Control strategies for mechanical ventilation in low-energy residences

Annex 68 Expert meeting, Nottingham

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2 Aim of the study

Objective

Propose and evaluate innovative ventilation strategies which could provide an ideal balance between energy use and IAQ in low-energy residences in Danish context

- Study and compare the performances of DCV with CAV systems. → Ranking of DCV and CAV strategies.
- Understand if current DCV systems are able to control harmful contaminants. → Build-up of VOC during non-occupied periods, with minimum ventilation rate at 0.3 l/s per m^2.
- Investigate further energy saving measures with reduced minimum ventilation rate. → Build-up of VOC during non-occupied periods, with minimum ventilation rate at 0.1 l/s per m^2.

2 Objectives related to Annex 68

- Test the ability of IDA ICE to model emissions from indoor air pollutants
- Determine limitations, advantages and disadvanatages of doing the simulaitons with IDA ICE
- Compare results with more dedicated IAQ simulation tools

IDA

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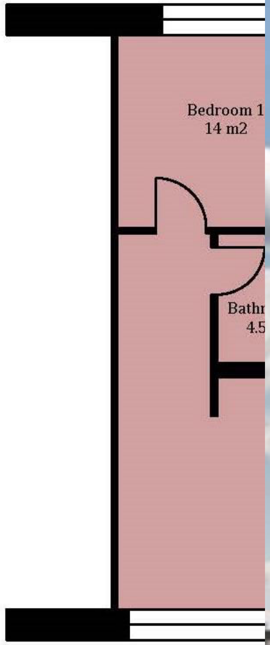

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throom use)
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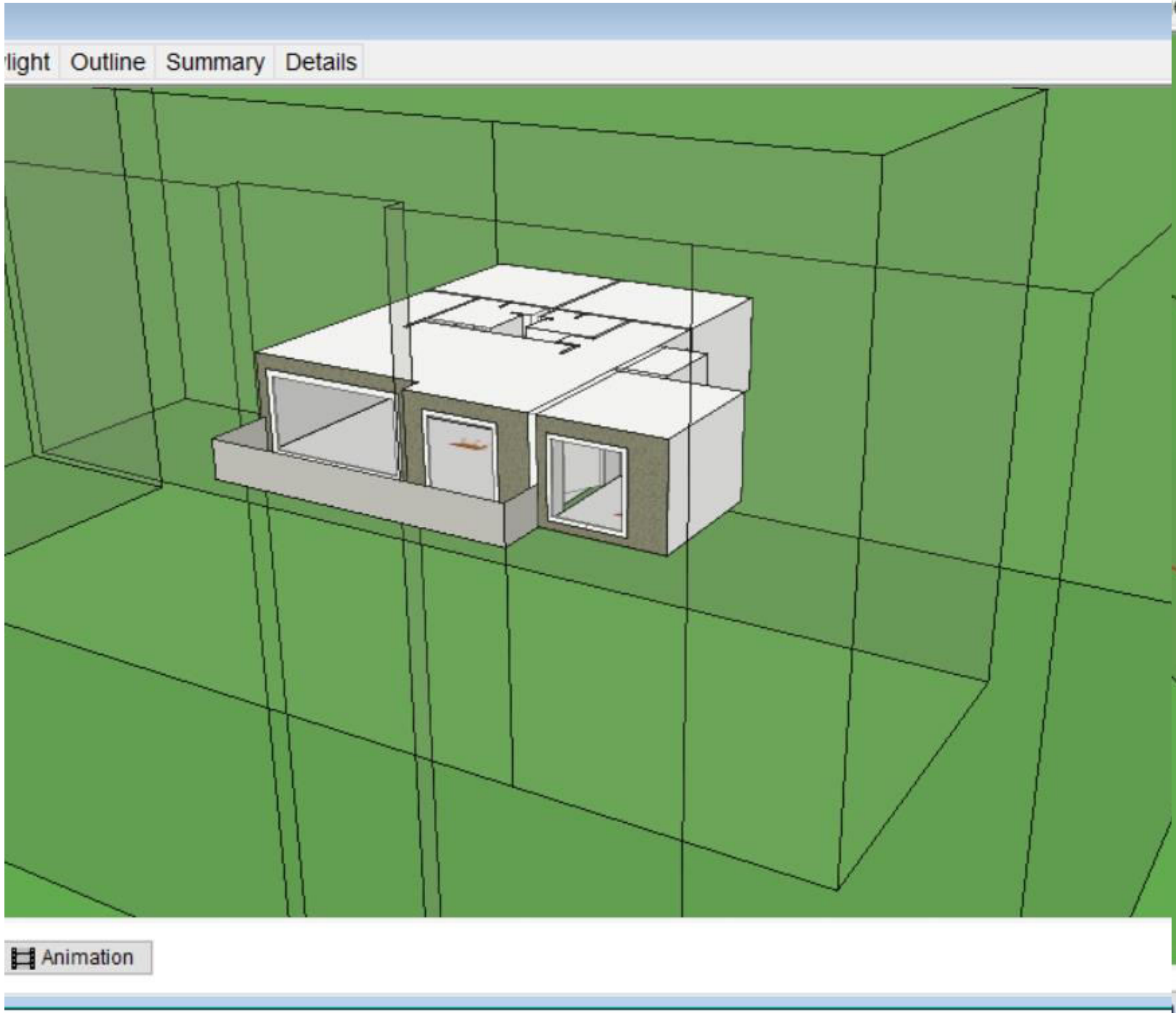
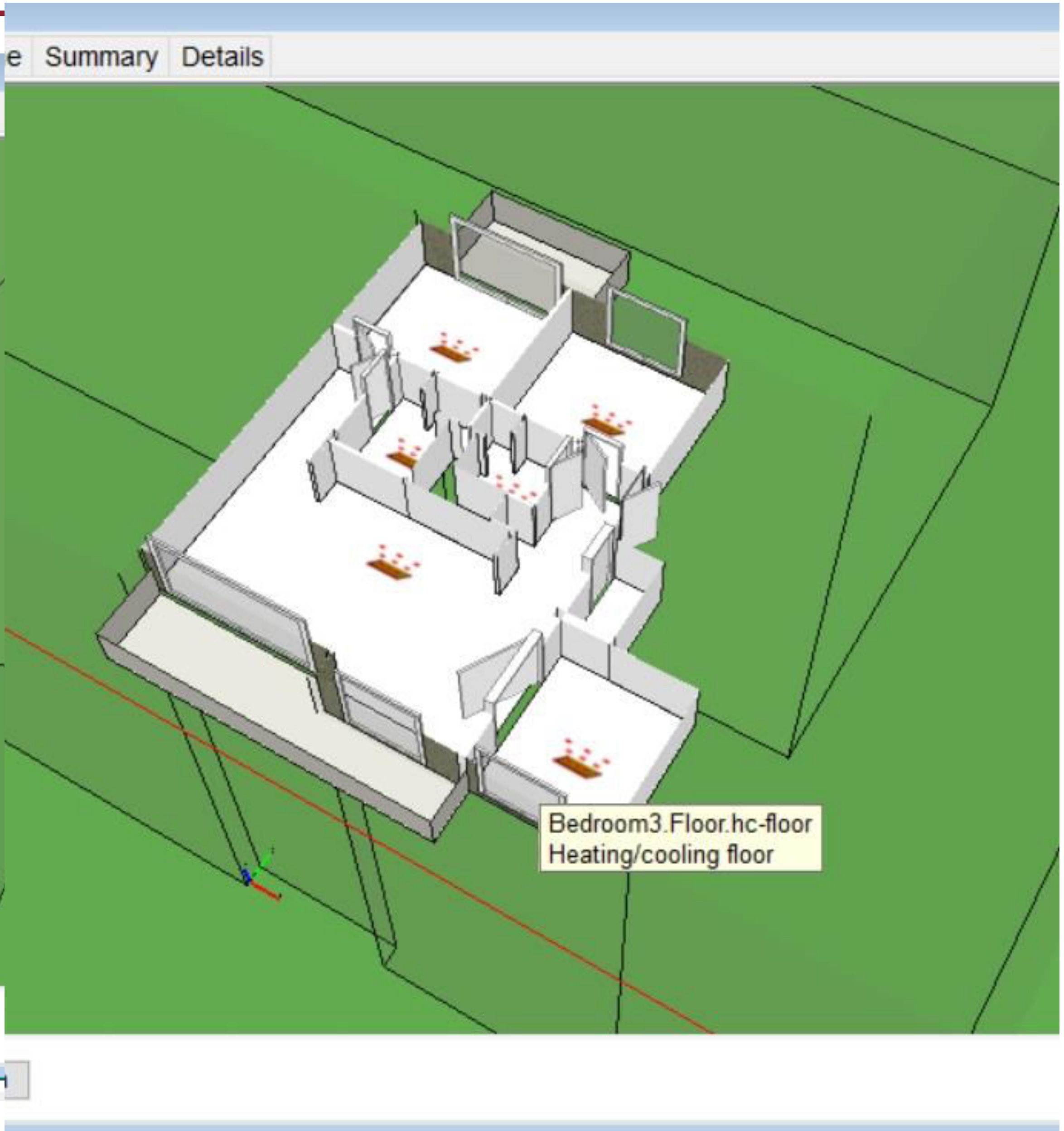
Floor plan of the

5 Methods


Outline
Summary
Details
Animation


Summary
Details
Bedroom3.Floor.hc-floor
Heating/cooling floor

Standard ventilation strategies

Strategy name	Type of sensor	Description
CAV min	-	Minimum airflow rates
CAV	-	Increased airflow in the bathrooms
VAV stepwise	CO_2 control	Central sensor in the exhaust duct of the AHU
VAV stepwise	RH control	Central sensor in the exhaust duct of the AHU
VAV stepwise	T control	Central sensor in the exhaust duct of the AHU
VAV proportional	CO_2 control	Central sensor in the exhaust duct of the AHU
VAV proportional	RH control	Central sensor in the exhaust duct of the AHU
VAV proportional	T control	Central sensor in the exhaust duct of the AHU

Advanced ventilation strategies

Strategy name	Type of sensor	Description
VAV balanced	CO_2 control	Room-based sensors
VAV balanced	RH control	Room-based sensors
VAV balanced	T control	Room-based sensors
VAV balanced	CO_2 and RH control	Room-based sensors
VAV unbalanced	CO_2 control	Room-based sensors
VAV unbalanced	RH control	Room-based sensors
VAV unbalanced	T control	Room-based sensors
VAV unbalanced	CO_2 and RH control	Room-based sensors

Max VAV airflow – 80 L/s

«Innovative» ventilation strategies

Standard strategies

Advanced strategies

Innovative strategies

The best strategies are studied with reduced minimum ventilation rate (0.1 L/s per m2)

Reduction to 0.1 L/s per m^2 during non-occupied hours for:

- 10 hours
- 8 hours
- 6 hours
- 4 hours

- CAV
- VAV with stepwise central RH sensor
- VAV with stepwise central CO_2 sensor
- VAV with proportional central RH sensor

Modelling of emissions

TVOC by 'Holmberg and Hesaraki (2015)'

Emission rate calculated for average 'steady-state' concentration of 0.1 mg/m3 => 3 µg/s.

TVOC 'DS/EN 15251'

Emission rate of TVOCs in low-polluting buildings should be below 0.2 mg/m^2 per h.

Formaldehyde

Emission rate calculated as the sum of the emissions from paints, flooring and carpets in each room. **Salthammer and Uhde (2009)**

Benzene

Emission rate calculated as the sum of the emissions from paints, flooring and carpets in each room. **Salthammer and Uhde (2009)**

- Modelling of emissions – IDA ICE, Challenge:
  ICE offers only a mass balance over CO2 in the simulated building

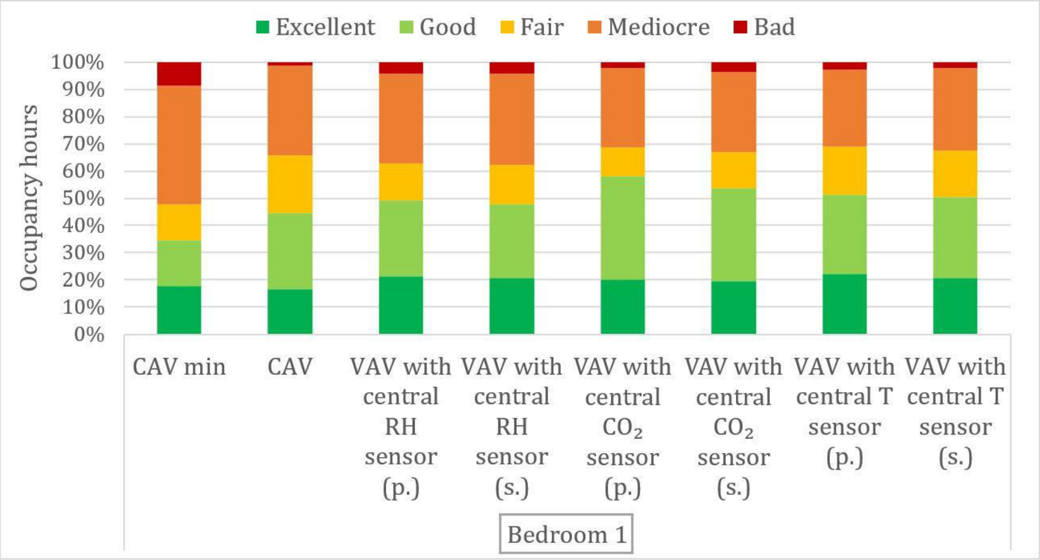
SOLUTION:

- ❑ Utilization of an ”Equipment” component – additional emission of CO_2 (mg/s)
- ❑ Two models are created:
  a) Without VOC emission – to obtain airflows based on CO_2
  b) VOC emission = CO2 emission from ”Equipment”, airflows provided from external data file from a)
- ❑ Outdoor concetration neglected

Results – should be considered preliminary

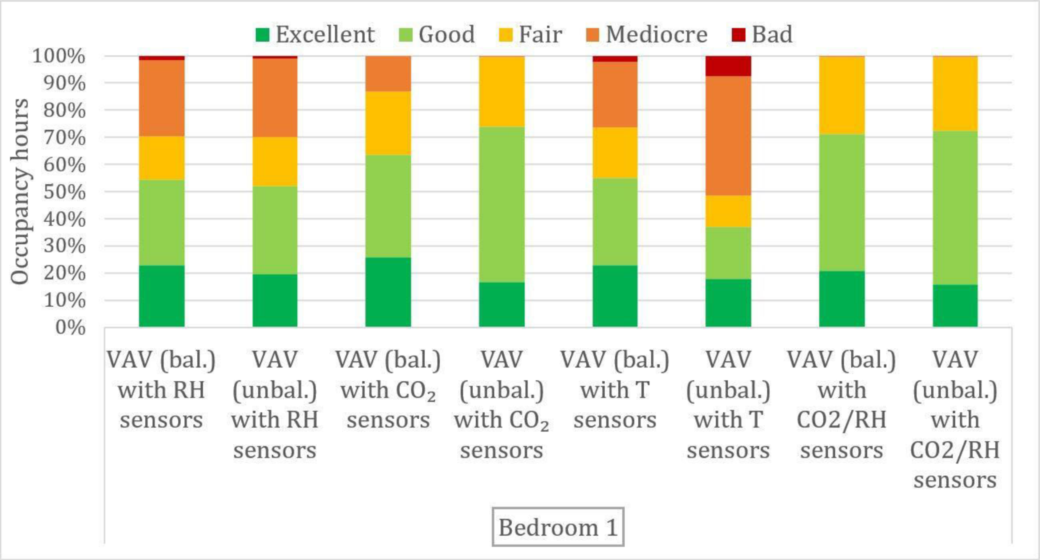
- IAQ in terms of CO_2 concentration

Standard strategies



Abbreviations: s.=stepwise; p.=proportional.

Advanced strategies



Abbreviations: bal.=balanced; unbal.=unbalanced.

- **Excellent:** CO_2 concentration between 400 and 600 ppm
- **Good:** CO_2 concentration between 600 and 800 ppm
- **Fair:** CO_2 concentration between 800 and 900 ppm
- **Mediocre:** CO_2 concentration between 900 and 1200 ppm
- **Bad:** CO_2 concentration above 1200 ppm

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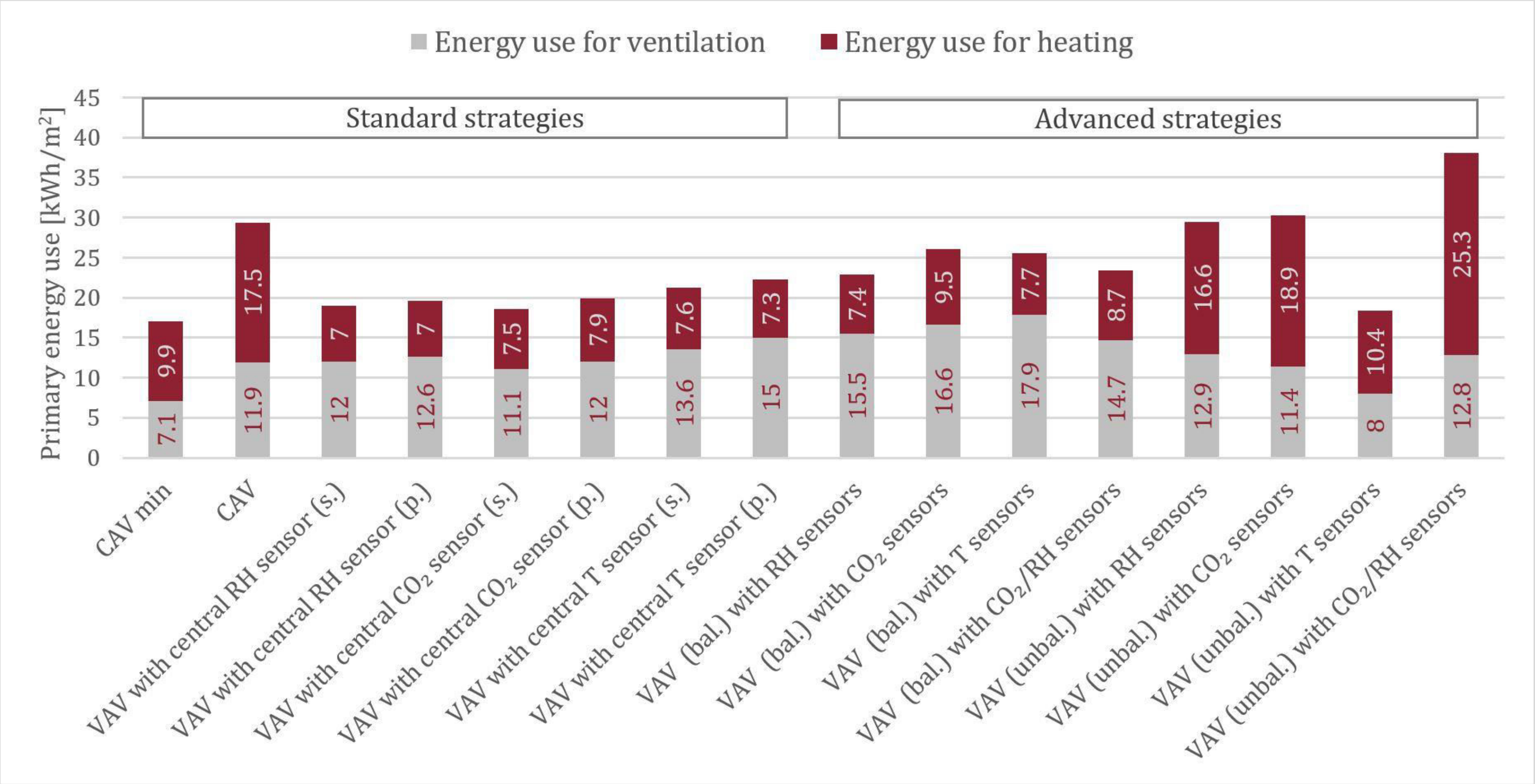
Results – should be considered preliminary

Energy use



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Results – should be considered preliminary

Ranking accodring to Toureilles (2015)

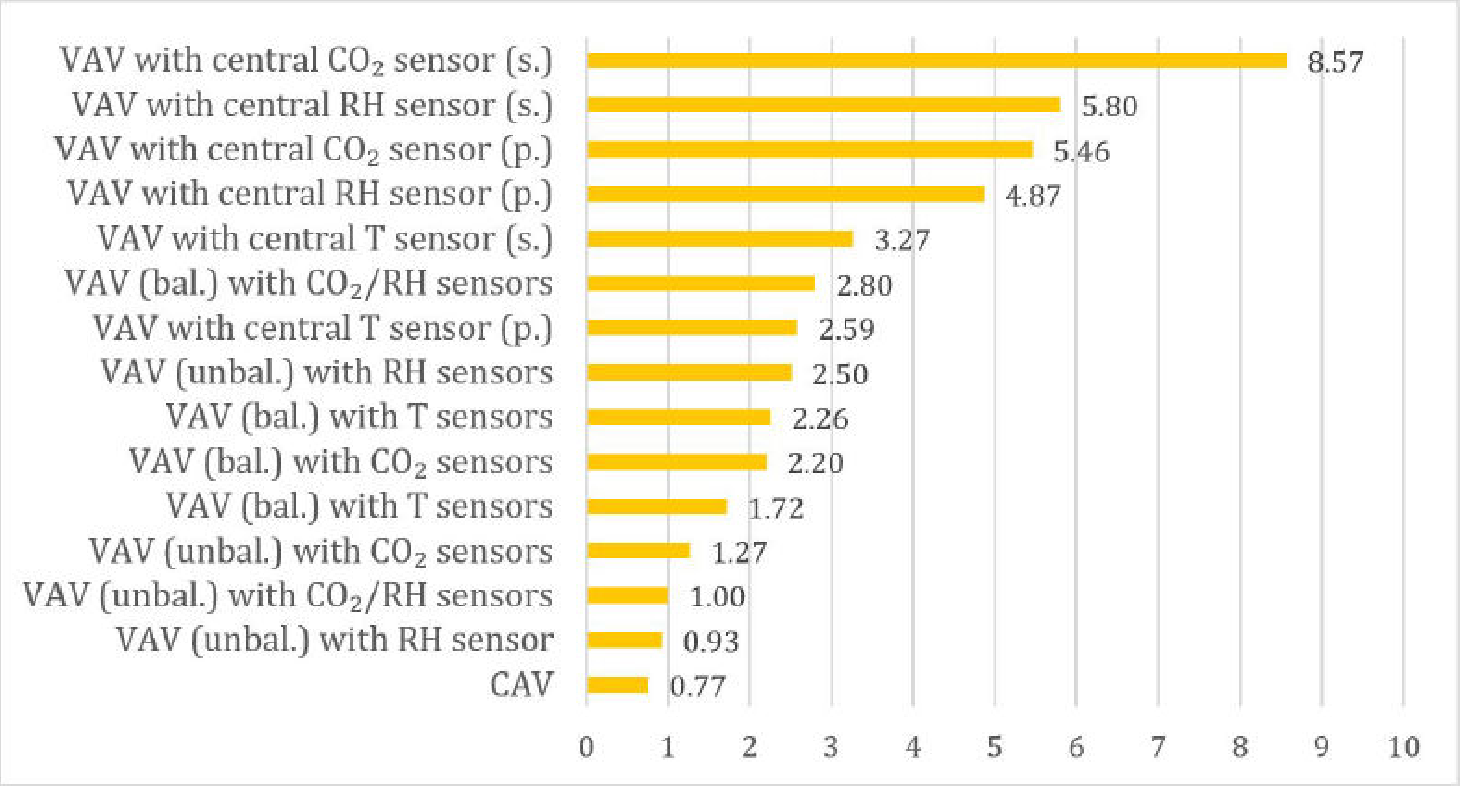
Index of global performance

$$I_g = \frac{I_{IAQ}}{I_{Energy}}$$

where:

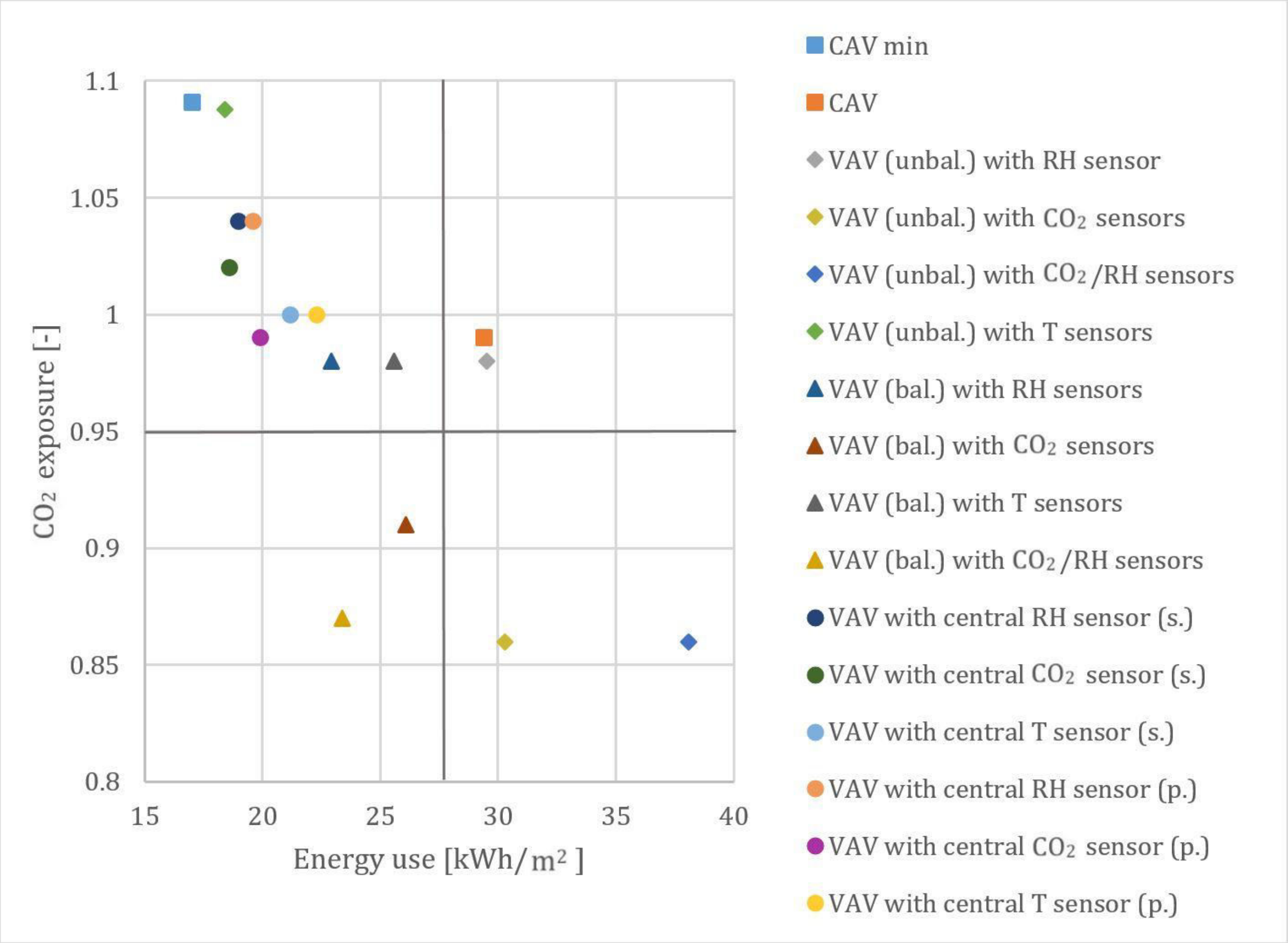
$$I_{IAQ} = \frac{I_{exp}^{max} - I_{exp}}{I_{exp}^{max} - I_{exp}^{min}}$$

$$I_{Energy} = \frac{E - E_{min}}{E_{max} - E_{min}}$$

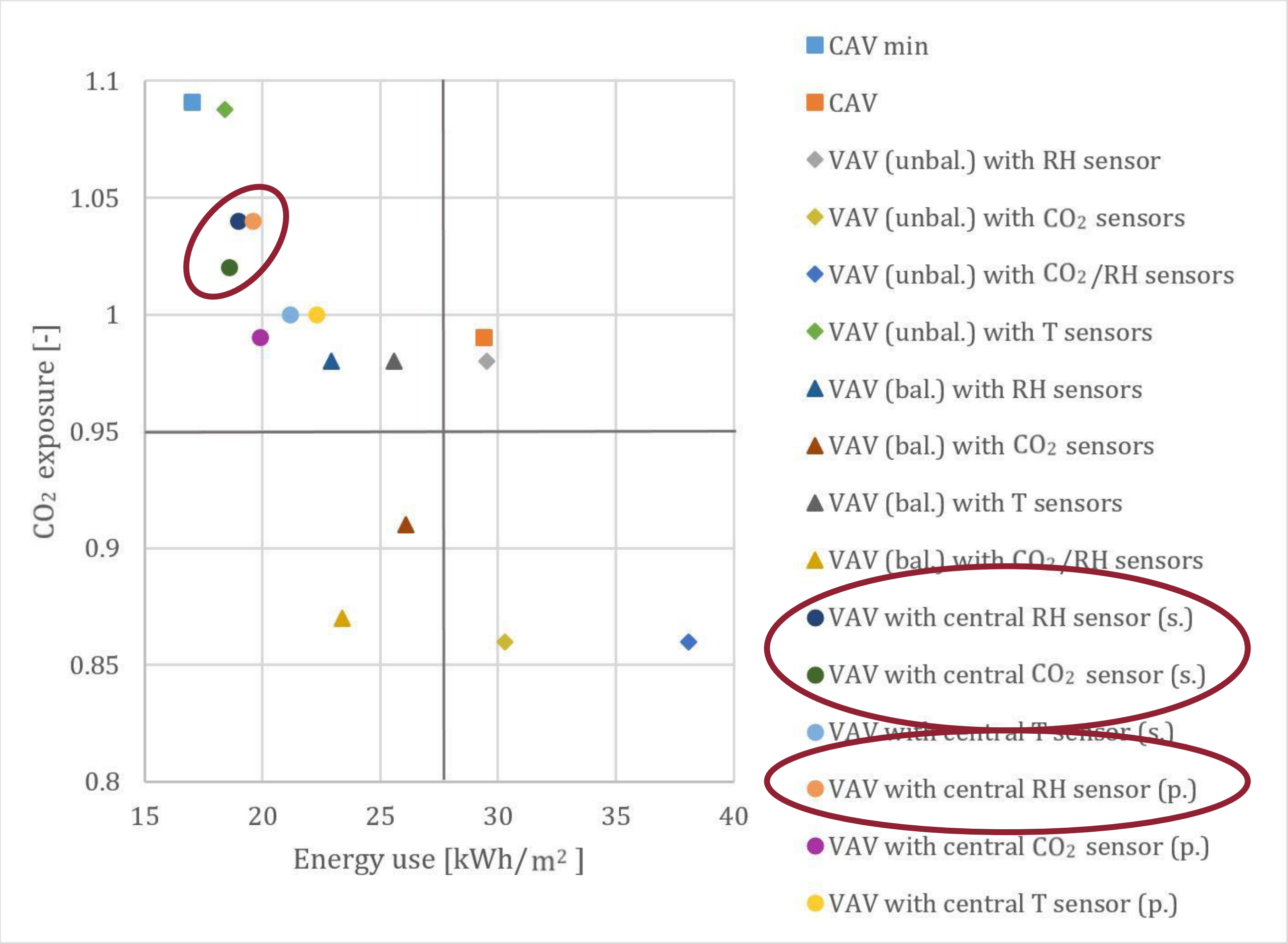


(c) Living room

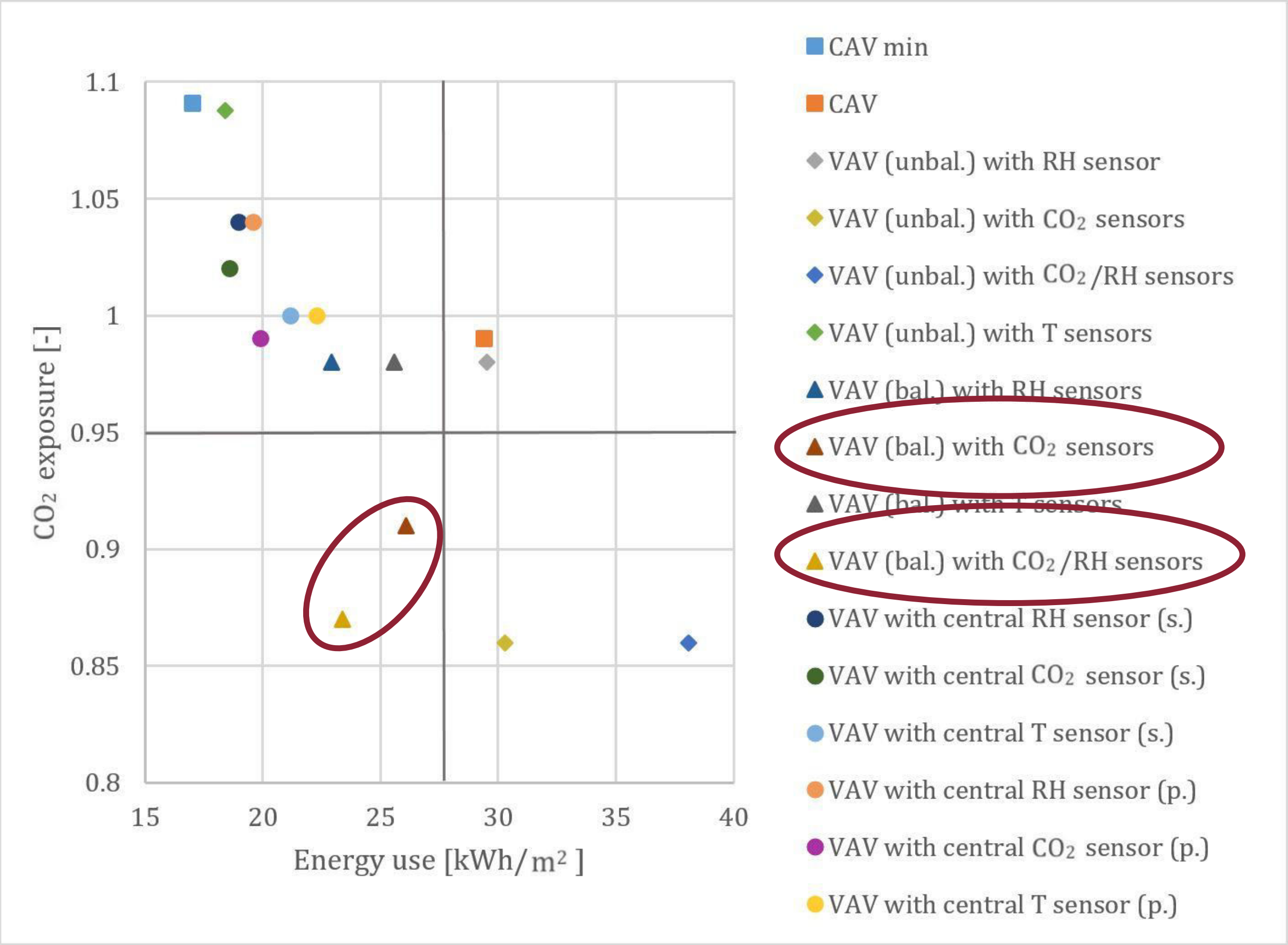
Trade-off between energy use and CO_2 exposure in the Ig



Trade-off between energy use and CO_2 exposure



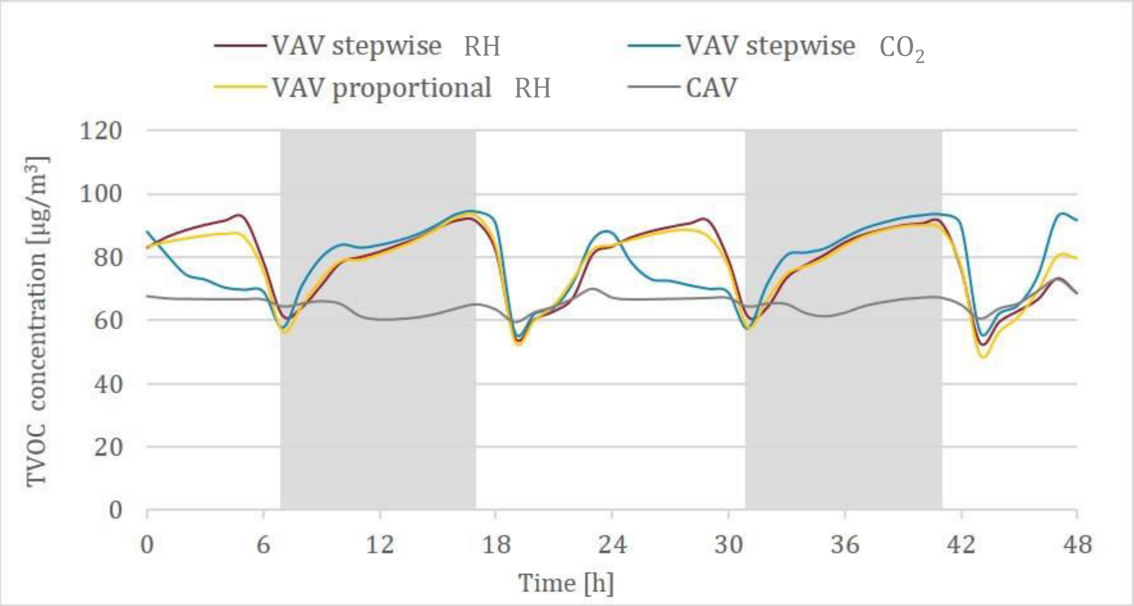
Trade-off between energy use and CO_2 exposure



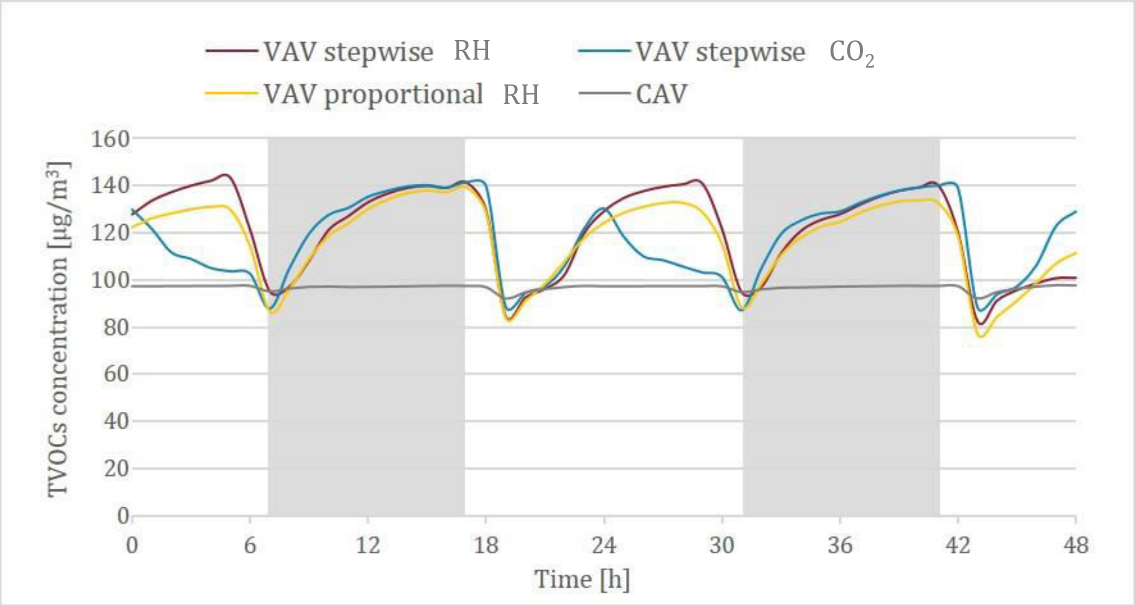
6 Results regarding emissions – very preliminary !!!

- TVOC – Living room

TVOC - Holmberg and Hesaraki (2015): systems with minimum ventilation rate equal to 0.3 l/s per m^2.



TVOC - DS/EN 15251 systems with minimum ventilation rate equal to 0.3 l/s per m^2.

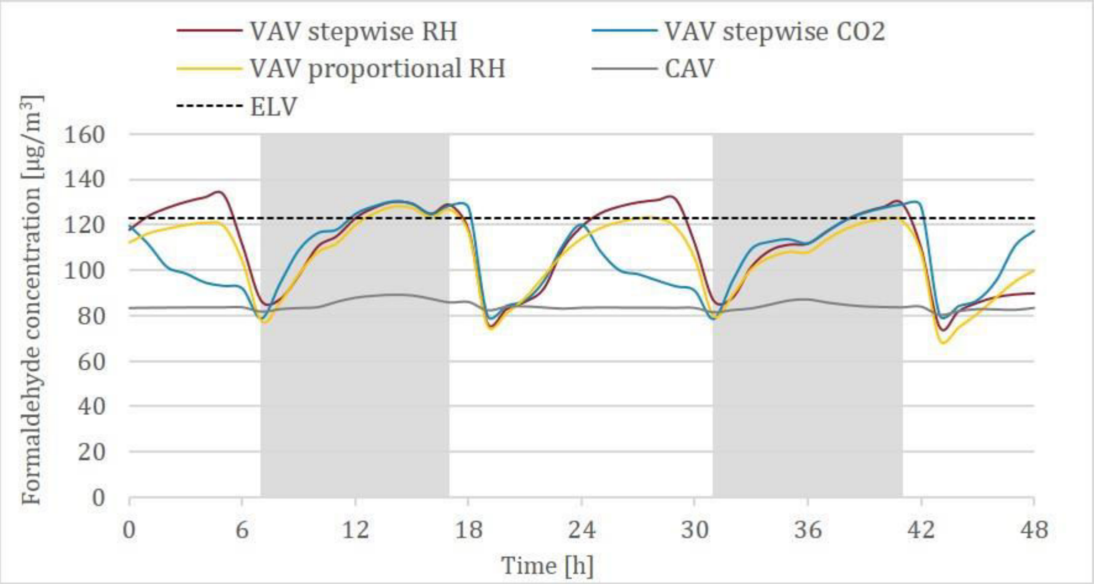


Exposure limit value (ELV)= 600 μg/m^3

Results regarding emissions – very preliminary !!!

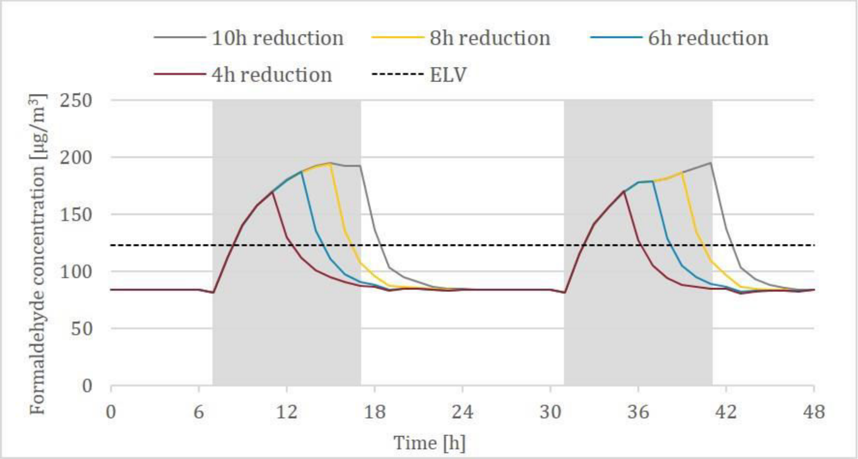
Formaldehyde

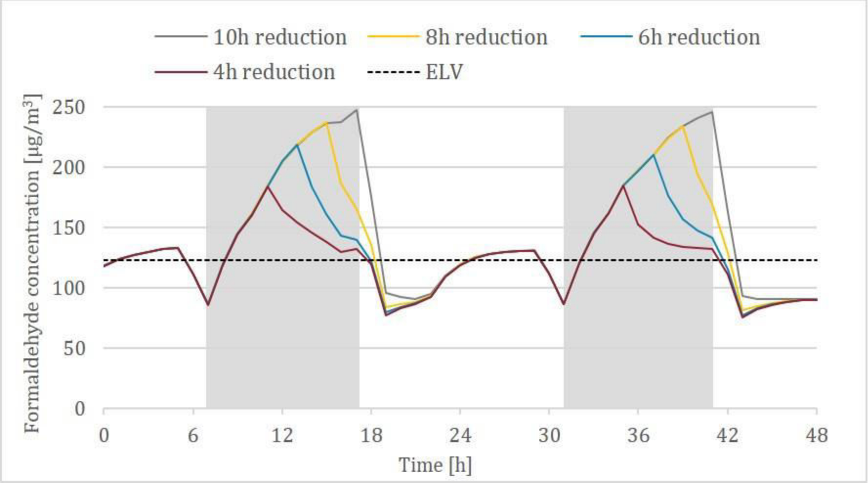
Formaldehyde concentration for the systems with minimum ventilation rate equal to 0.3 l/s per m^2



Exposure limit value (ELV)= 123 µg/m^3

Formaldehyde concentration: CAV system and VAV with stepwise RH sensor with minimum ventilation rate equal to 0.1 l/s per m^2.

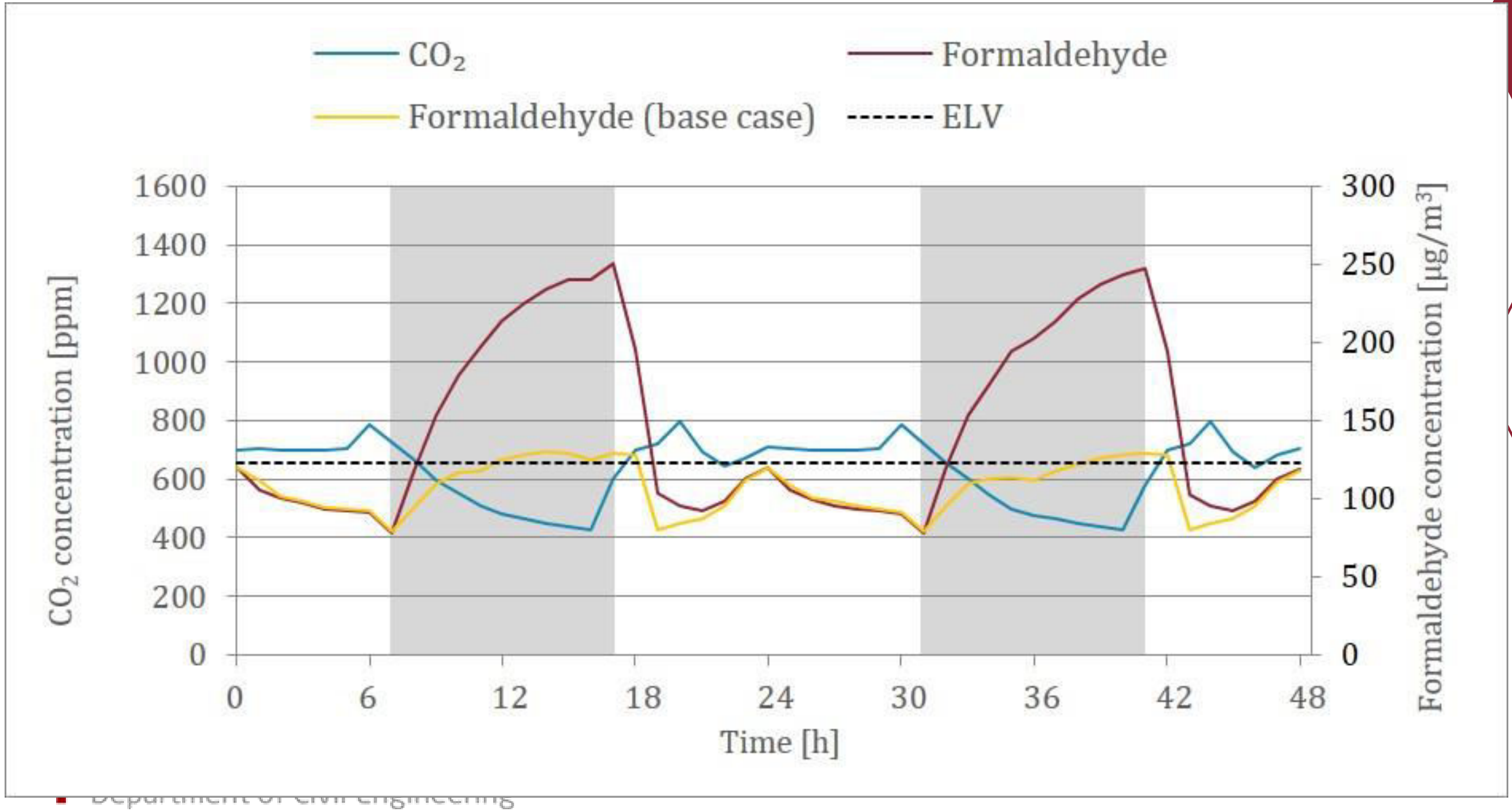




Results regarding emissions – very preliminary !!!

Formaldehyde

Formaldehyde and CO_2 concentration for the 10 hours reduction case and the base case of VAV stepwise with CO_2 sensor.



10-hours-reduction case

Formaldehyde concentration 2 times higher than in the base case

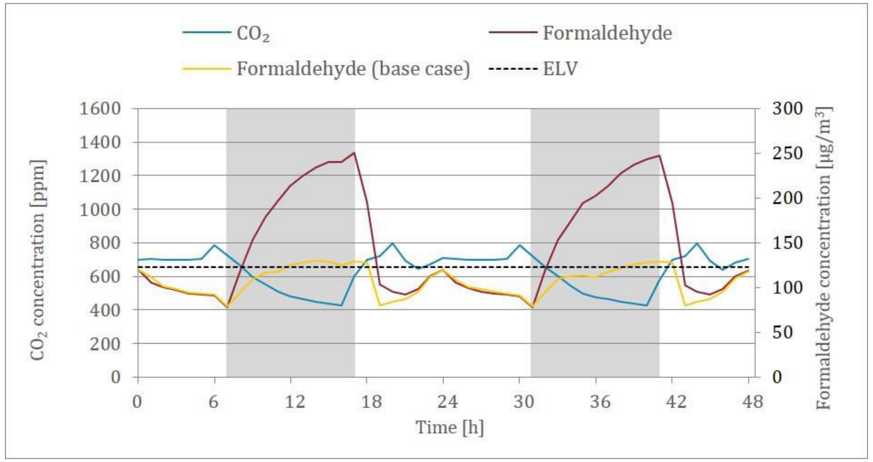
CO_2 and RH differ from the base case of less than 1%

Concentration below the ELV after 1 hour of boosting

Results regarding emissions – very preliminary !!!

Formaldehyde

Formaldehyde and CO_2 concentration for the 10 hours reduction case and the base case of VAV stepwise with CO_2 sensor.



Scenario	Formaldehyde concentration at 17:00 [µg/m³]	Formaldehyde concentration at 18:00 [µg/m³]	Formaldehyde concentration at 19:00 [µg/m³]
10h reduction	250	195	103
8h reduction	166	148	87
6h reduction	140	133	82
4h reduction	132	129	81

10-hours-reduction case

Formaldehyde concentration 2 times higher than in the base case

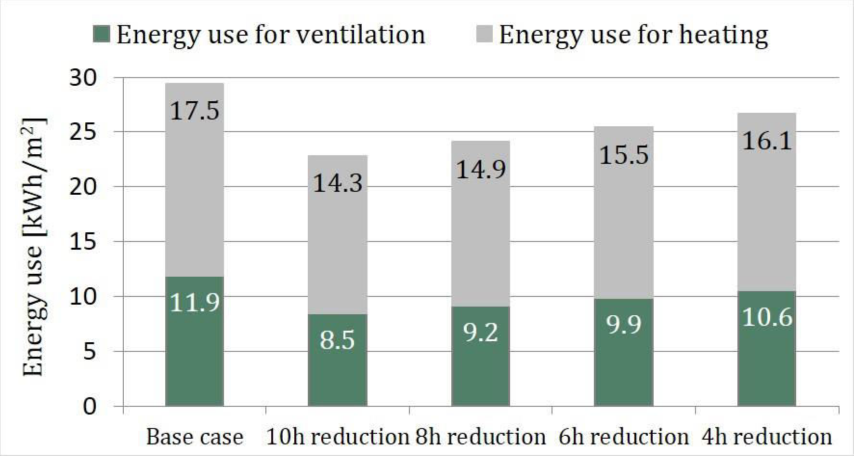
CO_2 and RH differ from the base case of less than 1%

Concentration below the ELV after 1 hour of boosting

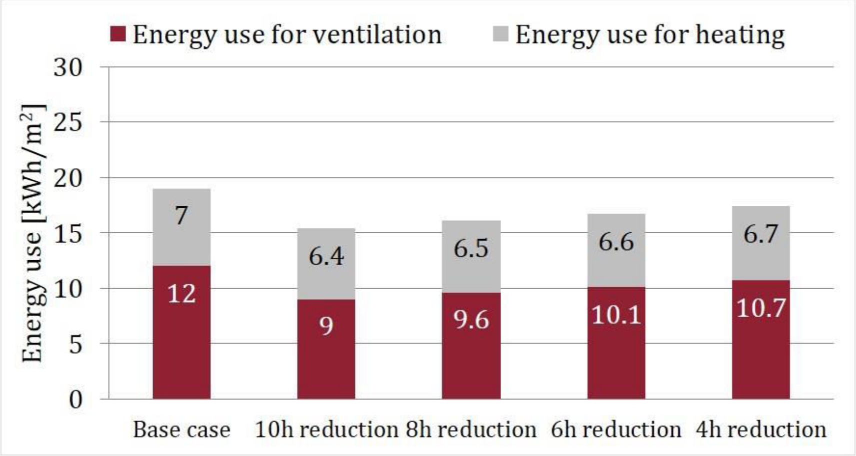
Results regarding emissions – very preliminary !!!

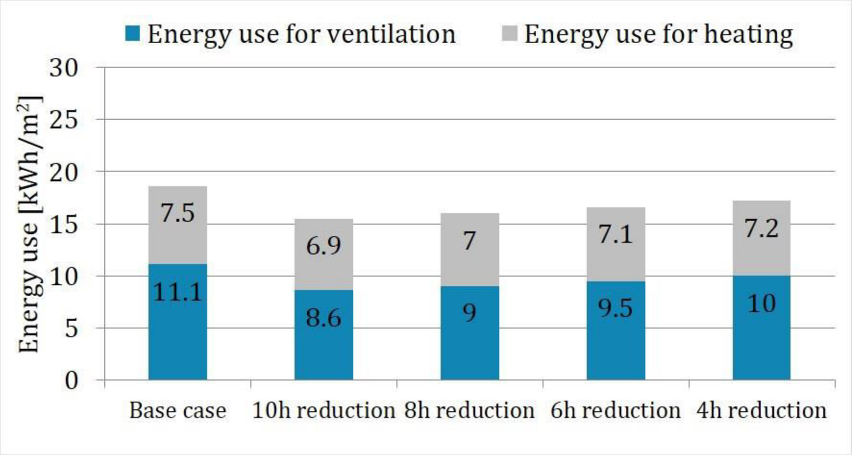
Energy use

CAV system



VAV systems: stepwise RH and stepwise CO_2 sensor





CAV system energy saving: between 22% and 9%

VAV systems with RH sensor energy saving: between 19% and 8%

VAV system with CO_2 sensor energy saving: between 16% and 7%

7 Conclusions

- Sensors on Relative Humidity are suggested in order to control potentially increased indoor moisture production rates.
- Central sensor in the exhaust duct of the AHU provides the best compromise in terms of energy savings and IAQ.
- Reducing the ventilation rate to 0.1 l/s per m^2, a good level of IAQ in terms of contaminants is reached only after one hour of ventilation in boosting mode.
- Decreasing the ventilation rate for 10 hours during non-occupied periods is a potential energy saving measure, which reduces the energy use of up to 19% compared to the base case.
- Formaldehyde resulted difficult to control on the short-term, but it is expected an exponential decrease over time.

7 Future work

- Sensitivity analysis on type and size of dwelling, type and number of occupants, occupancy schedule, moisture production and climate zone.
- Integrate more advanced emission models – using PANDORA database, results from ST2, etc.
- Validate the results with dedicated software for contaminants simulations (e.g. CONTAM, IAQx) and with field measurements.
- Contaminants emission rate should be estimated accounting for an increased number of indoor sources (e.g. furniture, cabinets, electronic equipment), for sorption and desorption and for the influence of temperature and relative humidity.
- Test the performances of the system when the mechanical ventilation is switched off during non-occupied periods, adopting a boosting mode when the occupants get back home.

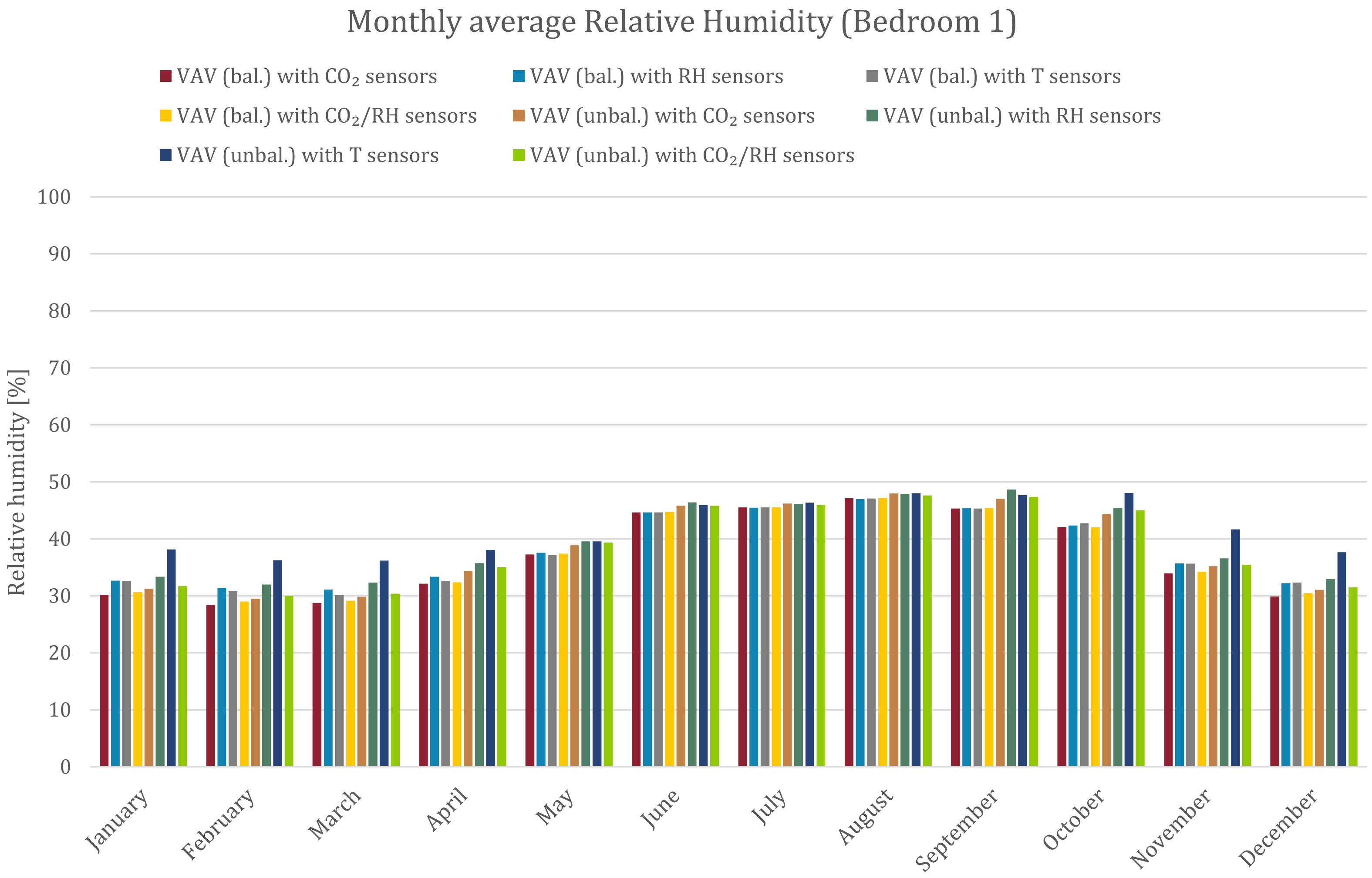
Thank you for the attention!

Relative humidity

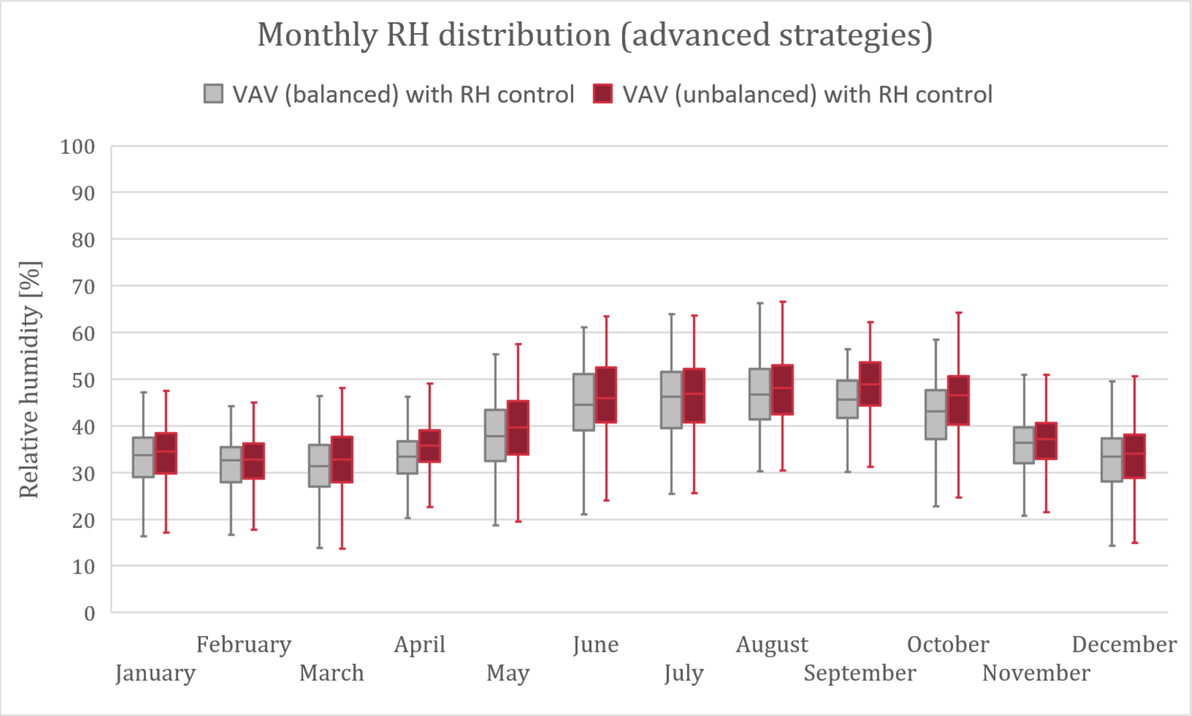
	RH<25% [h]			RH>60% [h]			RH<25% [h]			RH>60% [h]		
	B1	**BH1**	**LV**	**B1**	**BH1**	**LV**	**B1**	**BH1**	**LV**	**B1**	**BH1**	**LV**
CAV min	443	644	623	191	333	335	5	7	7	2	4	4
CAV	710	827	935	102	145	157	8	9	11	1	2	2
Centralized VAV with stepwise RH sensor	580	828	790	47	65	102	7	9	9	1	1	1
Centralized VAV with proportional RH sensor	590	834	798	48	51	82	7	9	9	1	1	1
Centralized VAV with stepwise CO2 sensor	730	964	933	60	82	120	8	11	11	1	1	1
Centralized VAV with proportional CO2 sensor	804	1020	1017	58	72	109	9	12	12	1	1	1
Centralized VAV with stepwise T sensor	755	1011	978	55	77	109	9	12	11	1	1	1
Centralized VAV with proportional T sensor	728	990	948	50	63	86	8	11	11	1	1	1

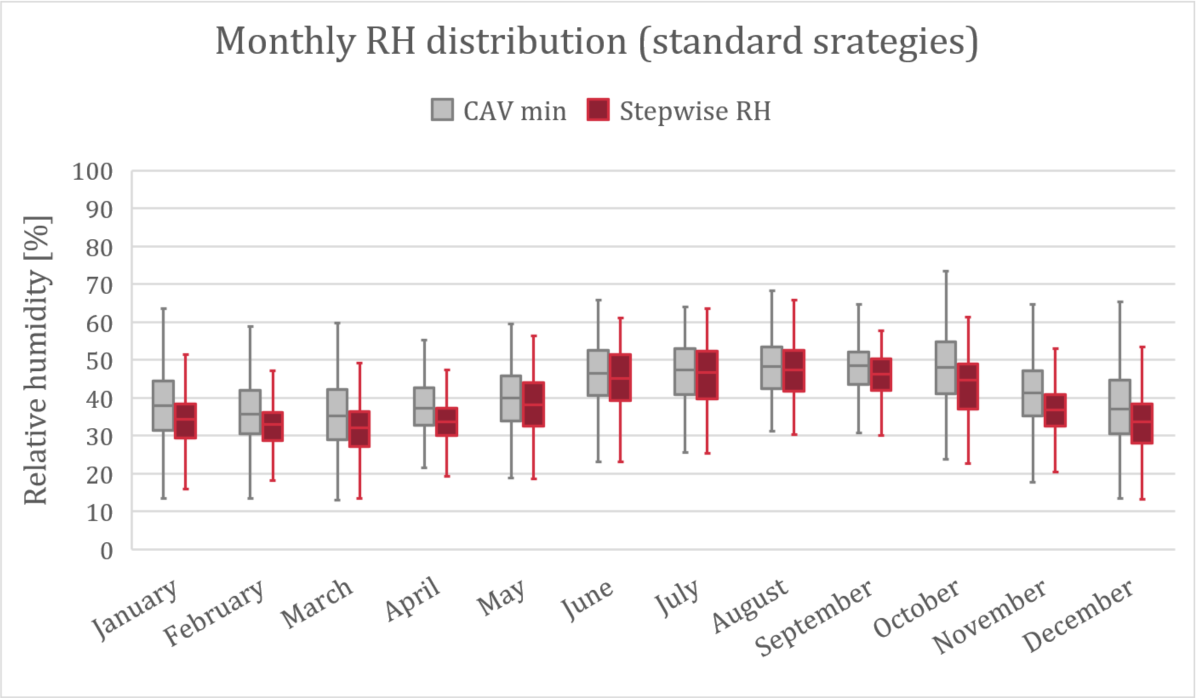
	RH<25% [h]			RH>60% [h]			RH<25% [h]			RH>60% [h]		
	B1	**BH1**	**LV**	**B1**	**BH1**	**LV**	**B1**	**BH1**	**LV**	**B1**	**BH1**	**LV**
Balanced VAV with proportional RH sensors	593	851	804	46	37	67	7	10	9	1	0	1
Unbalanced VAV with proportional RH sensors	495	737	692	100	106	133	6	8	8	1	1	2
Balanced VAV with proportional CO2 sensors	980	1219	1229	48	53	84	11	14	14	1	1	1
Unbalanced VAV with proportional CO2 sensors	806	950	955	80	107	134	9	11	11	1	1	2
Balanced VAV with proportional T sensors	787	1048	1006	55	68	84	9	12	11	1	1	1
Unbalanced VAV with proportional T sensors	432	629	600	202	397	377	5	7	7	2	5	4
Balanced VAV with proportional CO2&RH sensors	900	1108	1111	48	50	84	10	13	13	1	1	1
Unbalanced VAV with proportional CO2&RH sensors	733	880	866	68	82	106	8	10	10	1	1	1

Relative humidity

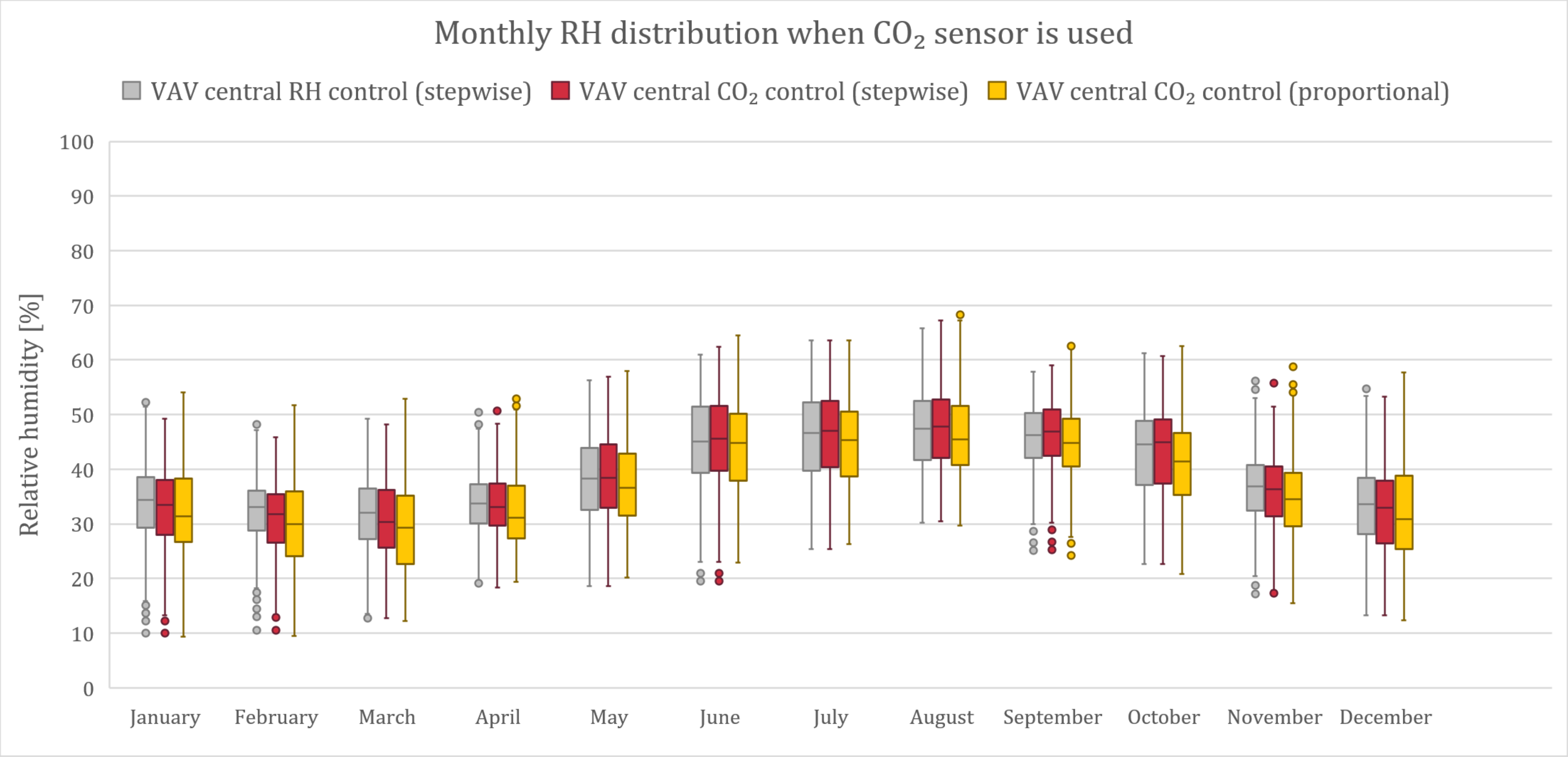


Relative humidity

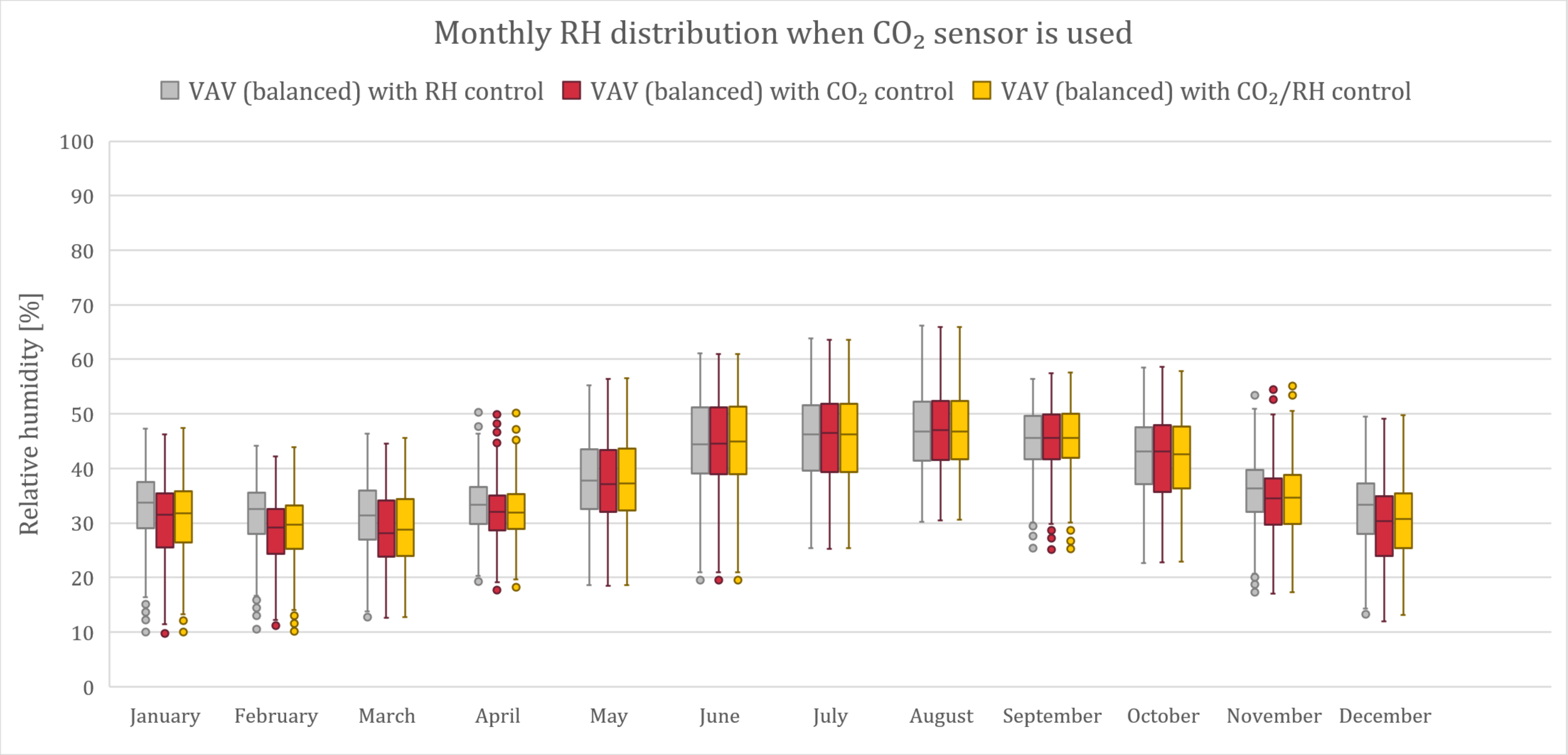




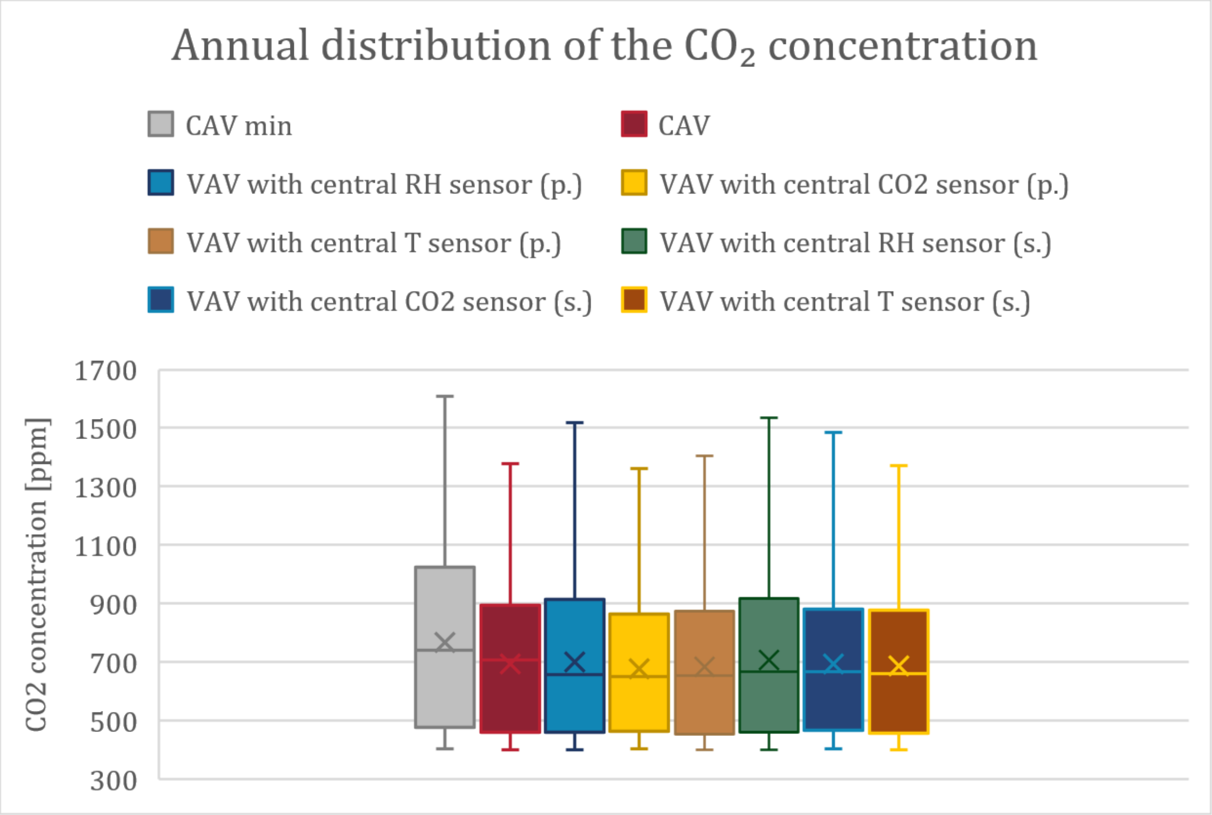
Relative humidity

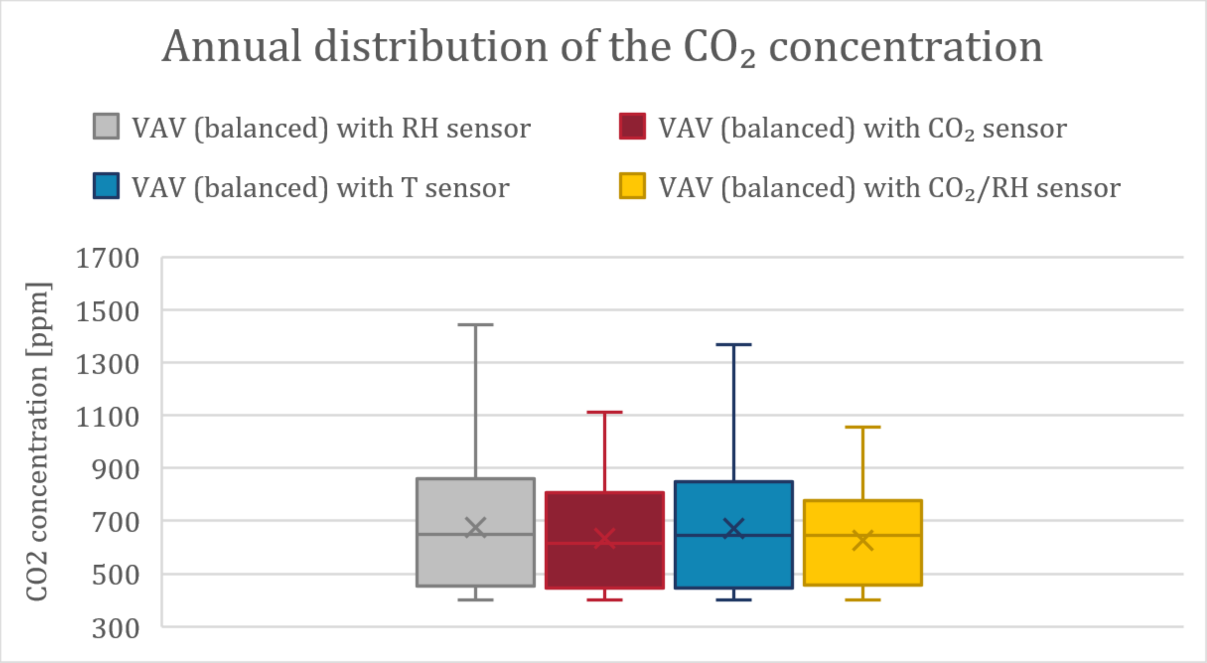


Relative humidity



CO_2 concentration





Supply airflows