DEMAND CONTROL VENTILATION IN RESIDENTIAL BUILDINGS

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Research Institutes of Sweden

Built Environment
Energy and circular economy

RISE

RISE: Research institutes of Sweden

The former individual institutes SP technical research institute of Sweden, Innventia and Swedish ICT have merged to RISE since this year

Background

Research project funded by the Swedish energy agency. Still on-going

Motivation:

- Obvious energy saving
- Ecodesign regulation for ventilation units and energy label for residential ventilation units rewards DCV
- Requirement on SEC-value (specific energy consumption)
    - Two parts of SEC value; one related to electric energy use and one related to heating
    - Different control strategies is valued differentially – relevant or not?
    - Requirement on heat recovery system-> gives an energy bonus

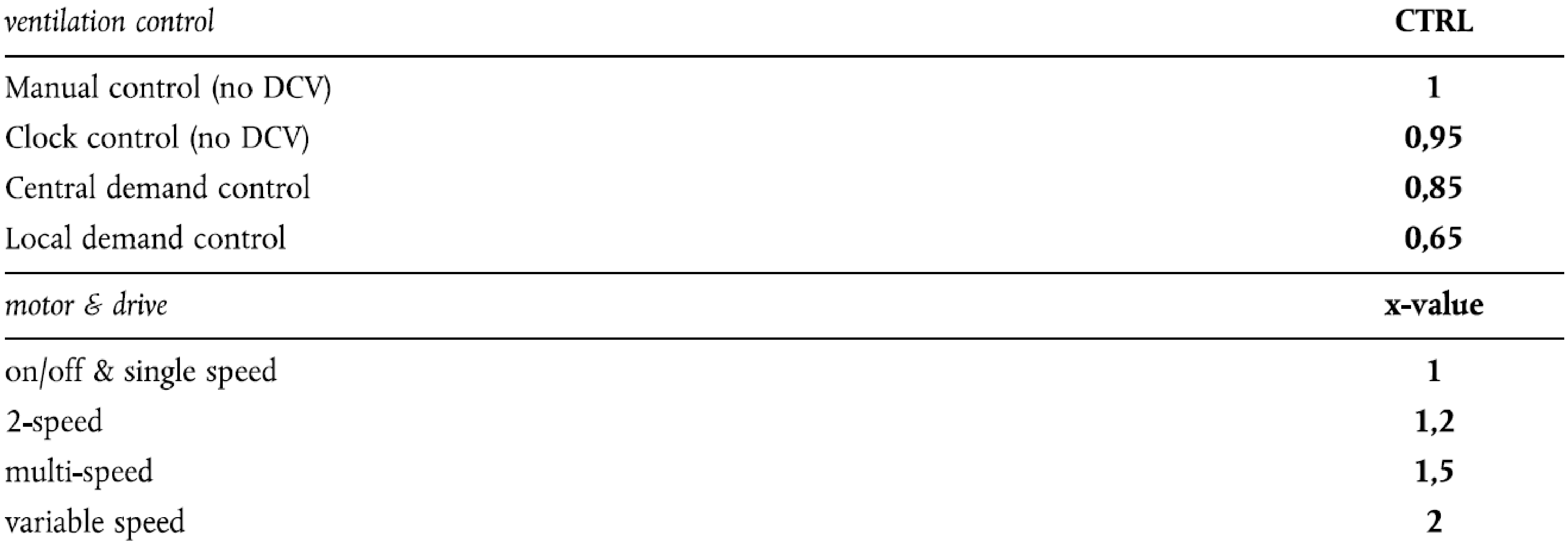
- The technology (variable speed fans, motor driven inlet devises, control etc.) is available, however:
    - Energy savings depends on system design and control strategies, control parameters and sensor placing
    - Knowledge is missing how the ventilation has to be controlled to ensure good indoor environment
- Risk for energy saving on expense of IAQ

Background

SEC-value (specific energy consumption)

- Two parts of SEC value; one related to electric energy use and one related to heating

$$SEC = t_a \cdot pef \cdot q_{net} \cdot MISC \cdot CTRL^x \cdot SPI - t_h \cdot \Delta T_h \cdot \eta_h^{-1} \cdot c_{air} \cdot (q_{ref} - q_{net} \cdot CTRL \cdot MISC \cdot (1 - \eta_t)) + Q_{defr}$$



ventilation control	**CTRL**
Manual control (no DCV)	**1**
Clock control (no DCV)	**0,95**
Central demand control	**0,85**
Local demand control	**0,65**
motor & drive	**x-value**
on/off & single speed	**1**
2-speed	**1,2**
multi-speed	**1,5**
variable speed	**2**

Background

What is Demand control ventilation?

- The ventilation flow is controlled on a measured demand
    - heat losses and fan energy can be decreased when demand is decreased ->energy saving
    - ventilation can be increased above design value when needed -> better indoor environment
- Commonly demand is measured by CO_2 or presence
- In residential buildings also other parameters has to be considered
    - Moisture generation by cooking, showering etc.
    - Temperature for thermal comfort
    - Other sources? Emissions from materials, particles, other emission… radon
- The effect of when ventilation is shut off of longer periods
- Delays

In the project:

- Control strategy on how the ventilation should be controlled in order to ensure indoor air quality, thermal comfort and avoid damages on the building
    - sensor placing, what parameters to measure and how often, number of zones etc

Carry through

- Model a demand control ventilation systems for a single family house
- Evaluate different types/levels of demand control ventilation systems and control strategies
- Install a demand control ventilation system in one single family house and evaluate its performance
- Measurements are on-going

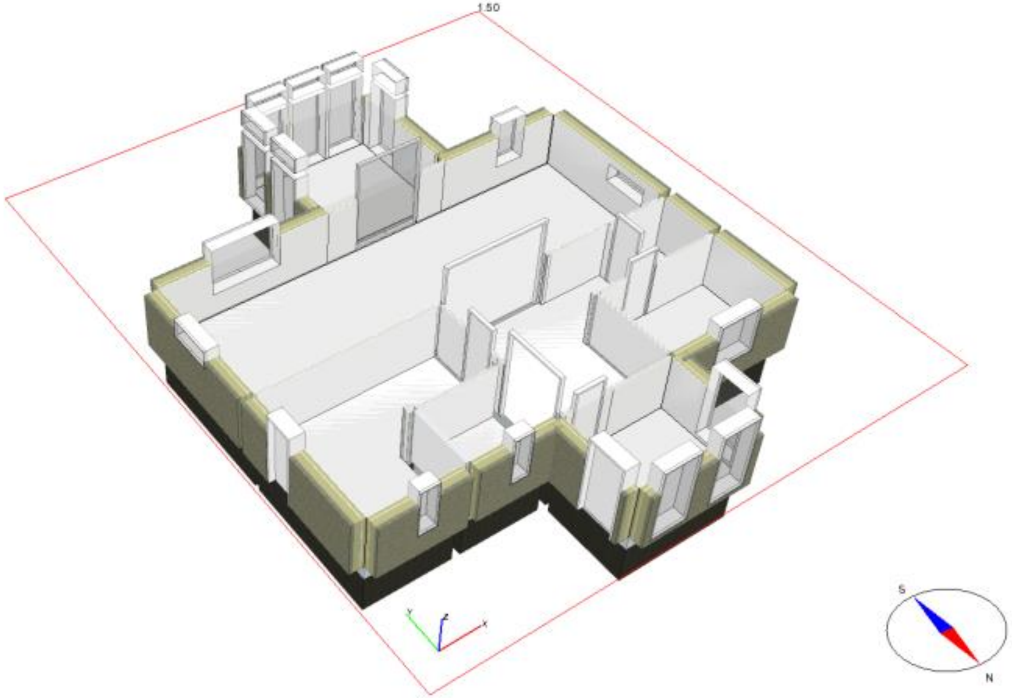
The research villa

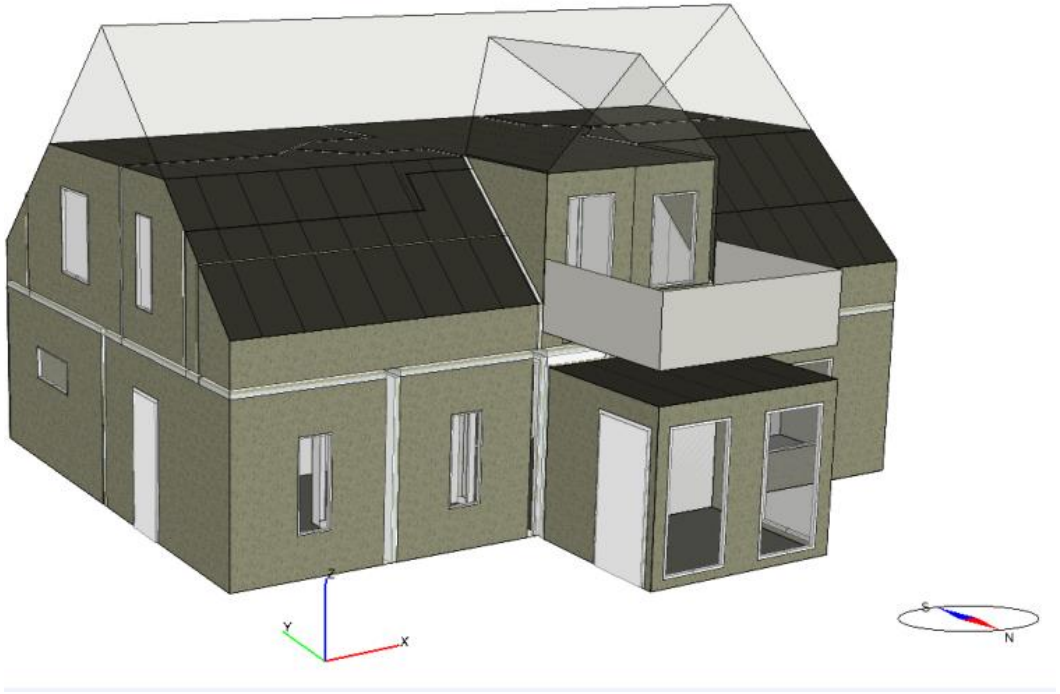
- Single family house at RISE premises in Borås
- The house has a demand control ventilation system installed
- Low energy house with heat recovery system in ventilation
- Similar house in Varberg where a family lives. CAV-system. Field measurements of CO2 and moisture (and VOC)

Simulation tool

IDA Indoor Climate and Energy (IDA-ICE)

- A tool for studying indoor climate and energy use of the building
- one-year detailed and dynamic multi-zone simulation
- It models the building, systems and control of the system

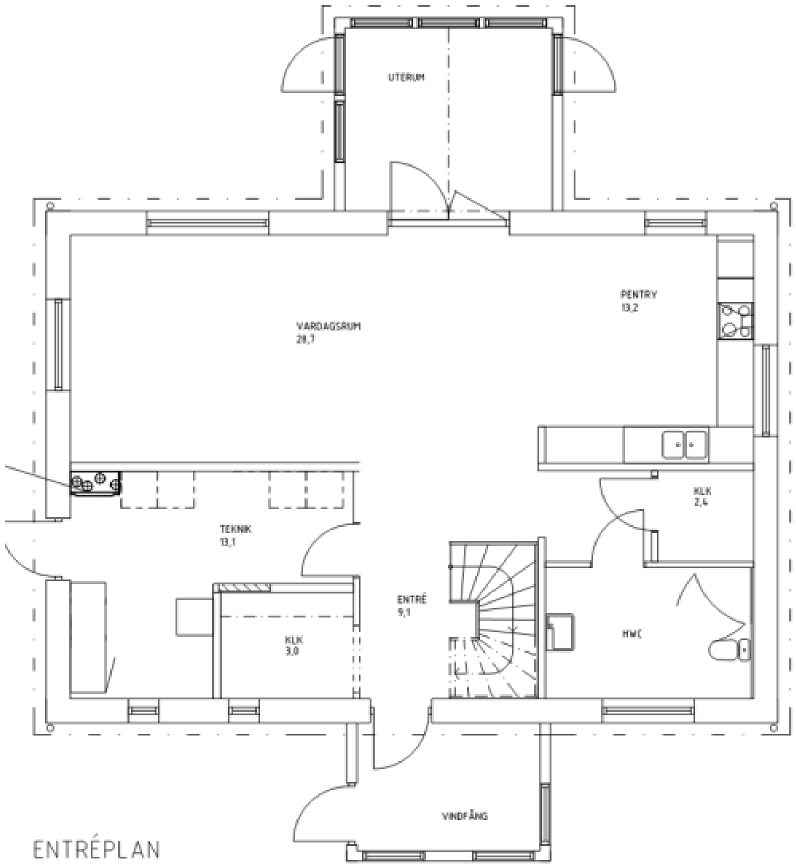




Simulation of demand control ventilation

- House model
  - Total living area: 155 m² (a single family house)
  - Two floor levels
  - Average U-value: 0.2 W/(K·m²)
  - Ventilation flow rate:
    - Existing system: 60/66 l/s
    - Demand control ventilation :
      - The minimum flow rate: 0.1 l/s/m²
      - The maximum flow rate: 90 l/s
  - Heat recovery efficiency: 82%

- Input data
  - Climate data: Gothenburg – Landvetter (Sweden)
  - Internal heat load: 30kWh/m² (Sveby)
    - Distributed to rooms with specific schedule
    - Uevenly distributed over a year



Simulation of demand control ventilation

- Input data(continued..)
  - CO2 loads
    - Depending on metabolism(activity level)
    - 11.875 l/h/met for an adult
    - Sleeping: 0.8 met; resting: 1.0 met; cooking: 1.5 met

  - Moisture loads
    - Different values have been found from literature (due to measurement conditions, human behavior, appliance, installation etc.)
    - we choose 3kg-5kg/day in this project (weekdays: about 4 kg; weekends: 5kg)
    - Field measurement at a "sister" house where a real family is living (Varbergsvillan)

      Monthly average moisture load during period of 2017-02-10 to 2017-03-10: 4 kg/day

      Major source: showering, preparing food, washing and drying clothes, dishwashing, occupant

  - Occupation time (ref: Sveby)
    - weekdays: 14 hours
    - weekend: 20 hours

Control strategies and system design

Control parameters

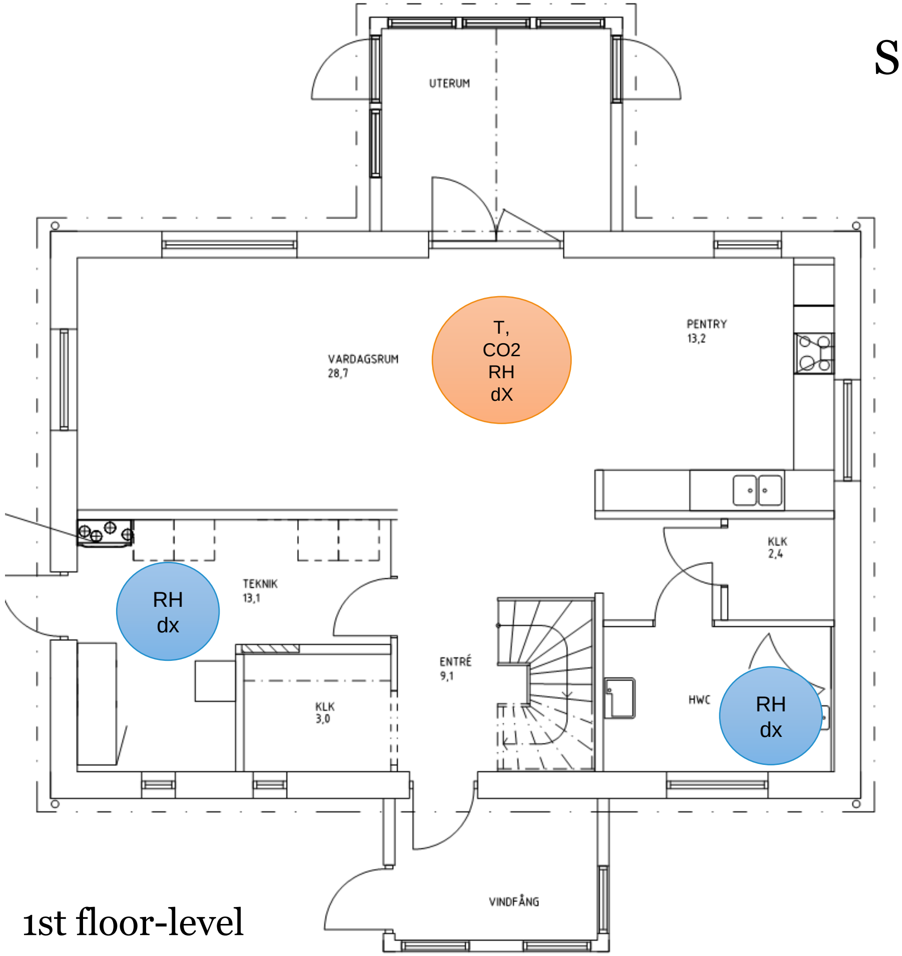
- temperature (T): 25°C
- carbon dioxide(CO_2): 700-1000 ppm
- relative humidity(RH): 20%-75%
- difference in absolute humidity indoor and outdoor(dx): 0.002-0.0025kg/kg

- Sensor placing
  - centrally sensor placing, one or more sensors are placed centrally, e.g. in exhaust duct
  - multiple sensor placing, one or more sensors are placed in each zone of the building

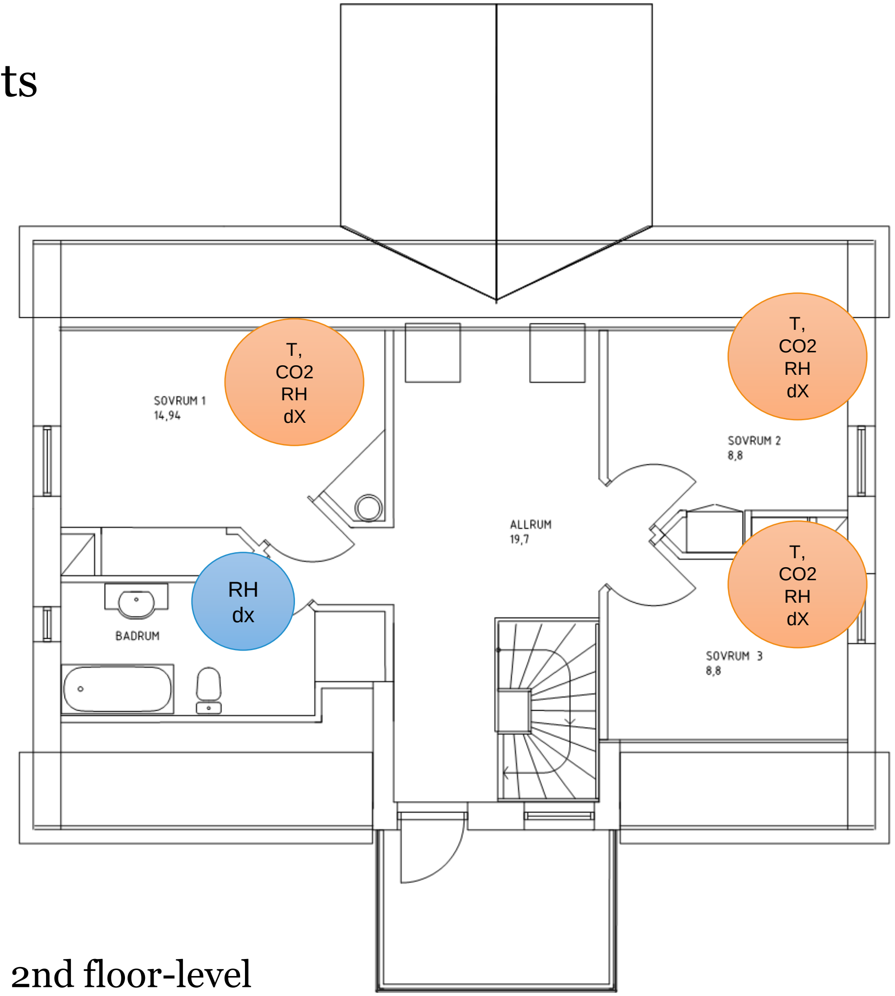
- Examples of zone
  - Every room is a zone (multiple zone control)
  - Every floor is a zone (Floor level control/two-zone control)
  - The building is a single zone(building level control/one-zone control; exhaust duct control)

Simulation of demand control ventilation

Sensor placements



1st floor-level



2nd floor-level

Simulation of demand control ventilation

Multiple-zone control (individual zone control)

  - The maximum signal of T, CO2, RH and dx determines the required flow rate for each room
  - To keep balanced flow rate, the total exhaust flow rate follows by the total supply flow rate.

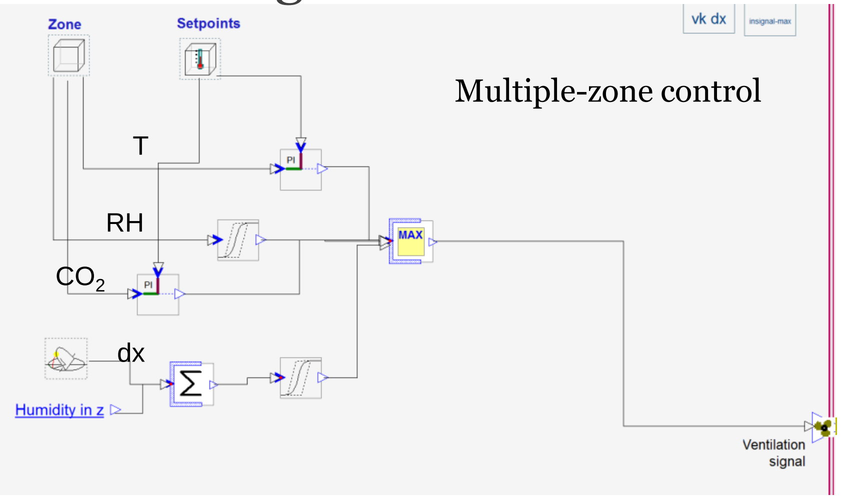
- Two-zone control(floor level control)

  Control signal: the maximum signal from the rooms connected to the each floor level

- One-zone control(building level control)

  Control signal: the maximum signal from all rooms inside the building.

- Exhaust duct control



Results of the modelling (one-year simulation)

Case	The average ventilation flow rate during the year (l/s)	Reduction of ventilation flow rate (%)	Space heating demand (kWh/m^2 in one year)	Reduction of space heating demand due to ventilation (%)	Fan electrical energy (kwh)	Reduction of the fan electrical energy (%)
Reference case	60	/	15,5	/	1090	/
Multiple-zone control	25,5	57,5	11,7	24,3	474,1	56,5
Two-zone control (floor level control)	29,2	51	11,9	23,1	550,2	49,5
One-zone control (building level control)	38,3	36,2	12,9	16,8	692,4	36,5
Exhaust duct control	41,1	31,5	13,4	13,1	748,5	31,3

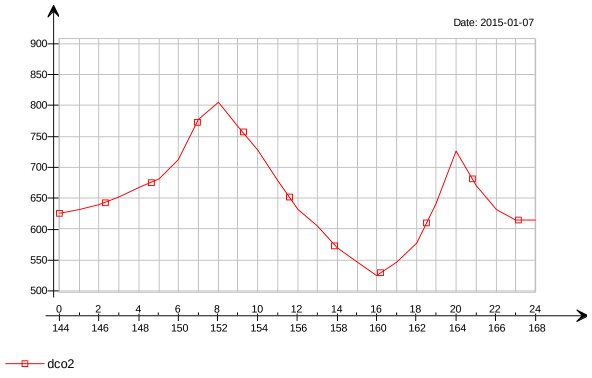
Results of the modelling

- During winter CO2 and dx will be the control variables used
- During summer temperature will be the control variable
- The energy saving during the winter time is much higher than that in the summer, as the ventilation is almost fully on in the summer due to temperatures
- Centrally placed sensors in the exhaust duct does not work properly with the set values of 700-1000 ppm

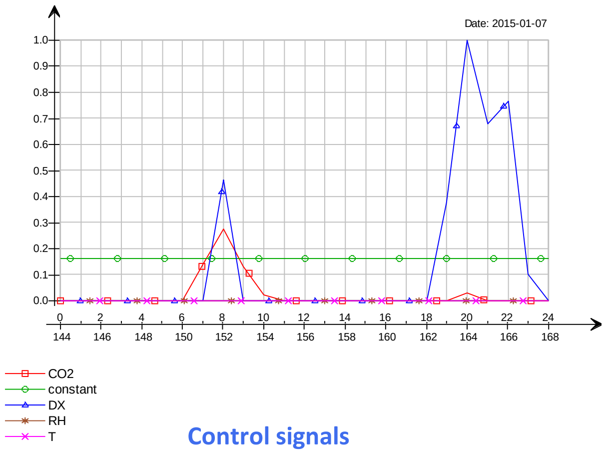
Results of the modelling (example: exhaust duct control)

Indoor air quality, control signal and ventilation flow rate

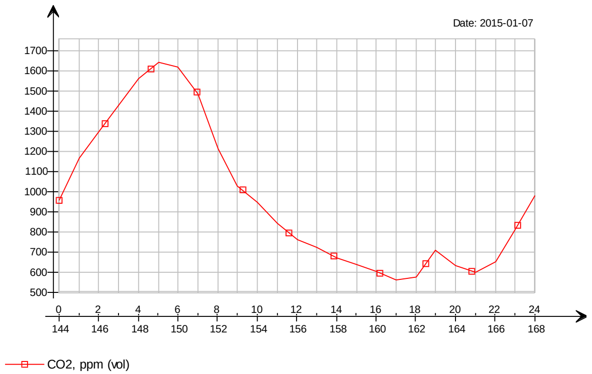
Normal or standard threshold of CO2: 700(L)-1000(H)ppm (**The system dose not work**)



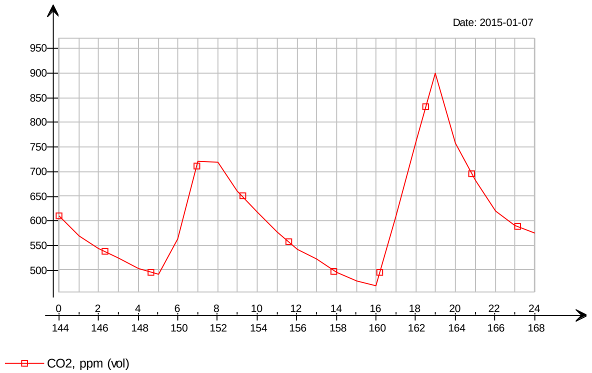
CO2 in the **exhaust duct**



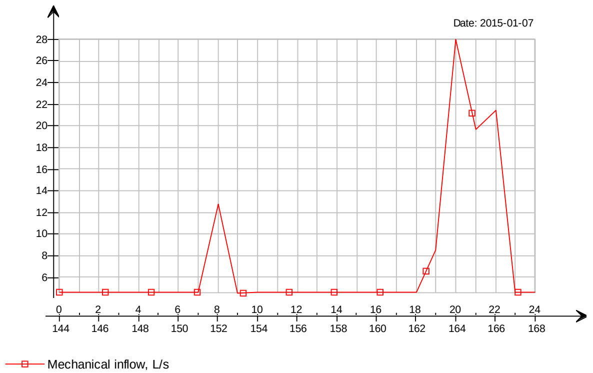
Control signals



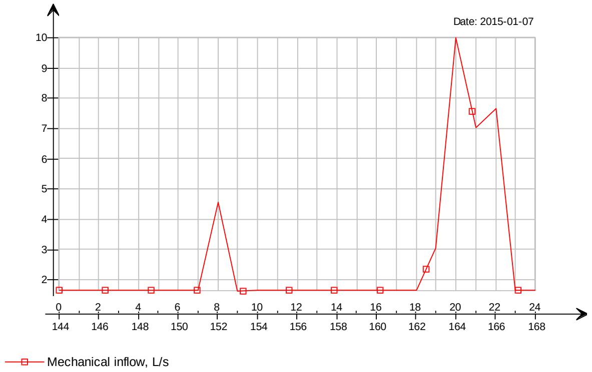
CO2 in **master bedroom**



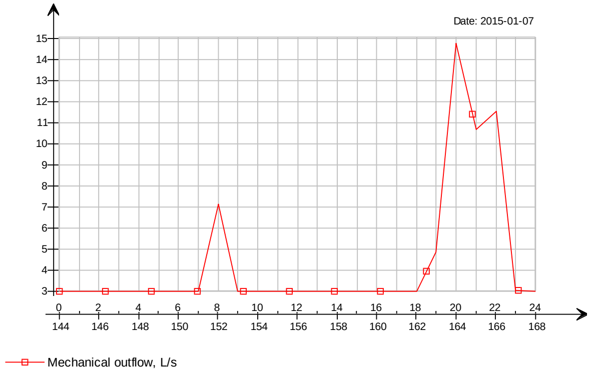
CO2 in the **living room and kitchen**



Supply flow rate in the **living room and kitchen**



Supply flow rate in **master bedroom**

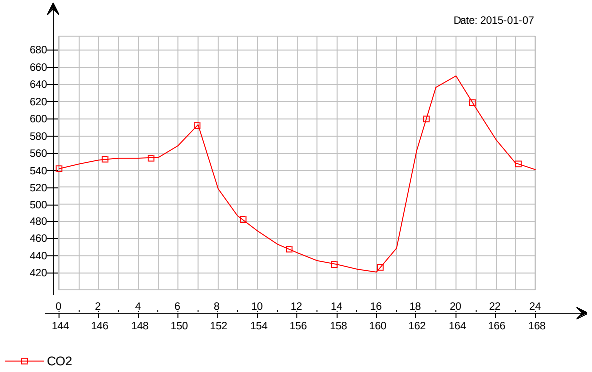


Outlet flow rate in the **bathroom**

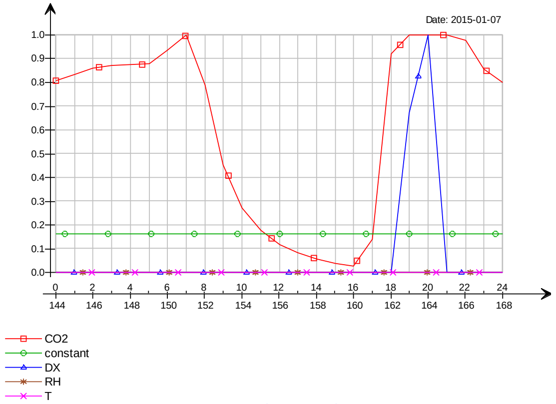
Results of the modelling (example: exhaust duct control)

Indoor air quality, control signal and ventilation flow rate

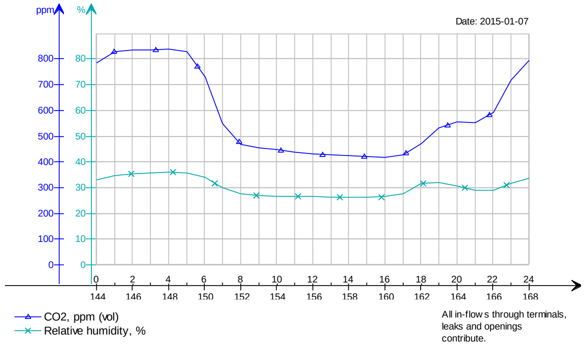
Tight threshold of CO2: 400(L)-600(H)ppm



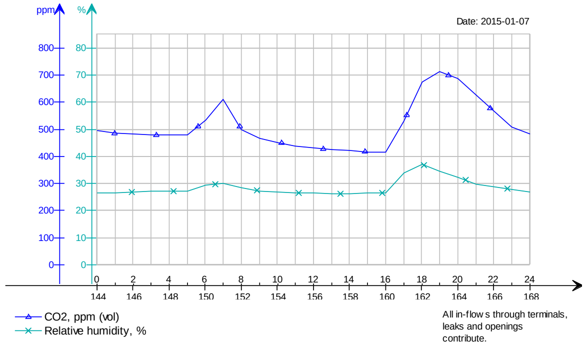
CO2 in the **exhaust duct**



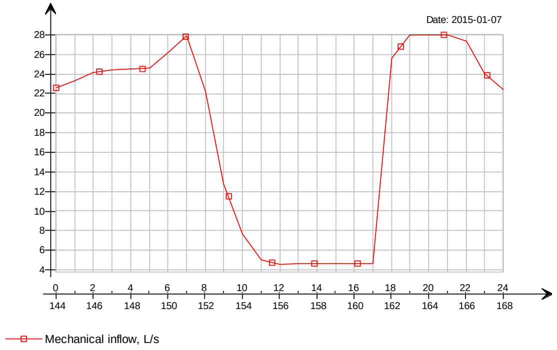
Control signals



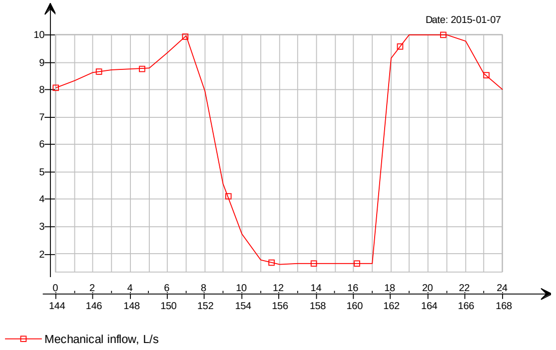
CO2 in **master bedroom**



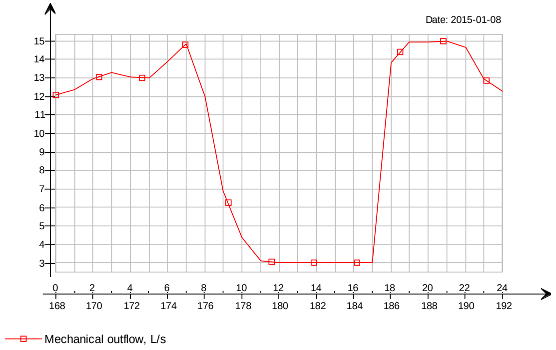
CO2 in the **living room and kitchen**



Supply flow rate in the **living room and kitchen**



Supply flow rate in **master bedroom**

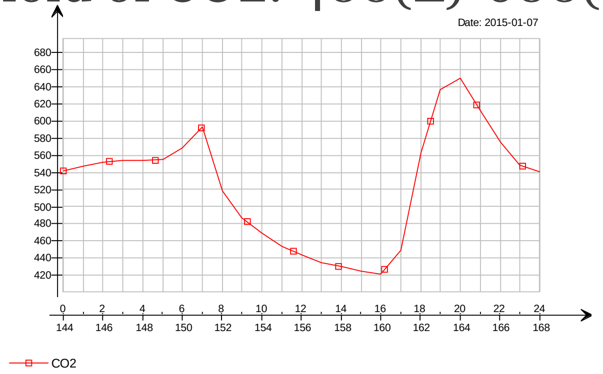


Outlet flow rate in the **bathroom**

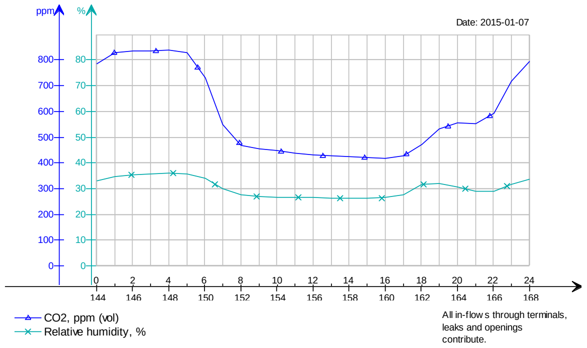
Comparing CO_2 with measurements

Indoor air quality, control signal and ventilation flow rate

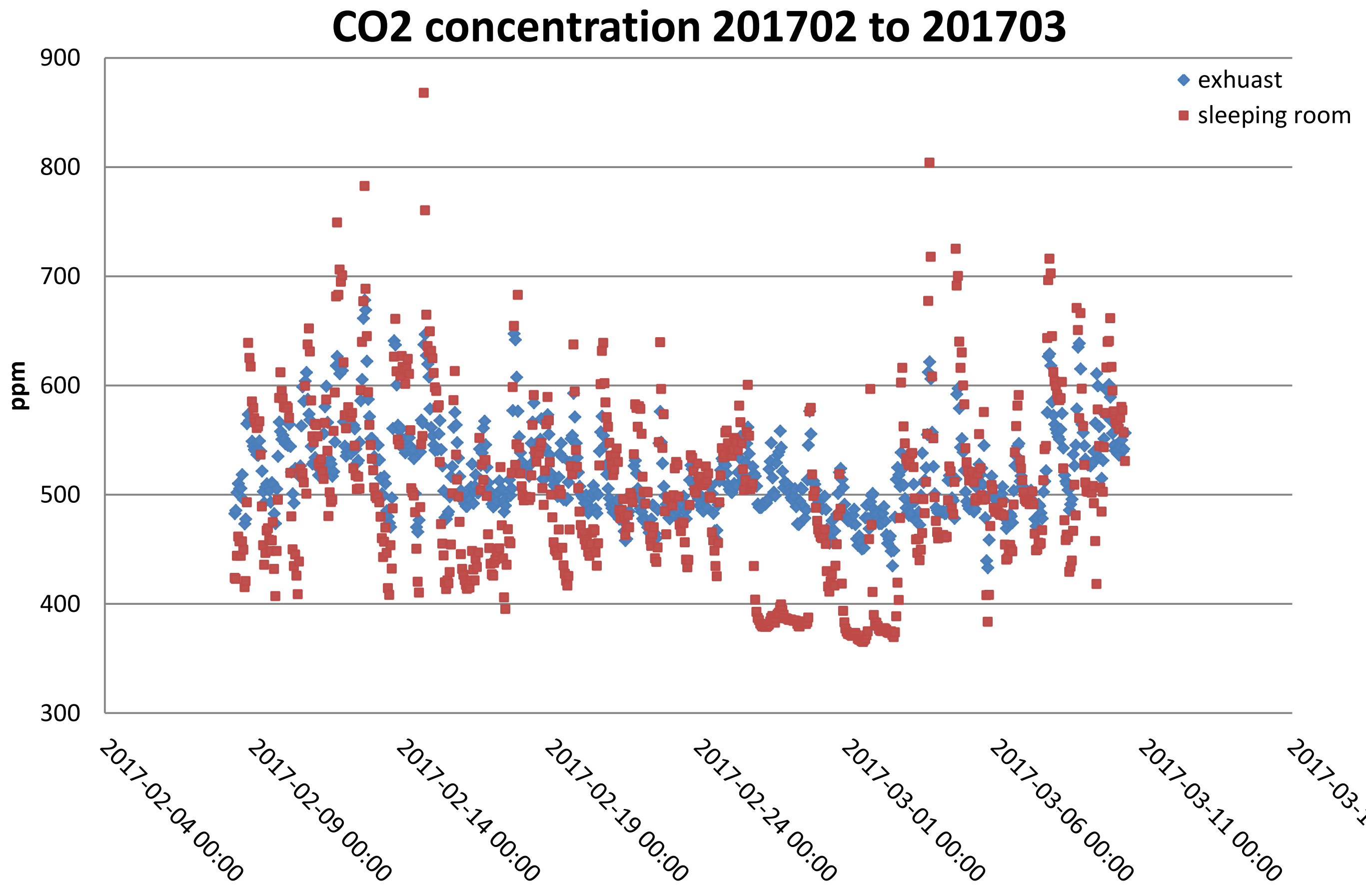
Threshold of CO2: 400(L)-600(H)ppm



CO2 in the **exhaust duct**



IAQ in **master bedroom**

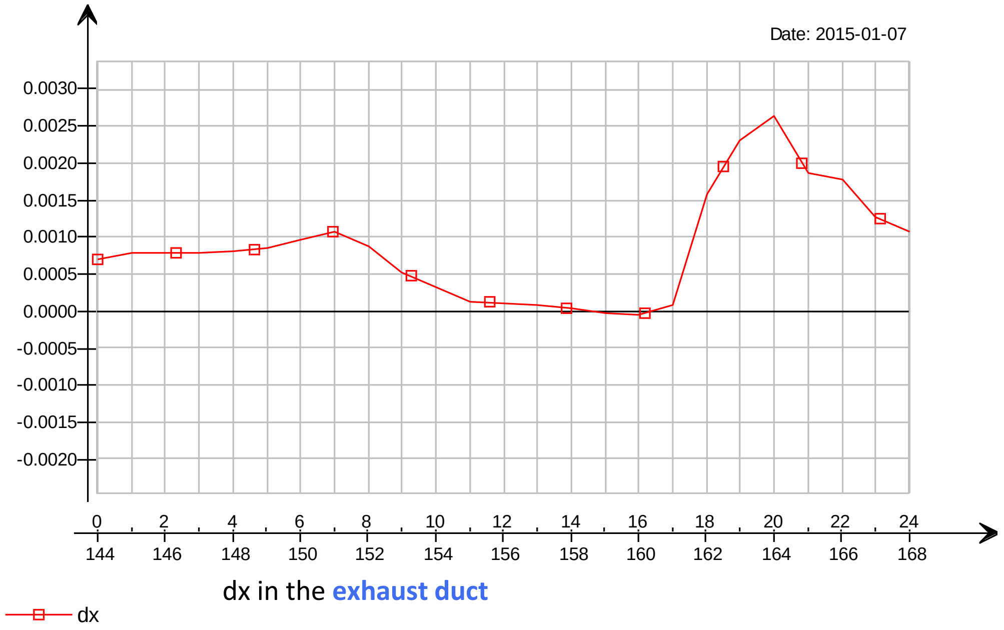


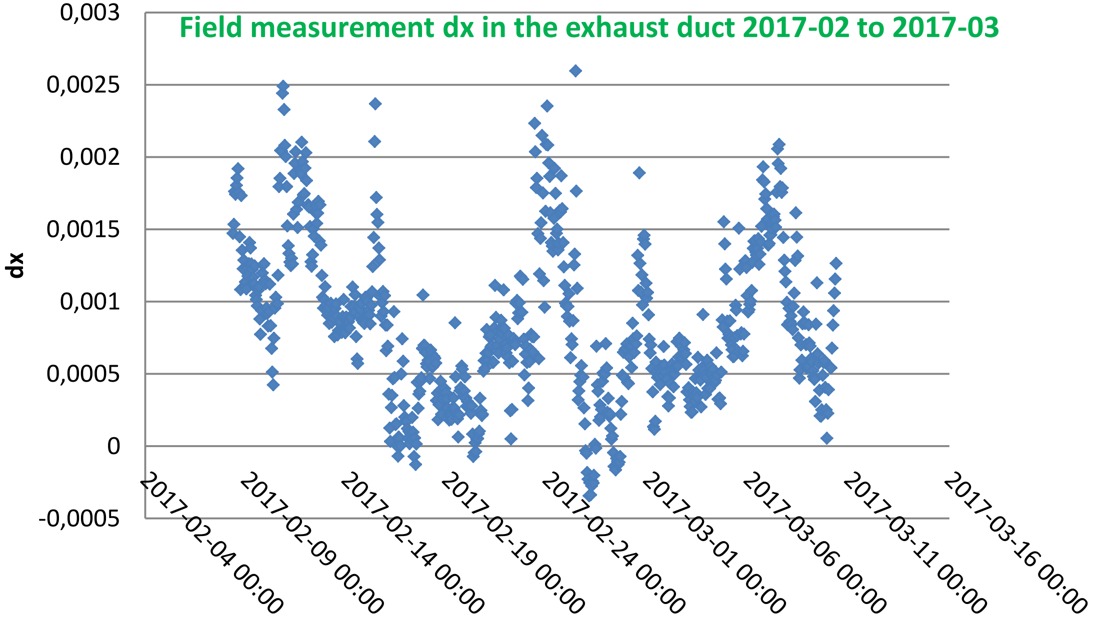
Note: the sleeping room is used by a child

Results of the modelling and comparing with measurement

Indoor air quality, control signal and ventilation flow rate

Threshold of CO2: 400(L)-600(H)ppm




Field measurement dx in the exhaust duct 2017-02 to 2017-03

Conclusion/discussions

- There is a great saving potential in using demand control ventilation, however it depends on number of zones and control strategy
    - Multiple-zone control gives the highest energy saving potential
    - One single zone gives the least energy saving potential
    - Saving potential is higher in winter than in summer due high room temperatures

- More than one control parameter needs to be measured to ensure IAQ, thermal comfort and eliminate risk of building damages

- Sensors need to be placed in more than one location (very small buildings exempted)

- In this project CO2, temp, RH, dx
    - next step VOC and particles

- Development of sensors
    - Self calibrating
    - Self calibrating towards outdoor environment

THANK YOU!

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