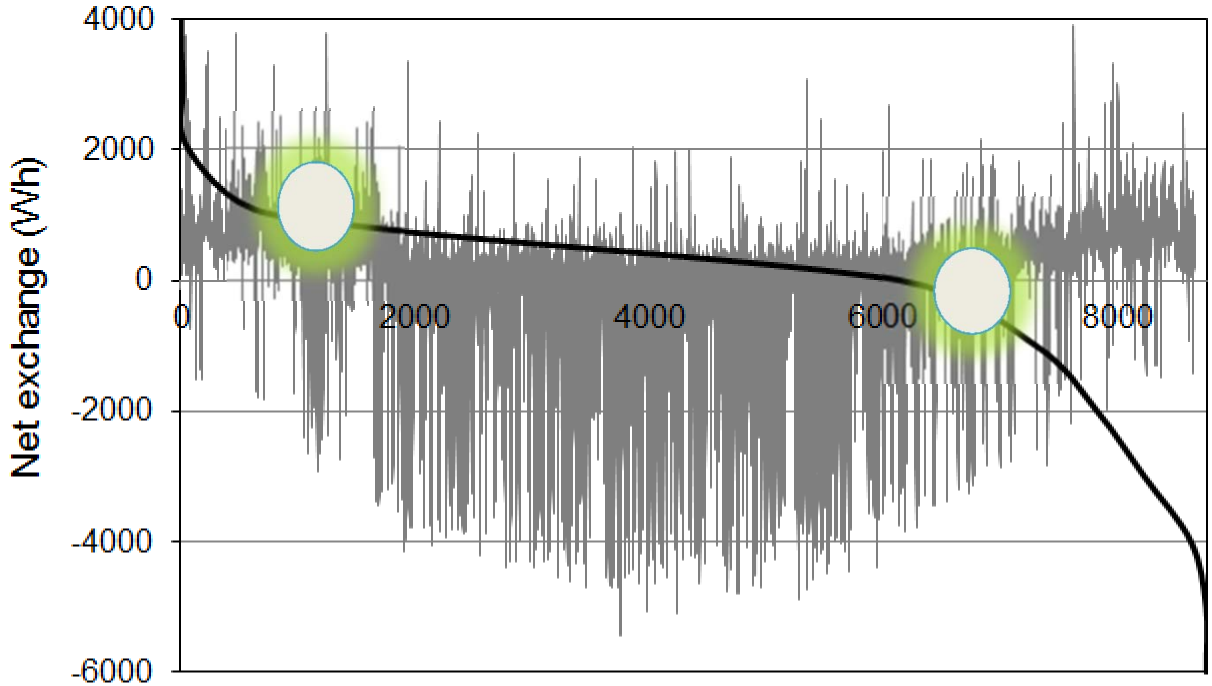
Influence on ZEB balance

- **ZEB balance**



Influence on grid interaction

- **Exchange with the grid**



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Source: Usman Dar

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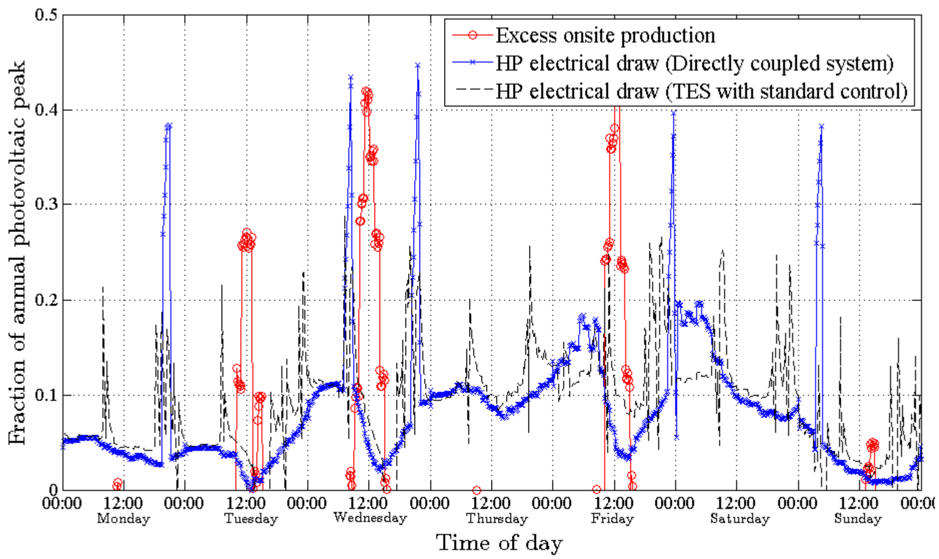
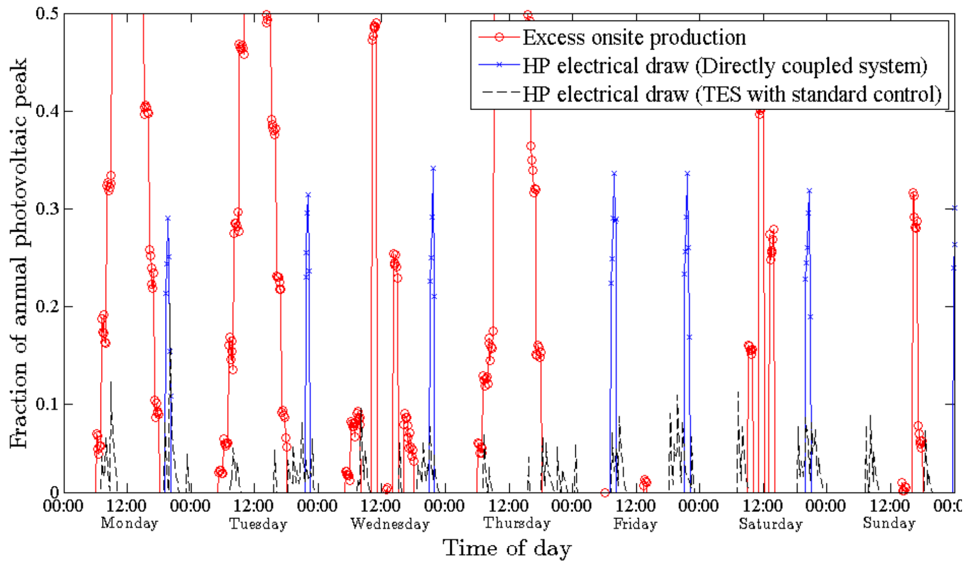
Grid interaction

Winter week of February



Summer week of July



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Source: Usman Dar

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Conclusions

- Better insulated envelope increases the significance of occupant-behavior
- **Short-term fluctuations** in internal gains do not influence the annual heating needs and system performance
- However, they influences building's interaction with the grid
- **Households' diversity** has far-reaching influence on both the energy performance as well as its interaction with grid
- **Recovery of system losses** in passive envelope is getting difficult compared to poorly insulated building
- **Design of heat storage and distribution systems** is very important and has large impact on overall system performance in well-insulated envelopes
- Design of systems using **predefined performance values** leads to overly-sized and/or poorly performing system
- ZEB can offer significant **flexibility to the grid** if proper control schemes are set in place

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- **Life Cycle Assessment as a tool for comparison of building services systems**

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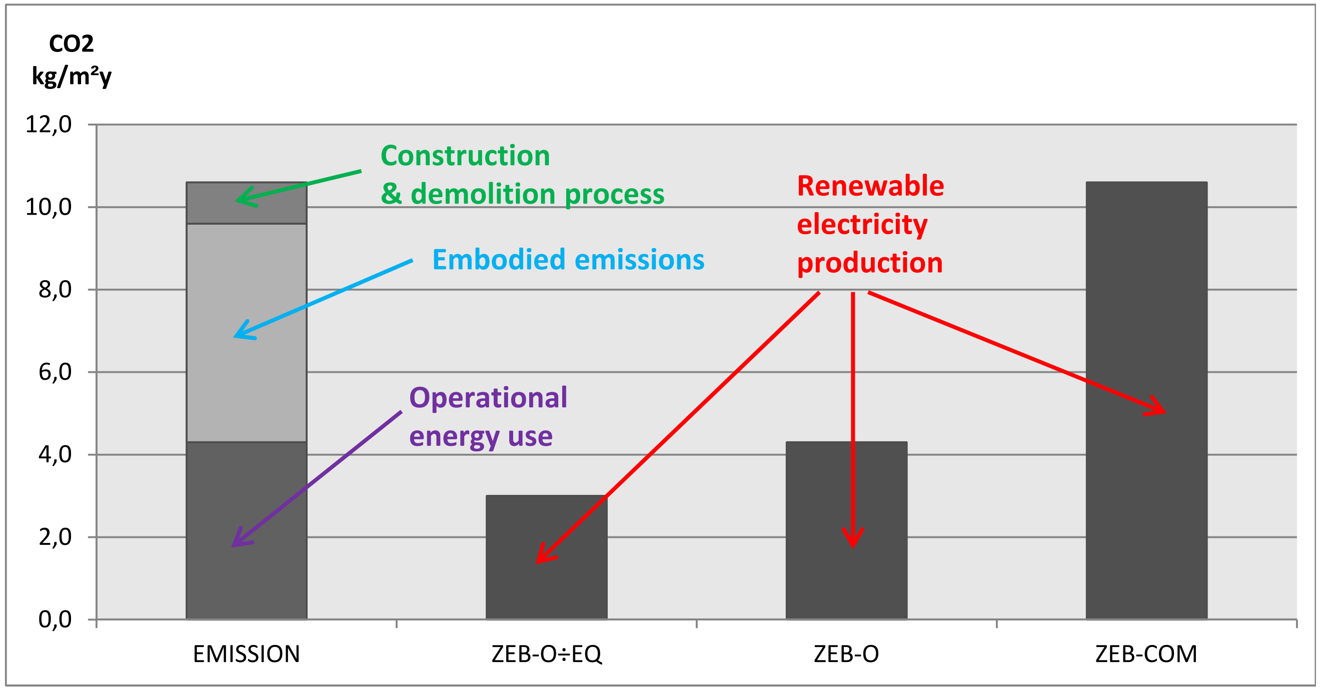
ZEB-Definition

ZEB-DEFINITION:

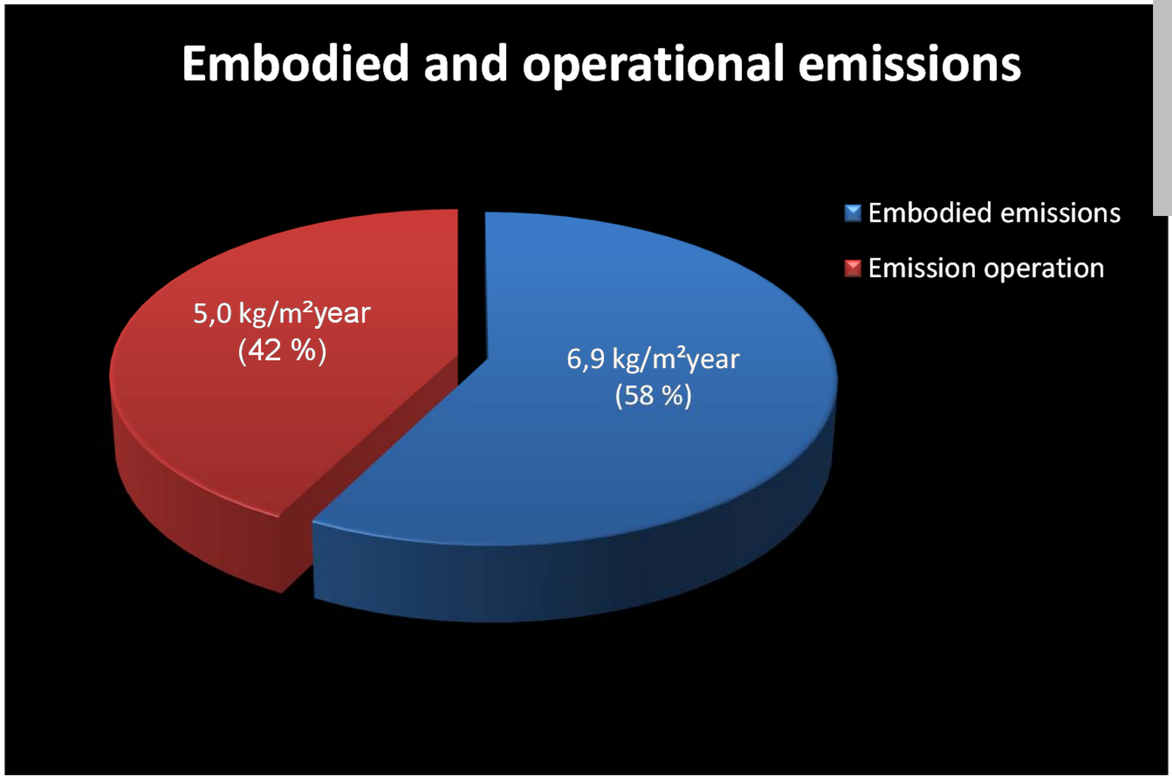
1. Ambition level
2. Rules for calculation
3. System boundaries
4. CO2-factors
5. Energy quality
6. Mismatch production and demand
7. Minimum requirement energy efficiency
8. Requirement indoor climate
9. Verification in use

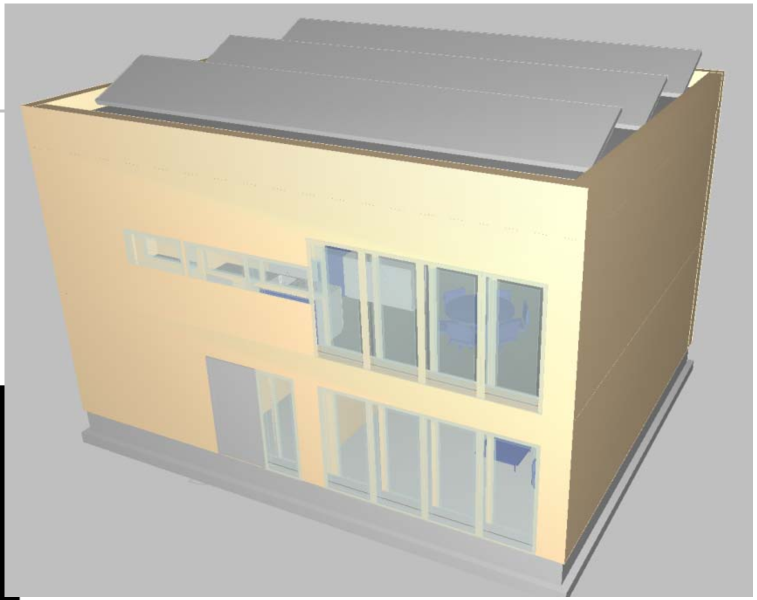


ZEB-O÷EQ: Balancing operational energy use exclusive equipment.
ZEB-O: Balancing operational energy use inclusive equipment.
ZEB-COM: Balancing operational energy, embodied emissions , construction and demolition processes

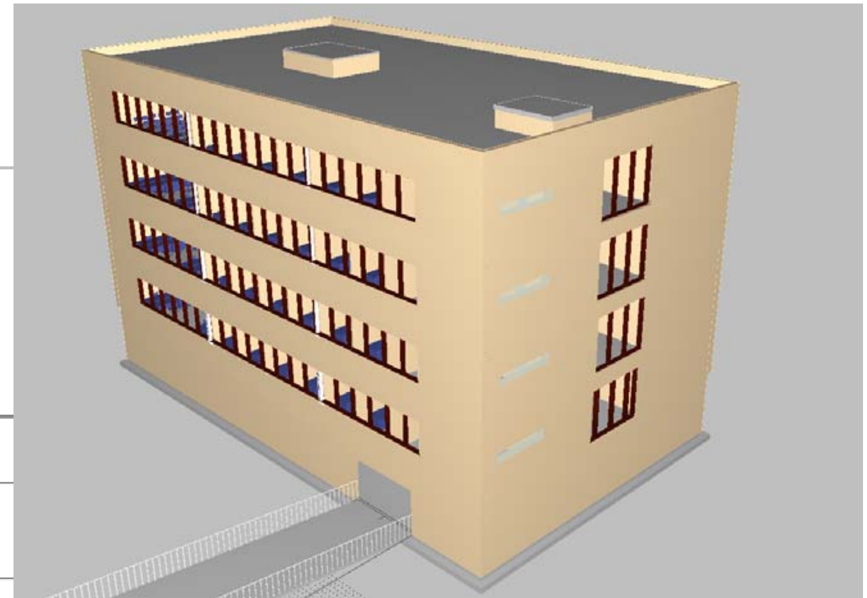
The main concept of a zero emission building is that renewable energy sources produced or transformed at the building site have to compensate for CO2 emissions from operation of the building and for production, transport and demolition of all the building materials and components during the life cycle of the building.

Concept Work - Dwelling





Concept work
Office Building



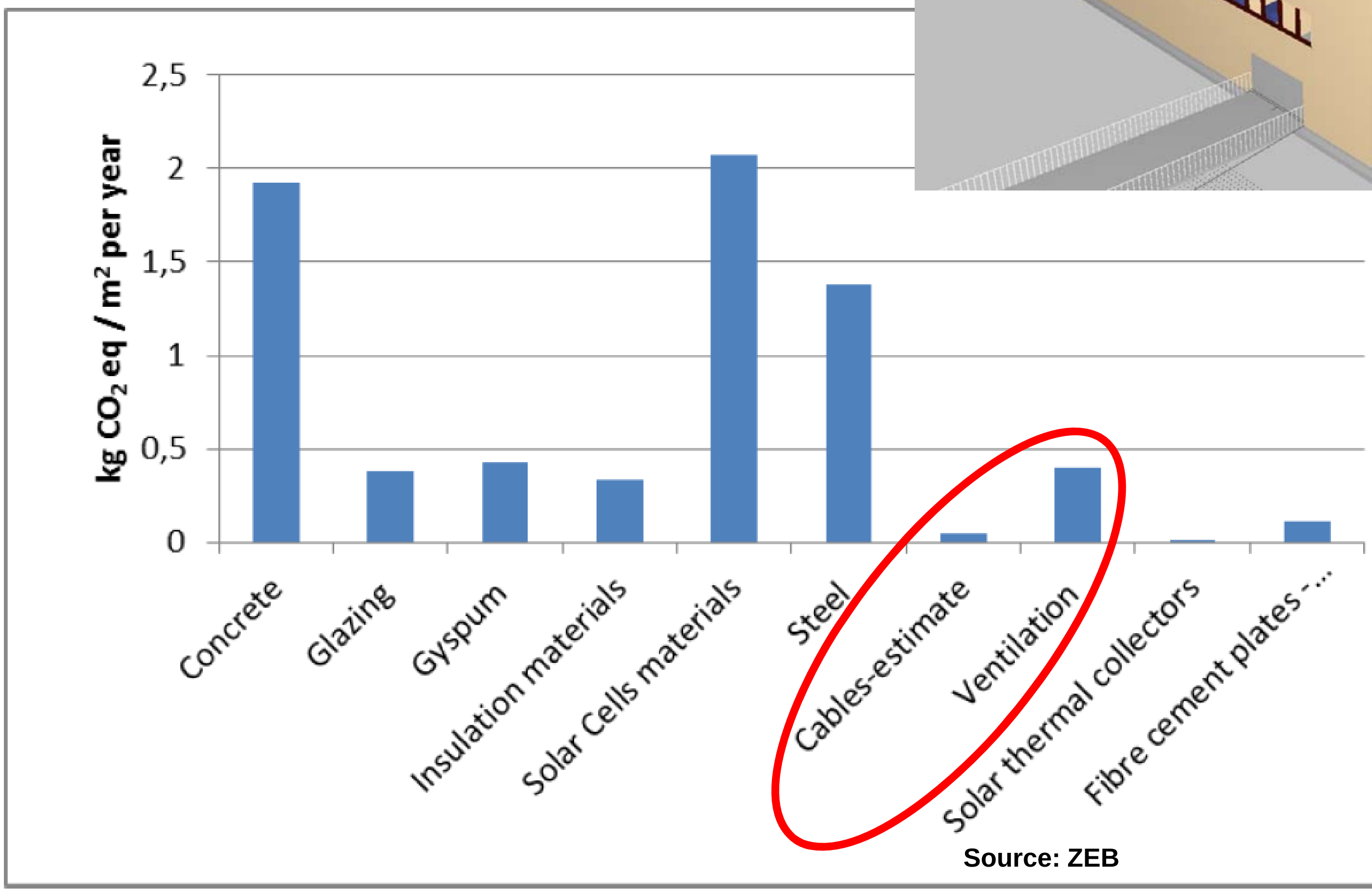
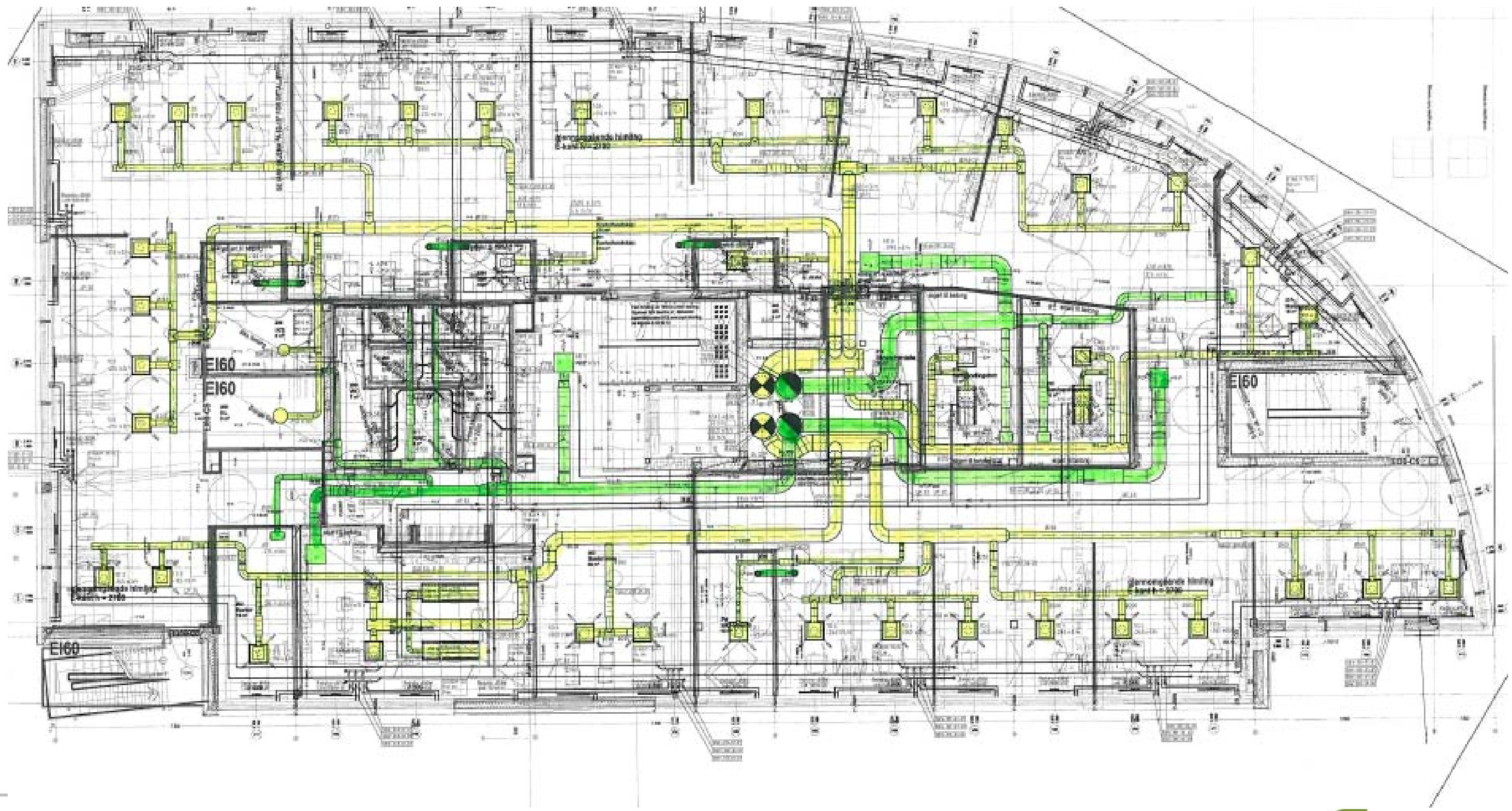


Figure 6.6 Green house gas emissions divided on main material and technical inputs

Life Cycle Assessment as a tool for comparison of building services systems
Case: VAV/DCV versus CAV in office buildings



ZEB The Research Centre on Zero Emission Buildings

Source: Jens Tønnesen

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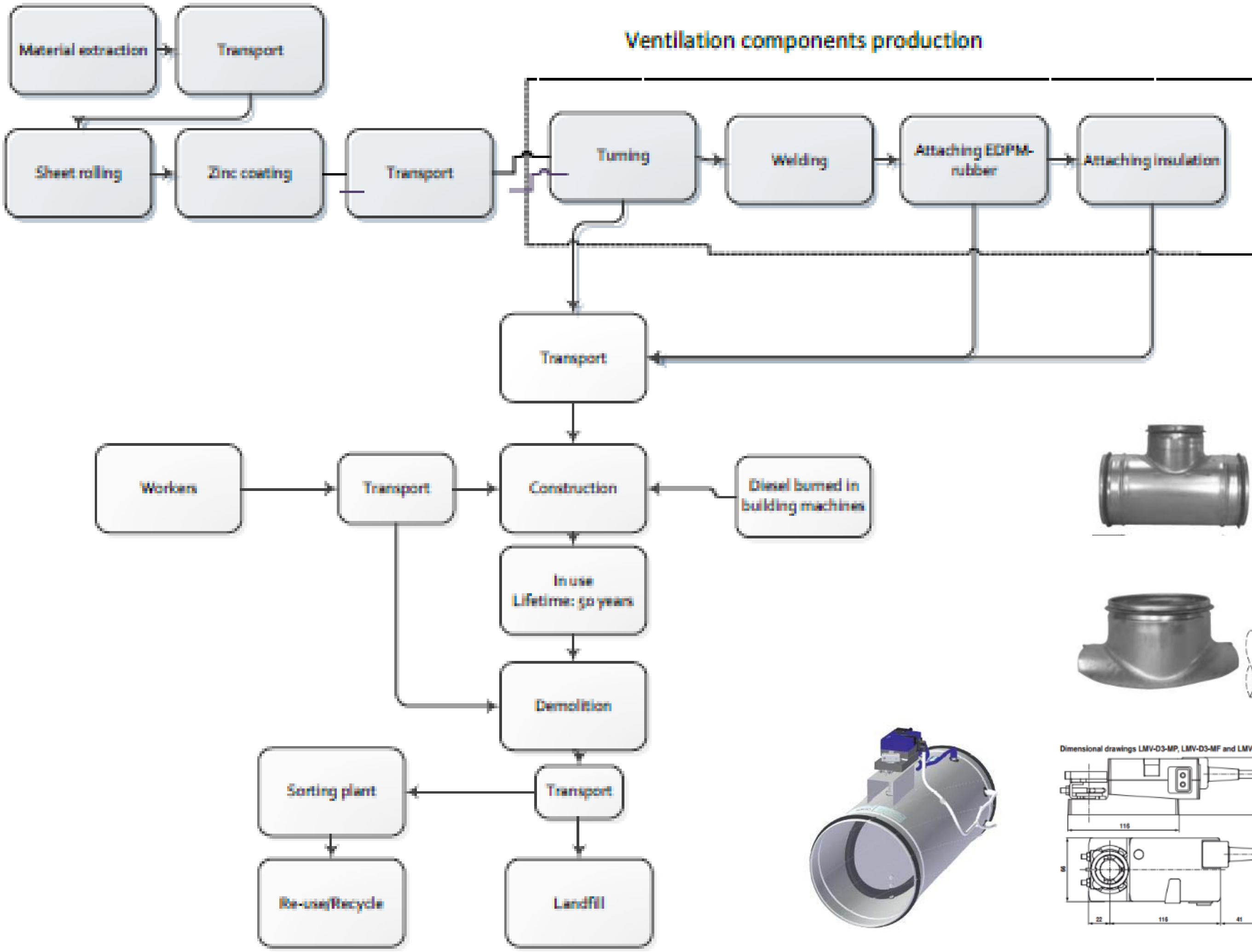
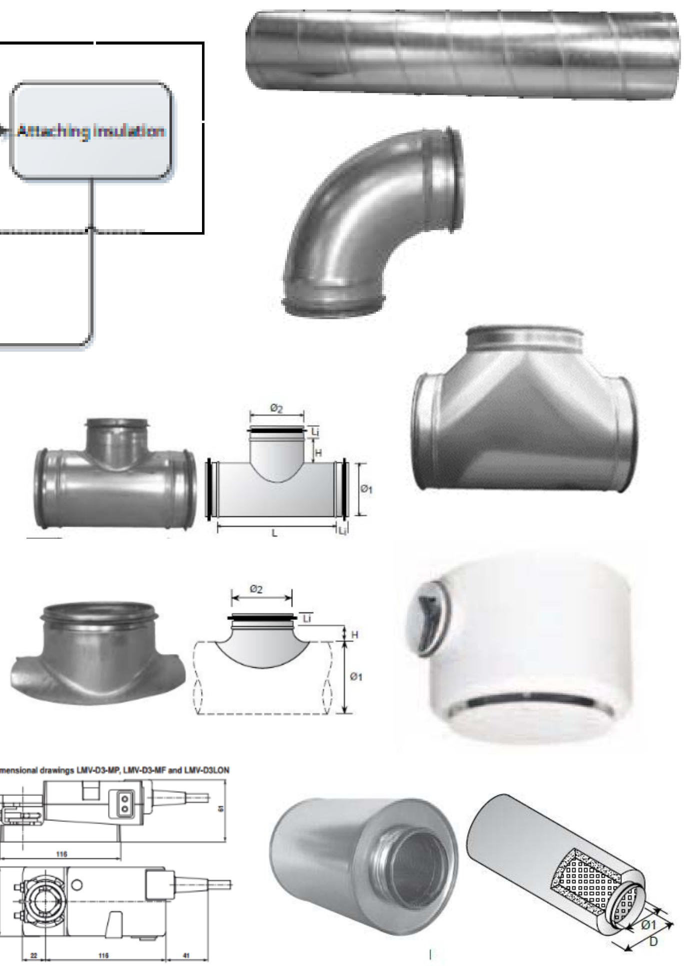
Life Cycle Inventory for ventilation ductwork components





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Source: Jens Tønnesen

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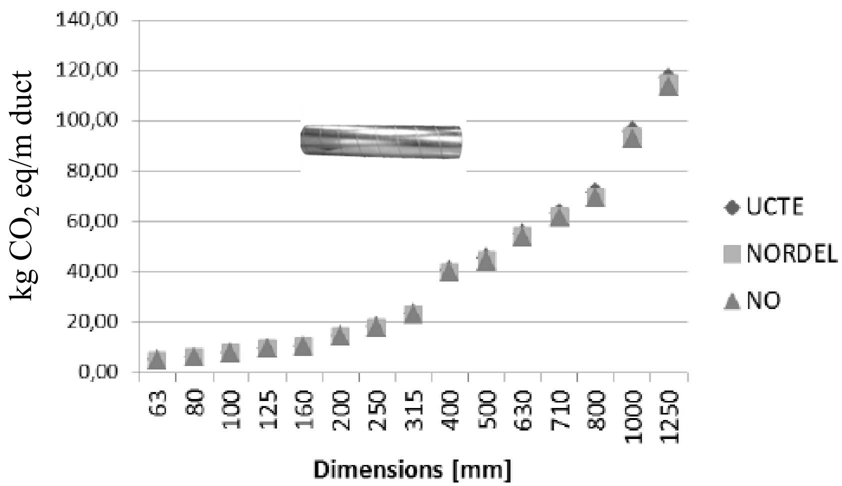
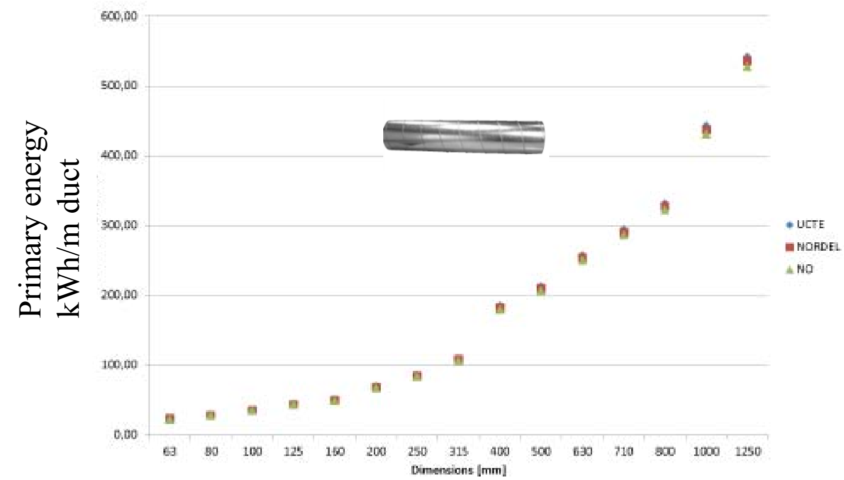
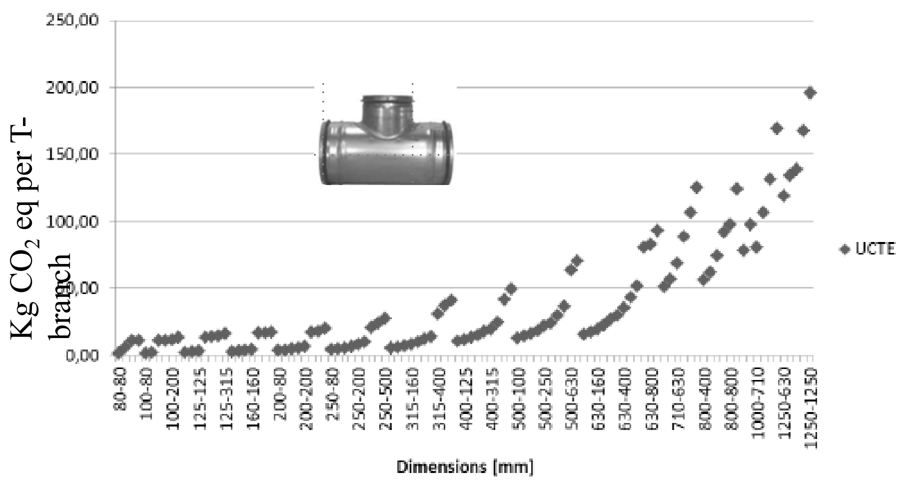
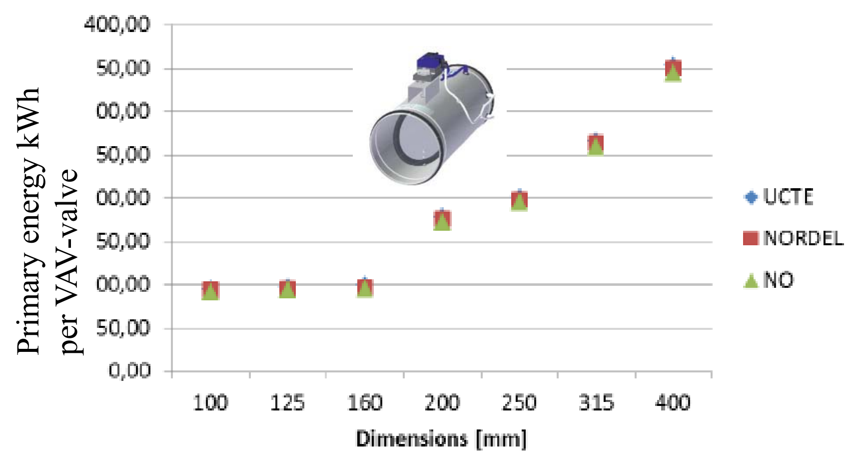
LCI-data – embodied energy and CO_2-eq









Source: Jens Tønnesen

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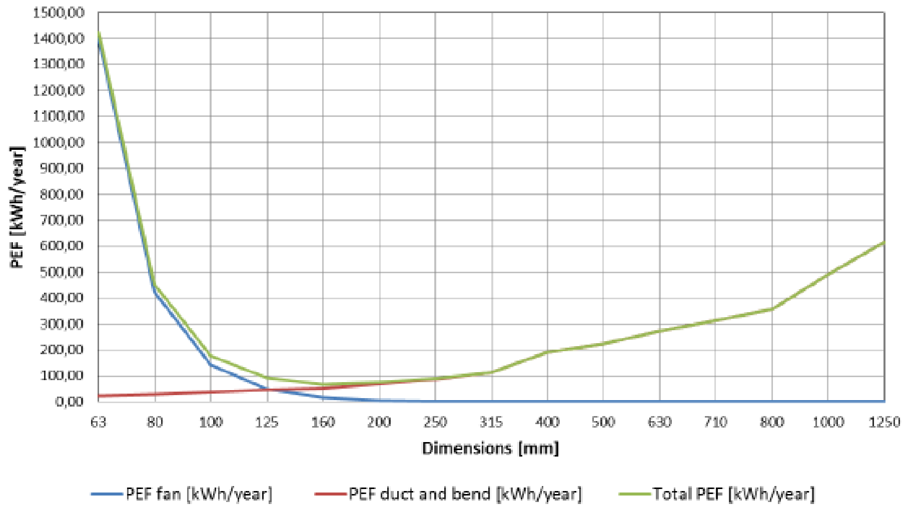
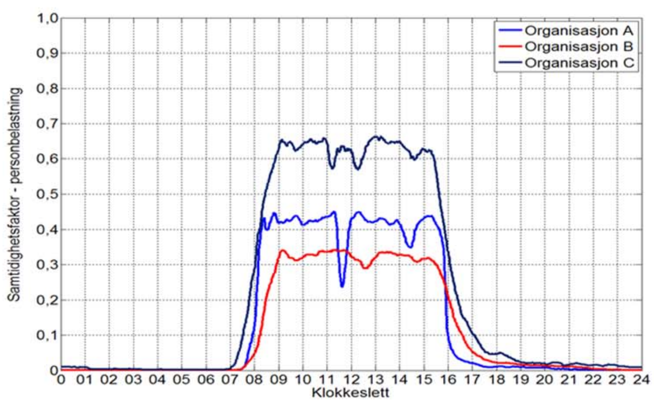
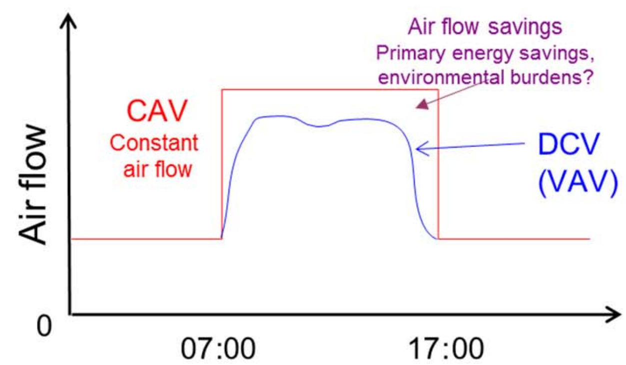
A systematic approach to LCA for the sizing of ventilation ductwork



Normalized occupational use of offices in 3 organisations





Based on: J. Halvardsson & HM Mathisen, NTNU

Five typical office areas with zone control

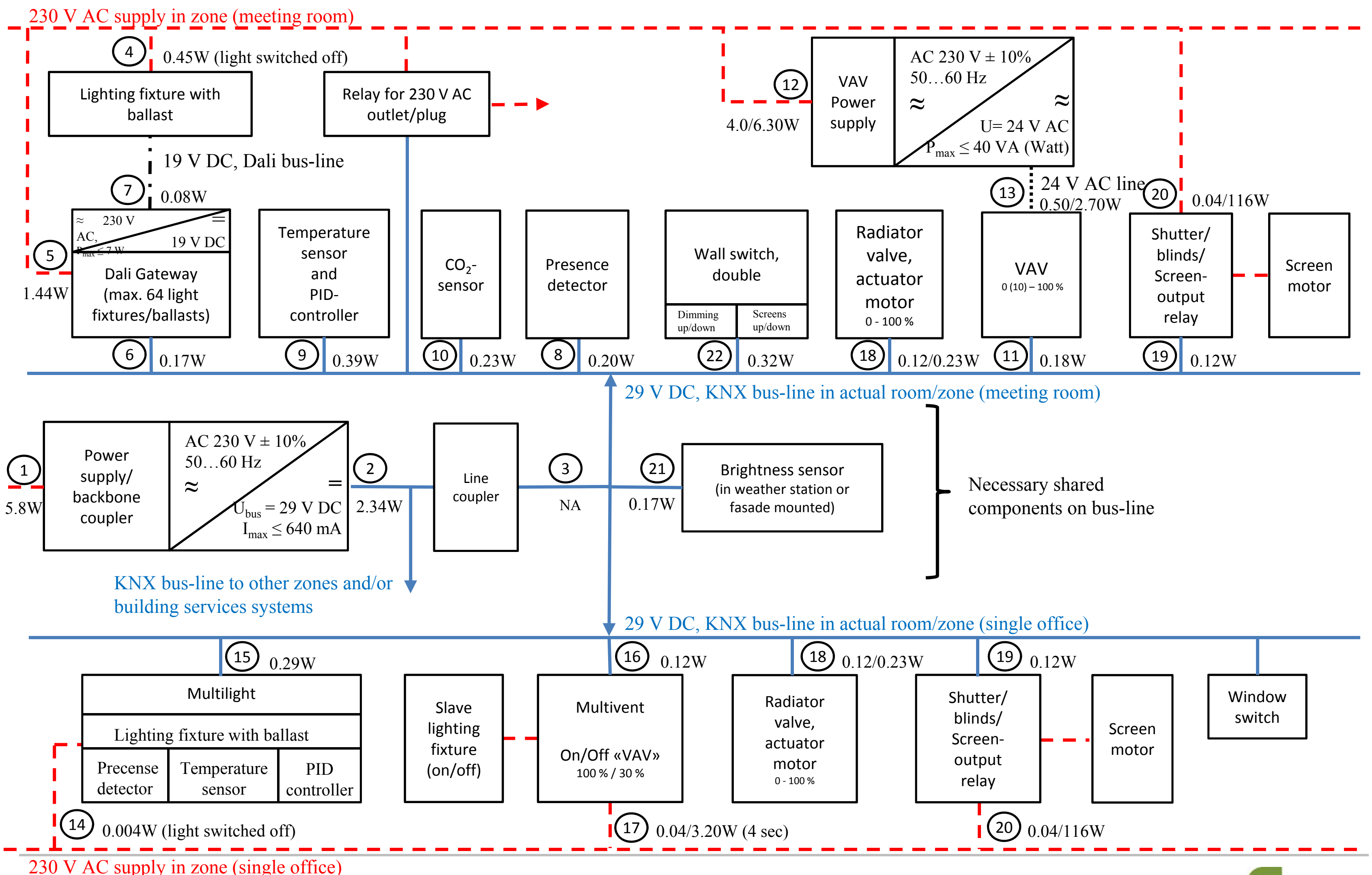
- Single office
- Office landscape
- Meeting room
- Advanced landscape
- Corridor

Equipment to achieve zone control according to “BACS energy efficiency class A” (EN 15232) in the office building – examples:

- **Temperature sensor**
- **CO_2 sensor**
- **Presence detector**
- **Constant light control**
- **Motorized radiator valve**
- **Modulating and on/off VAV**
- **Wall switches (light and screens)**
- **PID controller**

KNX-devices to be used in the office building

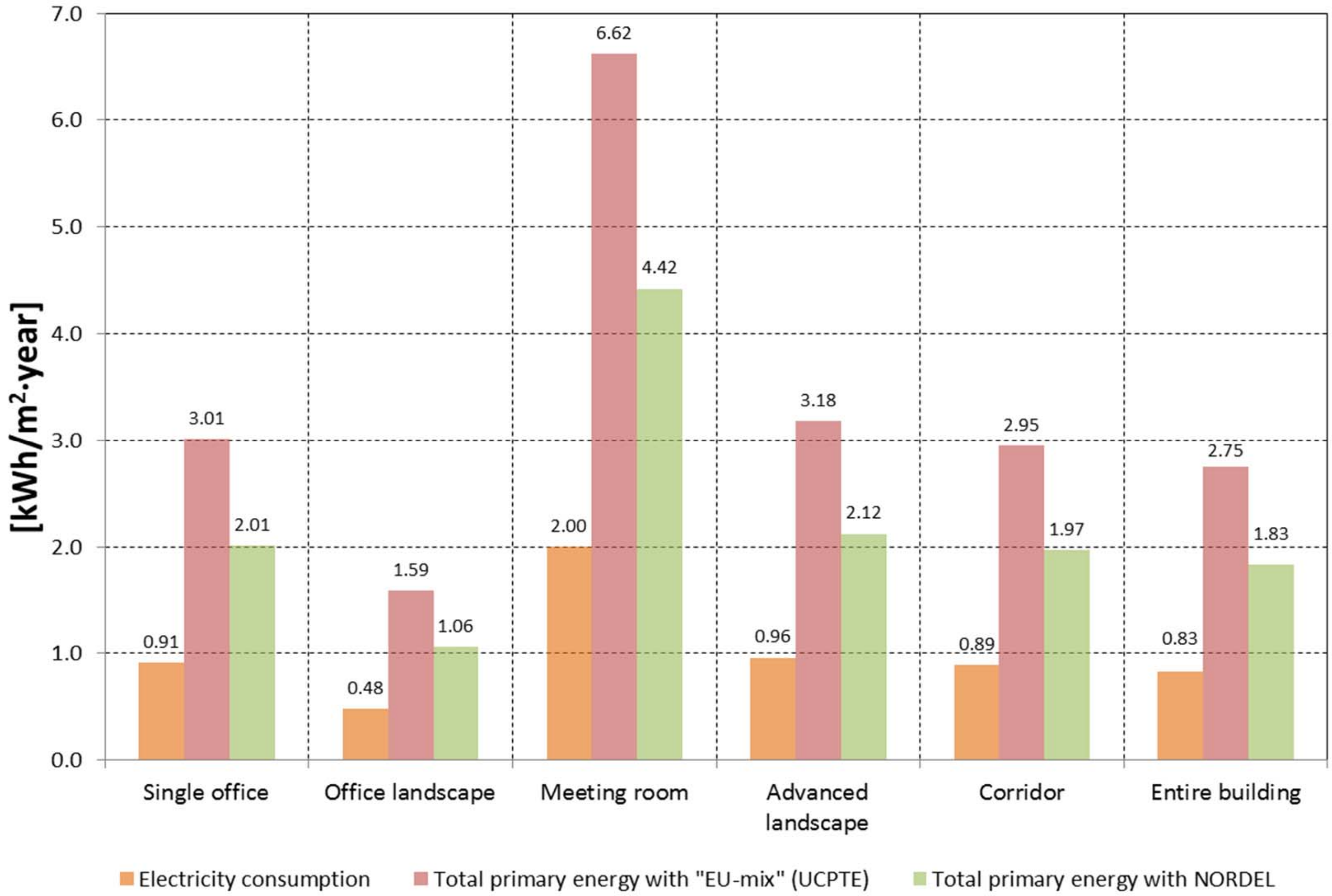
– individual measurements from the laboratory test



The Research Centre on Zero Emission Buildings

FORSKNINGS-SENTER FOR MILJØVENNLIG ENERGI

Electricity consumption and primary energy with different el-mix
for operating (standby) automatic components in 5 different room-zones + estimate entire building



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Thank you for your attention

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