P5 Final Presentation

Graduation – Xiao Guang Pan, 5501121

The COVID-19 pandemic


Het onderwijs, van basisschool tot universiteit, is deze week begonnen met het verzorgen van afstands-onderwijs. Vandaag: Frans Roovers uit Heerlen, mbo-docent bij Vista College en onderwijsadviseur bij Zuyd Hogeschool: „Beperk je instructie online tot een half uur."

ONLINE ONDERWIJS

Digitale lessen: de keukentafel als klaslokaal

Drukte in huize Roovers. Rechtsachter docent Frans Roovers die sinds deze week digitaal les geeft vanuit huis. Naast hem zijn vrouw Ivonne die zo weer de rust van de slaapkamer opzoekt om digitaal les te kunnen geven. Links twee van hun drie kinderen die momenteel noodgedwongen thuis zijn.

Docent Frans Roovers is redelijk goed thuis in online-onderwijs.

HEERLEN

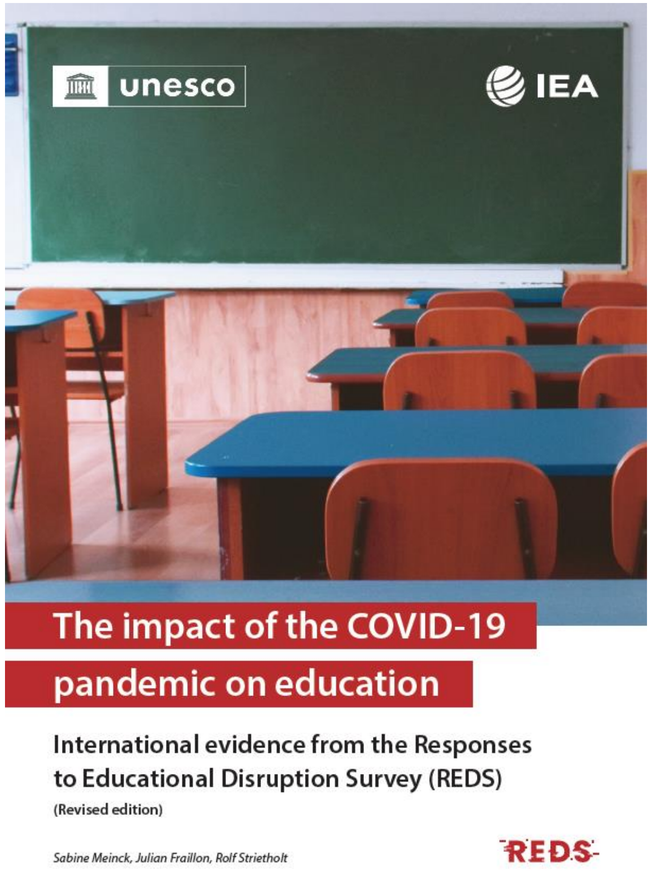
DOOR JOS VAN DEN CAMP

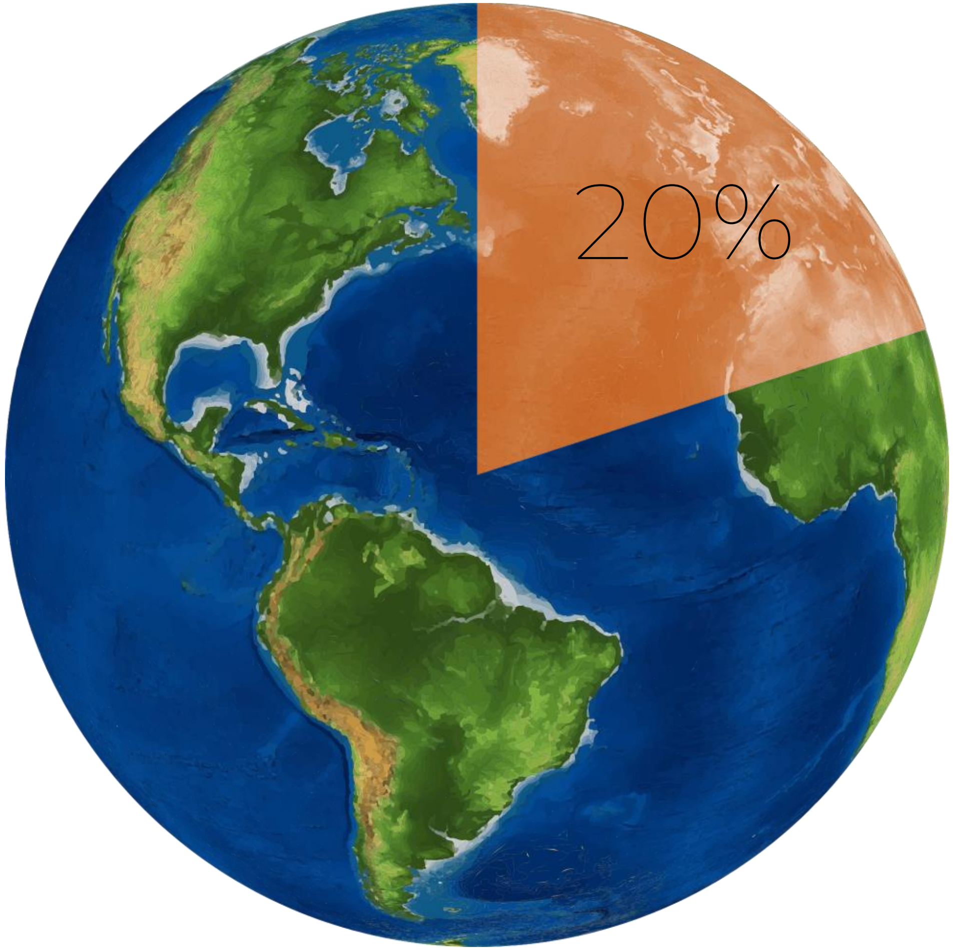
Geen gekakel

Interactie

Knap

Snelheid

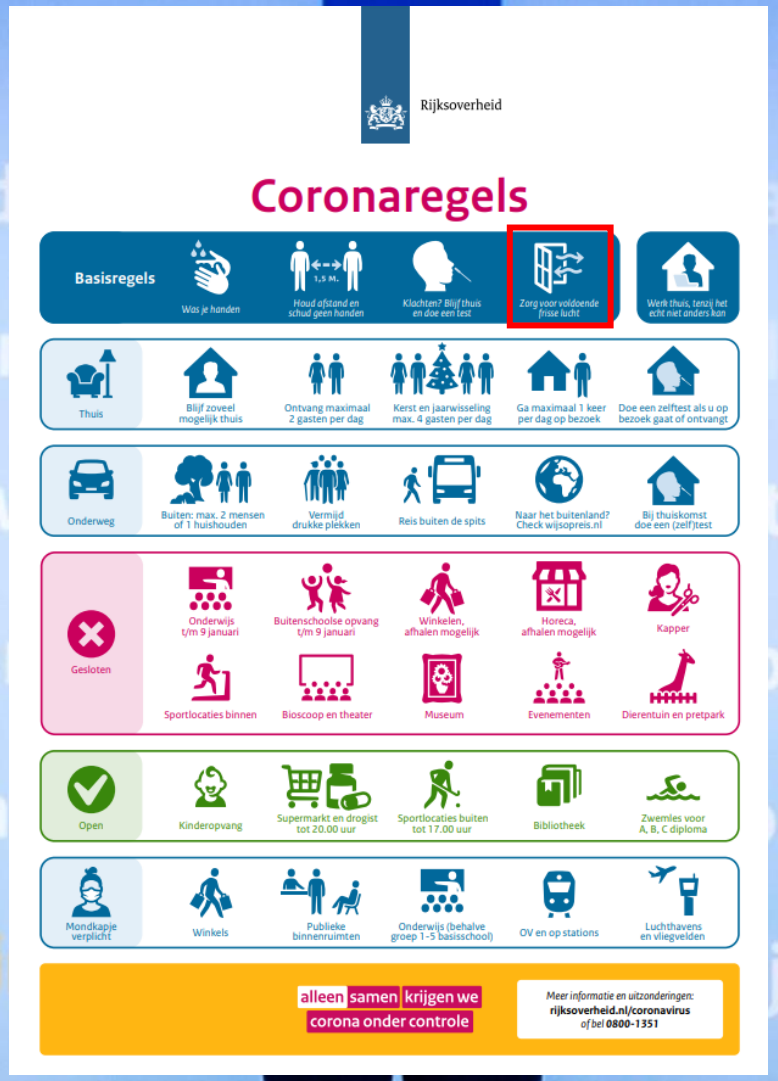


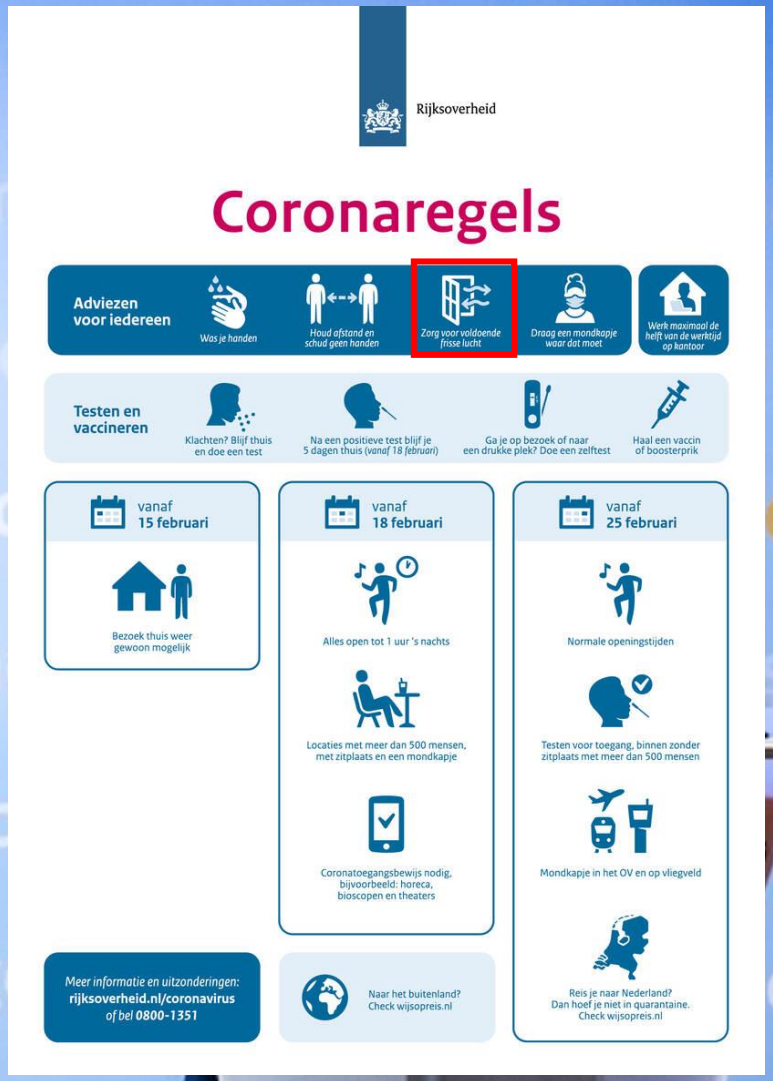


"More than 1.5 billion students and youth across the planet are or have been affected"

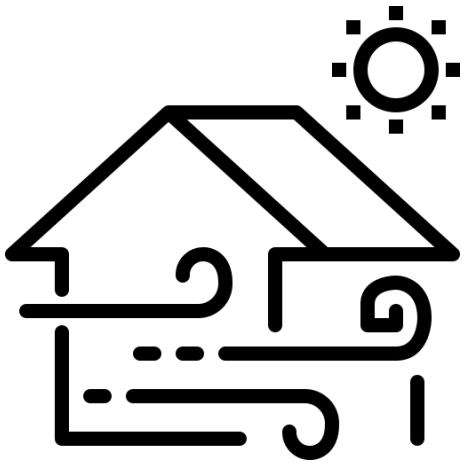
Global Education Coalition (GEC), 2022

The COVID-19 measures

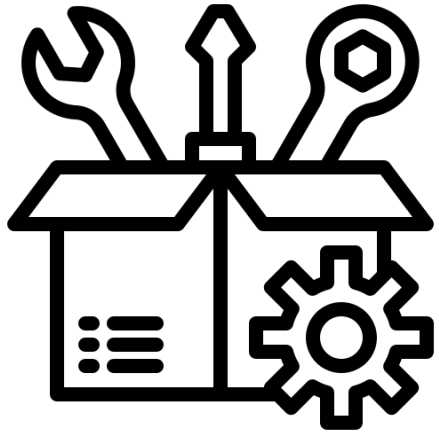




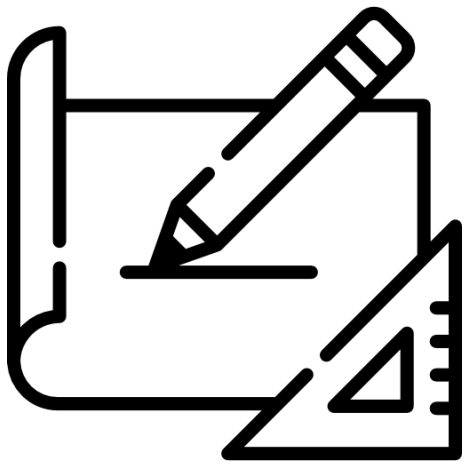
What are the problems



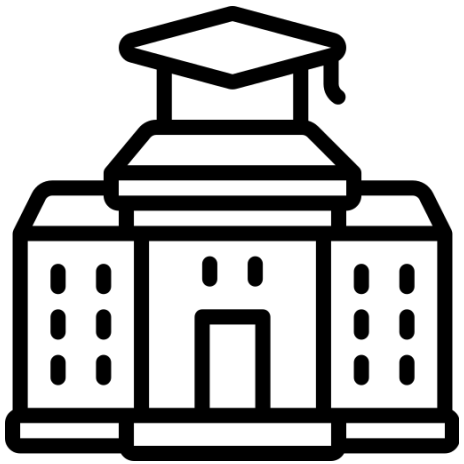
How much ventilation?



Costs & practicality



What designs or systems to use?



How to prepare schools?

The central question

How can smart, personal or decentralised ventilation improve the ventilation system design to make it more COVID-19-proof while not negatively impacting the comfort of the occupants in an educational environment and being both practical and cost-efficient?

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How can smart, personal or decentralised ventilation improve the ventilation system design to make it more COVID-19-proof while not negatively impacting the comfort of the occupants in an educational environment and being both practical and cost-efficient?

Overview

	Covid -19	Comfort	Costs
Baseline			
Decentral			
SMART			
Personal ventilation			

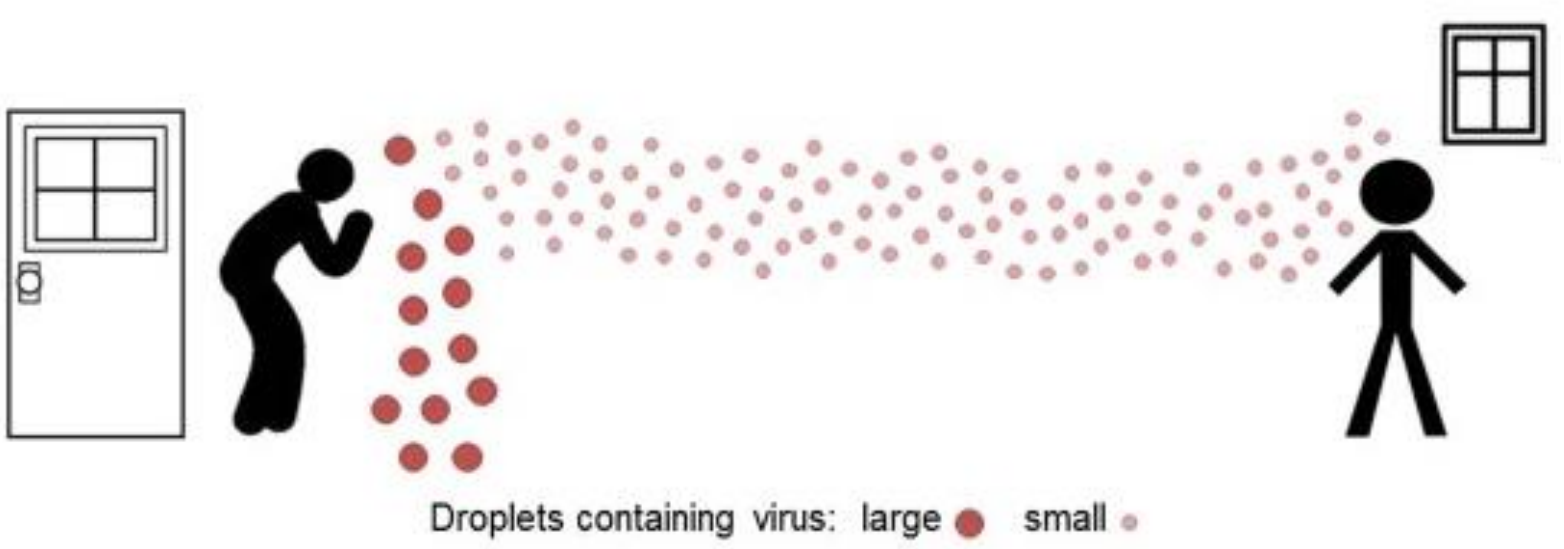
Covid-19

- *Risk of infection:*

$$P = 1 - e^{-\frac{flqt}{n}}$$

- CO_2 concentration

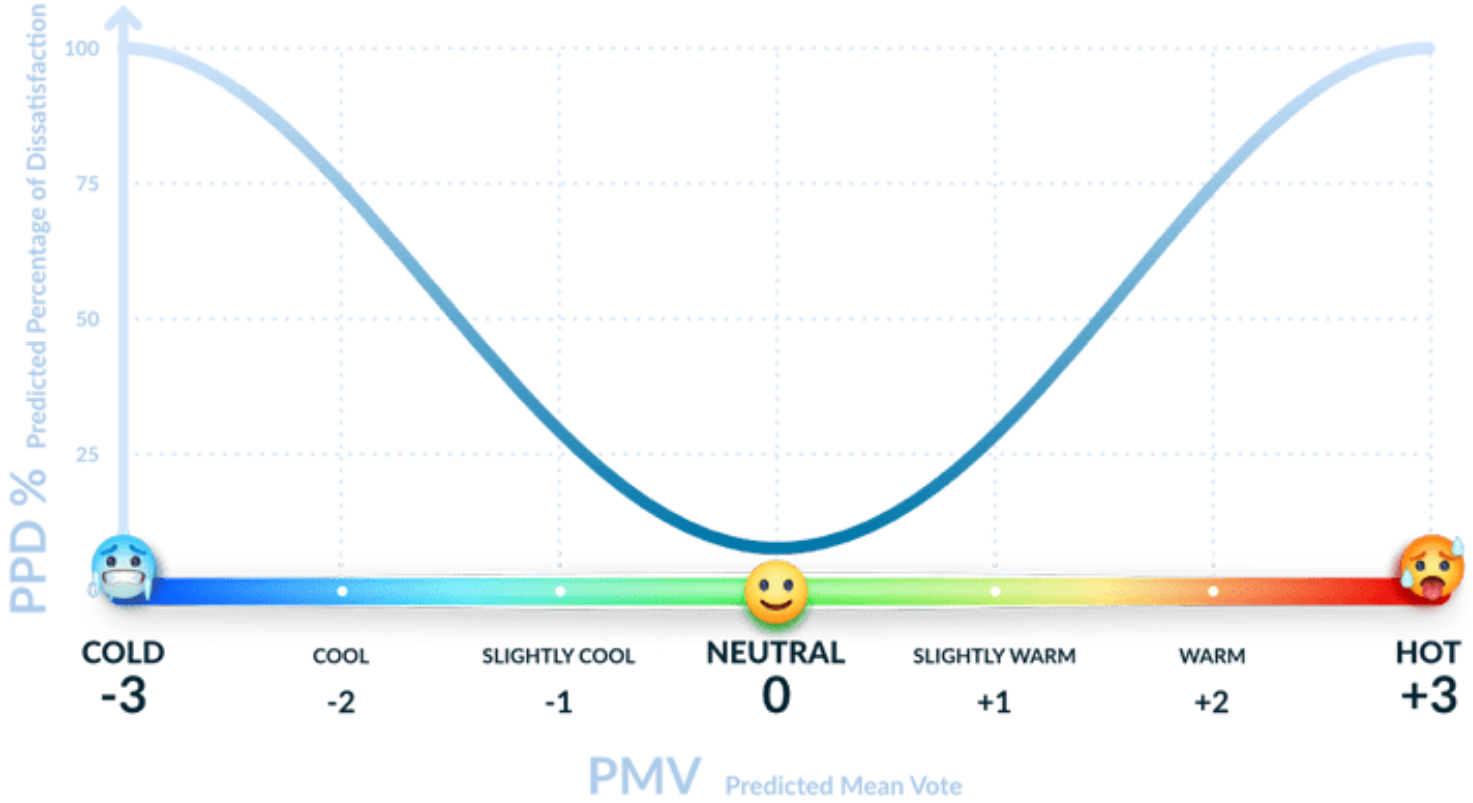
- Quanta generation:
  - ALPHA: 89 - 165
  - DELTA: 312 - 935
  - OMICRON: 725 - 2345



Deposition of different size droplets. Morawska, L., & Cao, J. (2020).

Comfort

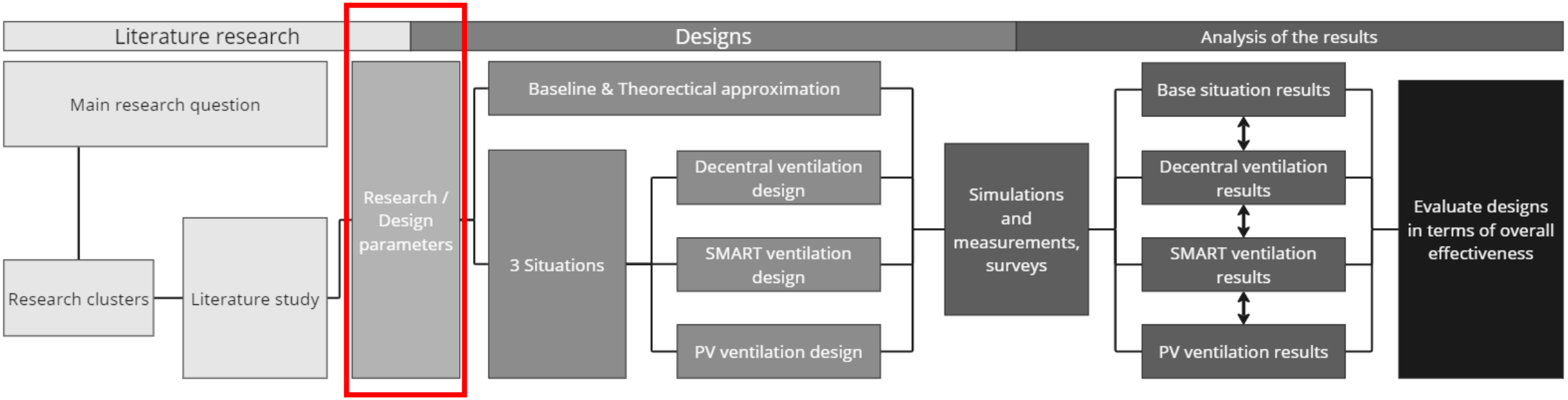
- *Predicted Mean Vote (PMV)*
- *Predicted percentage of dissatisfaction (PPD)*



Costs & Practicality

- *Price indication*
- *How does it impact the room?*

The research process



The case

What defines a standard classroom?

- *~ 50m2*
- *~ 30 students*
- *~ at least 2,6m height*

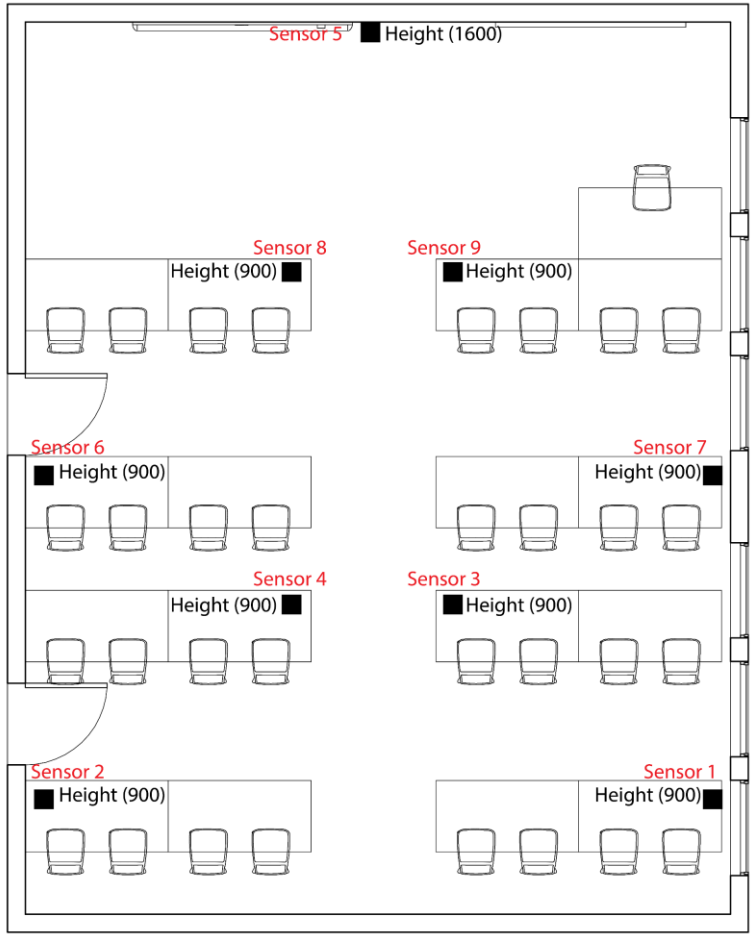
Hall P:

- *80m2*
- *32 students*
- *5,8 m*

Baseline

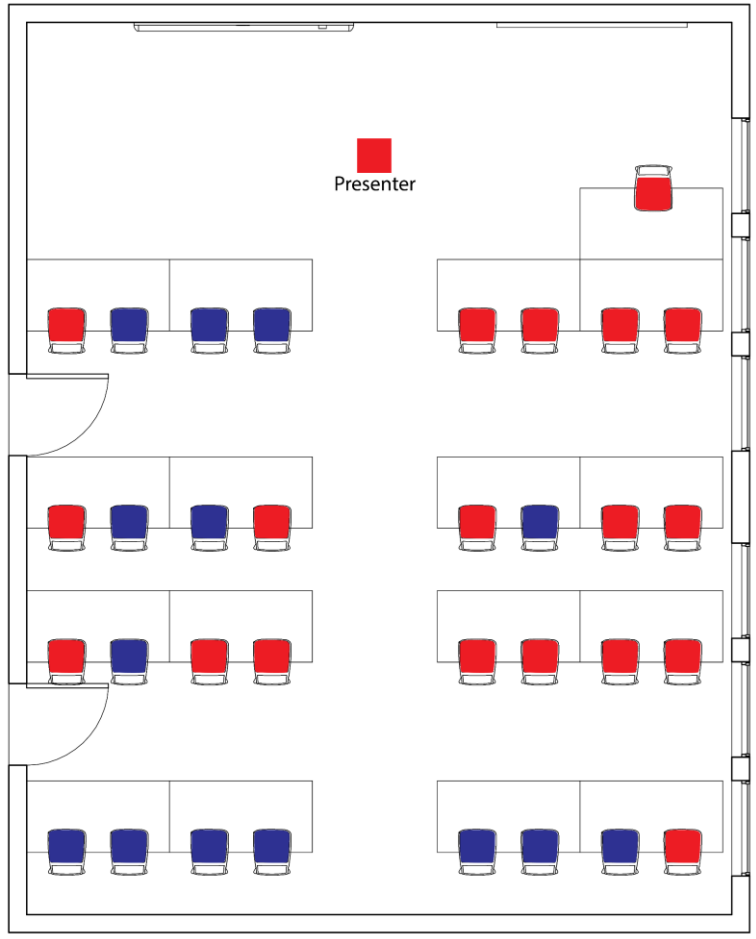
- *Benchmark*
- *Parametric research:*
  - *Volume*
  - *Ventilation rate*
- *Measurements, survey and simulations*

Measurement setup



Empty seat

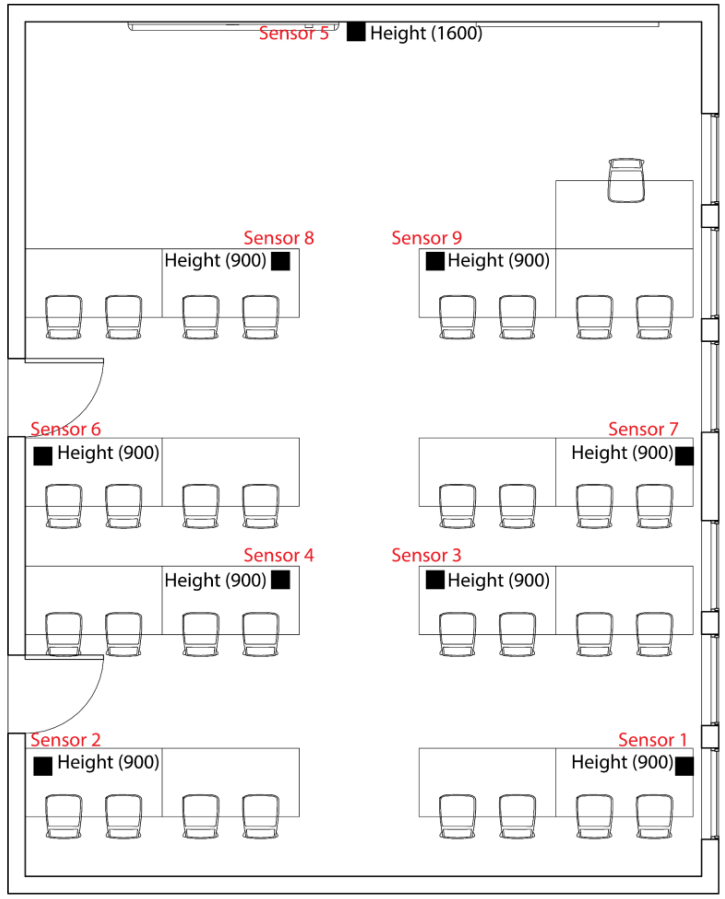
Occupied seat

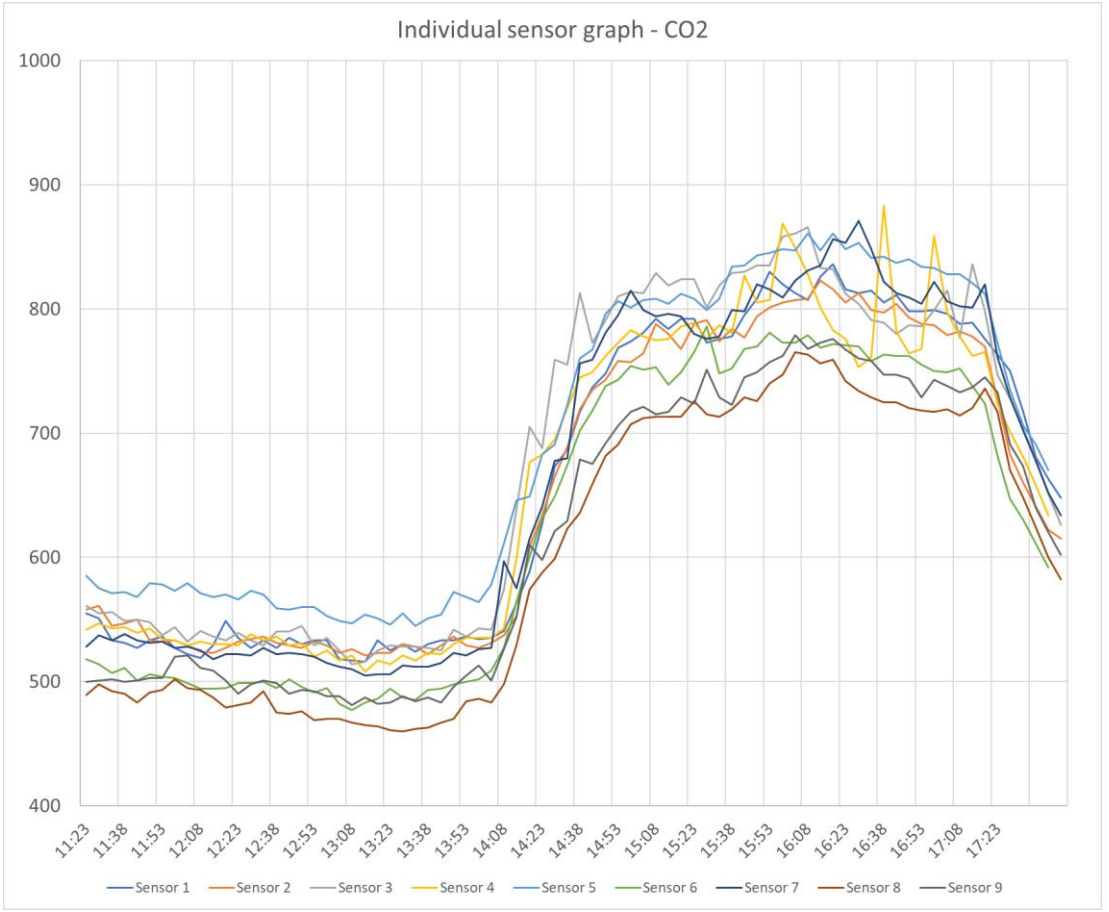


The initial results

CO2 concentration:

- *On average right side is higher*
- *Large discrepancy between sensors*

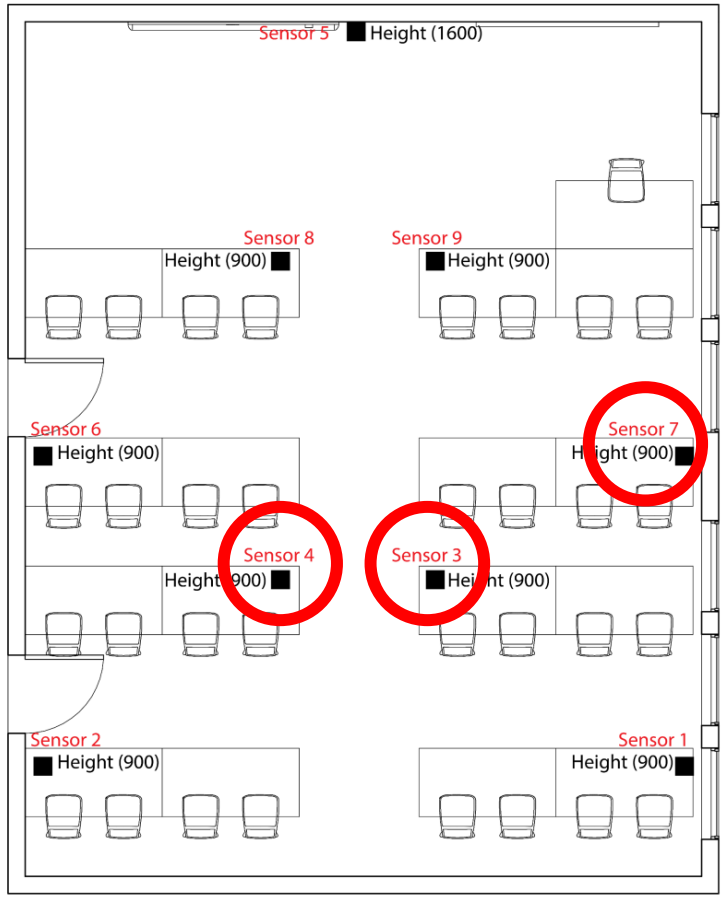


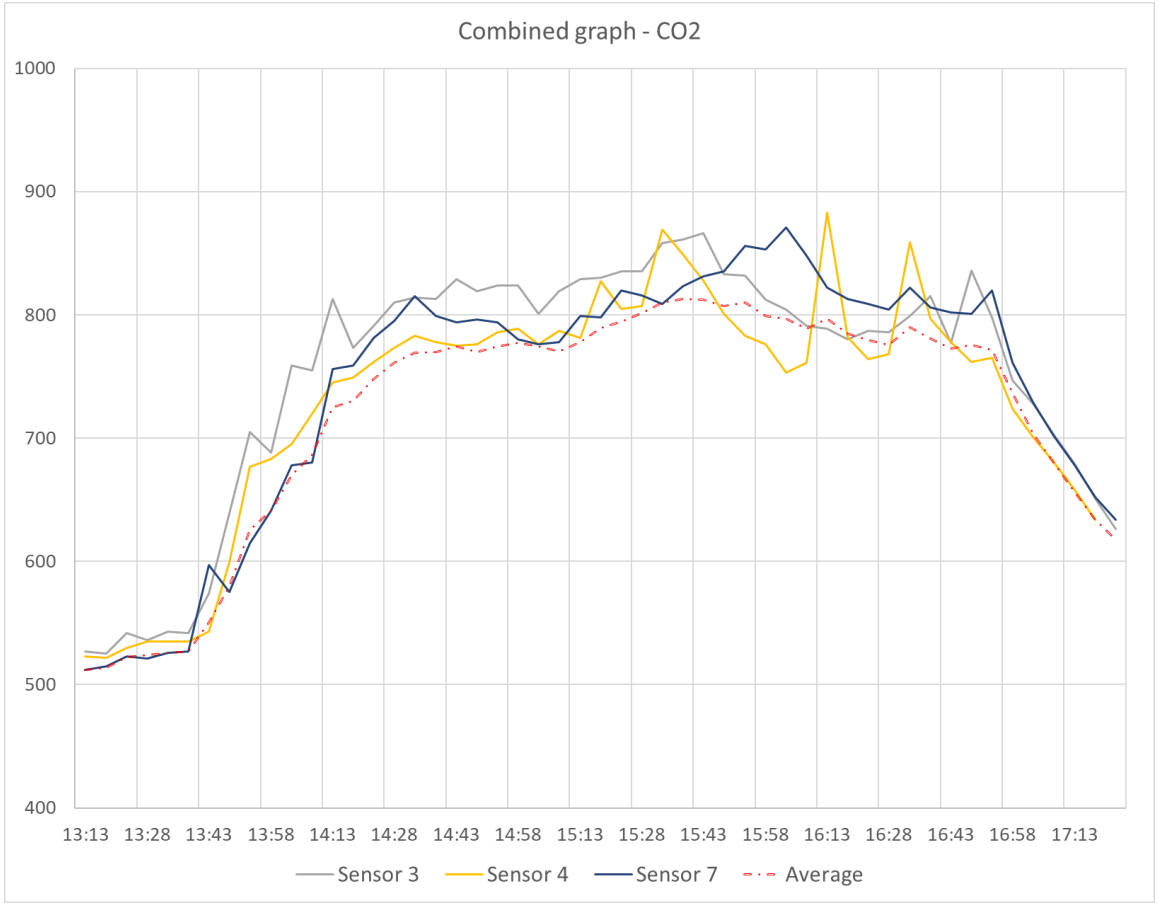


Results – CO2 highest

CO2 concentration:

- *Highest 3, 4 and 7*
- *(3): 866 PPM*
- *(4): 883 PPM*
- *(7): 871 PPM*

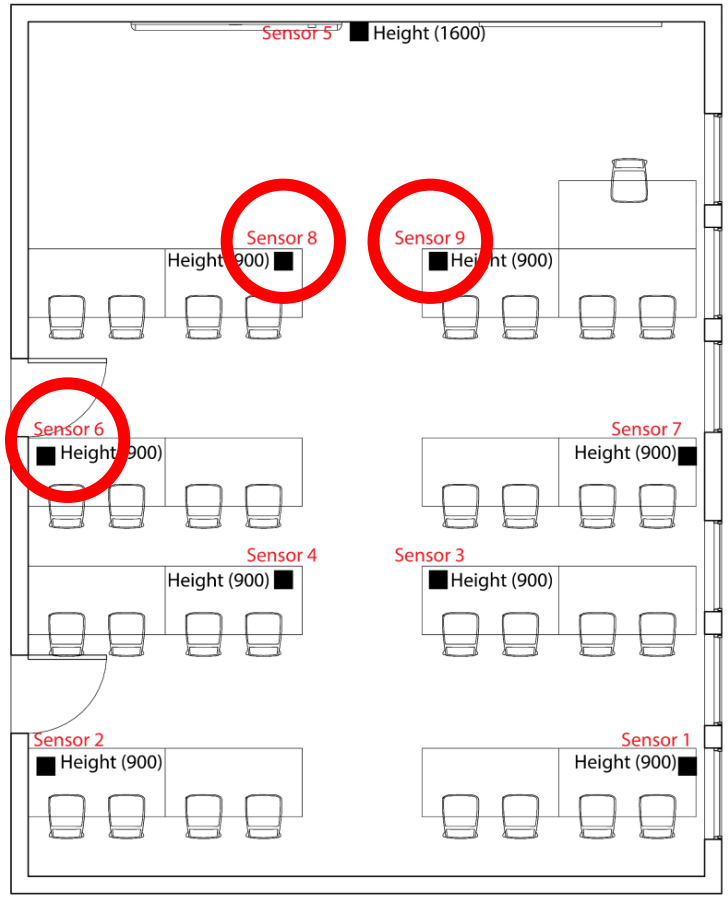


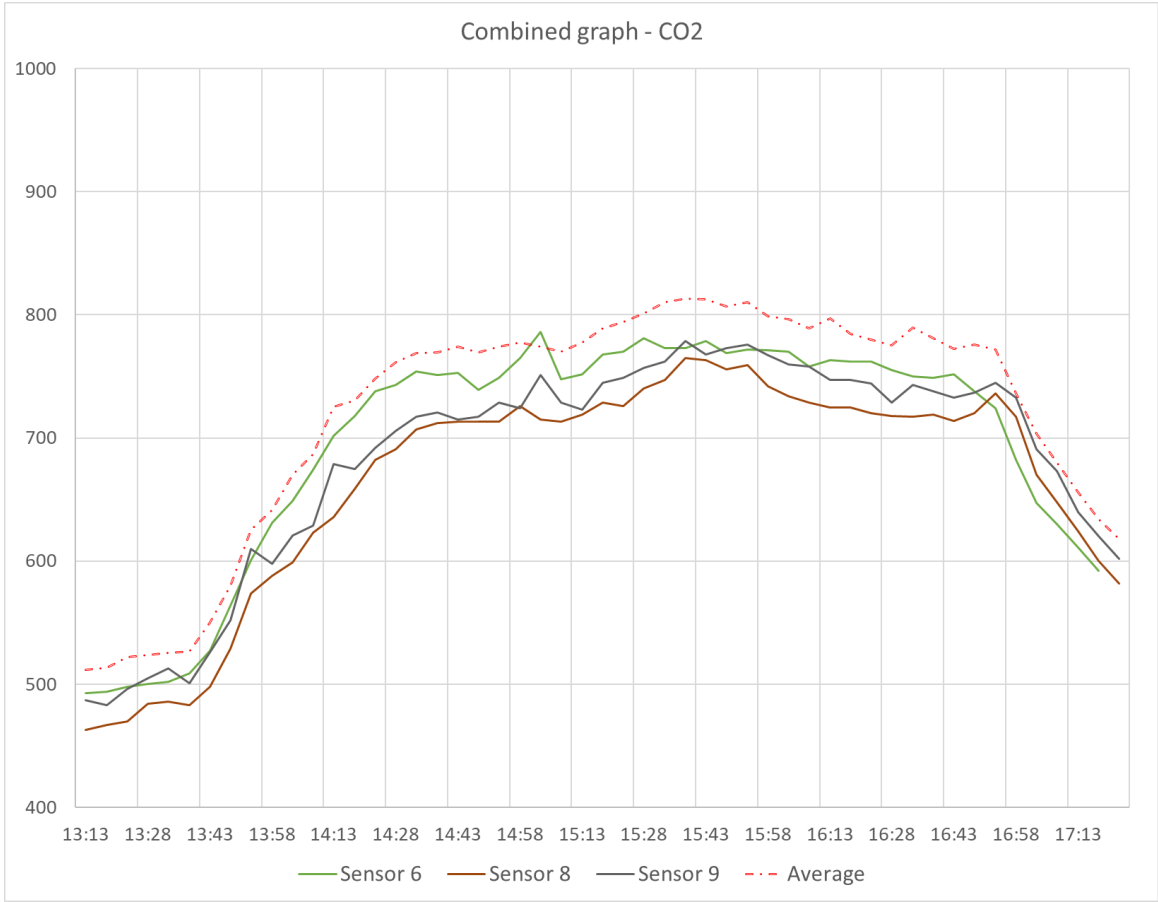


Results – CO2 lowest

CO2 concentration:

- *Highest 6, 8 and 9*
- *(6): 786 PPM*
- *(8): 765 PPM*
- *(9): 779 PPM*



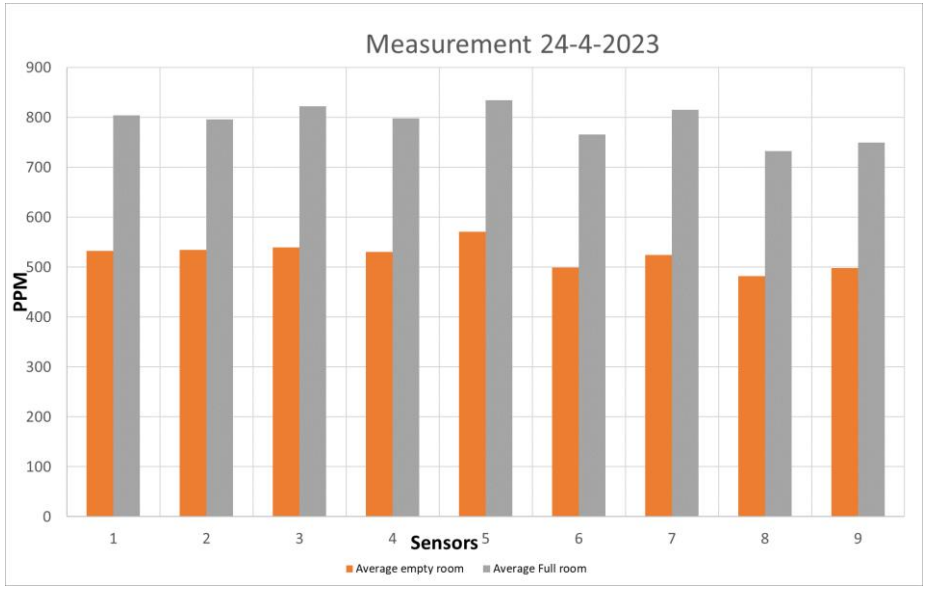


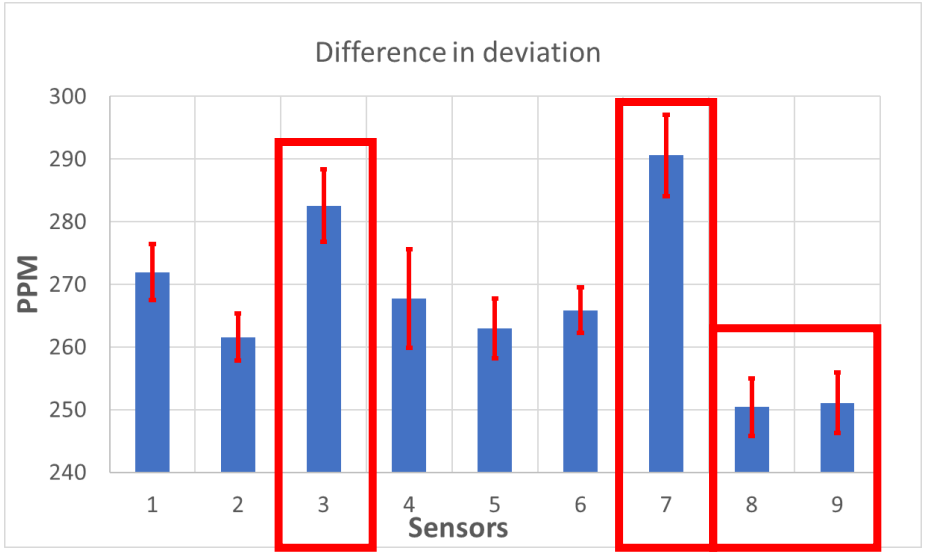
Deviation

Sensor	Average empty room	Standard deviation	Standard error
1	532	12	2
2	534	11	2
3	539	14	2
4	530	11	2
5	571	11	2
6	499	14	3
7	524	16	3
8	482	14	3
9	498	12	2

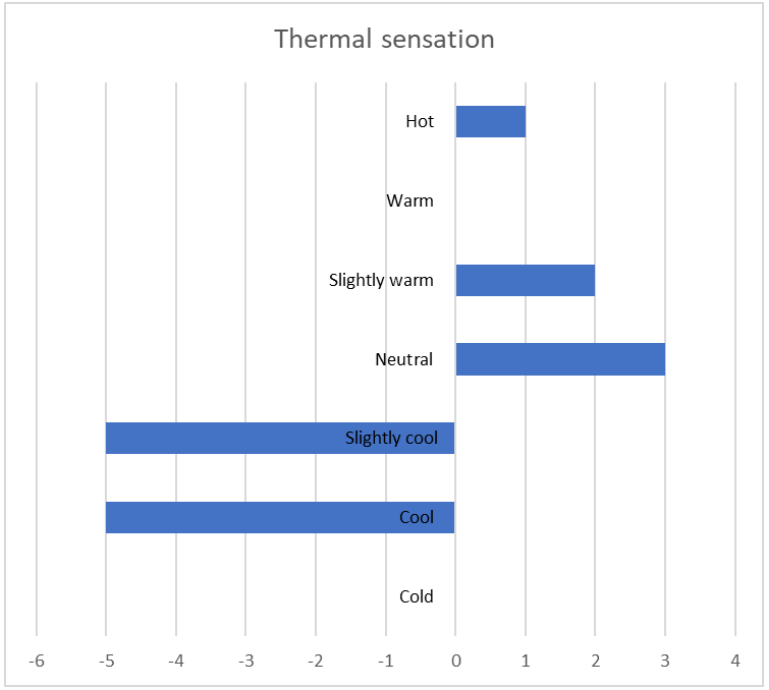
Sensor	Average Full room	Standard deviation	Standard error
1	804	17	4
2	796	14	3
3	822	23	5
4	798	34	8
5	834	19	4
6	765	12	3
7	815	26	6
8	732	17	4
9	749	19	4

Sensor	Difference	Standard error
1	272	4
2	262	4
3	283	6
4	268	8
5	263	5
6	266	4
7	291	7
8	250	5
9	251	5
average	267	

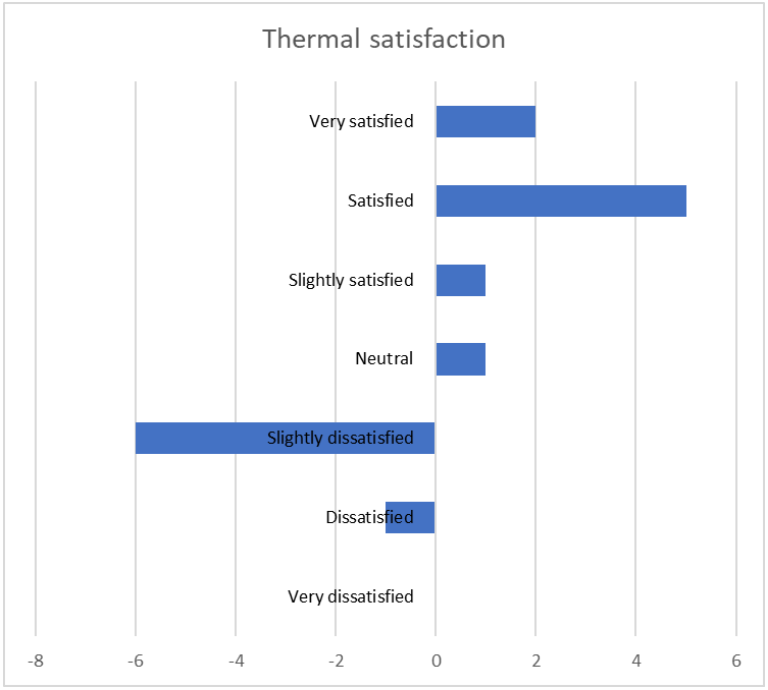




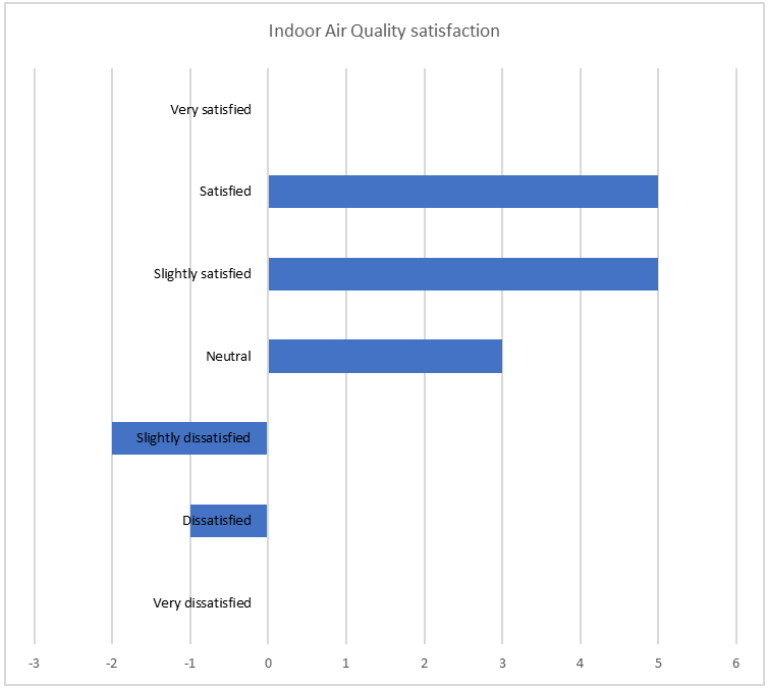
Comfort



Slightly cooler sensation



Equal parts dissatisfaction and satisfaction of thermal sensation



More satisfied with IAQ

Simulation set up

Accuracy:

- *Fine grid size*
- *Low relaxation*
- *Long run time*

Conversion:

Result x 1,2/1,8 + 460 PPM

Grid Mesh Settings

Co-ordinate system: Cartesian

Time dependence: Steady

Cut-cell method: SPARSOL | Settings

	X-Auto	Y-Auto	Z-Auto	
Domain size	10.00000	7.900000	5.800000	m
Domain origin	0.000000	0.000000	0.000000	m
Number of cells	50	53	42	
Tolerance	1.000E-3	1.000E-3	1.000E-3	m
No of regions	27	40	13	
Modify region	1	1	1	
Size	0.500000	0.300000	0.650000	
Distribution	Geom Prog	Geom Prog	Geom Prog	

Domain Settings

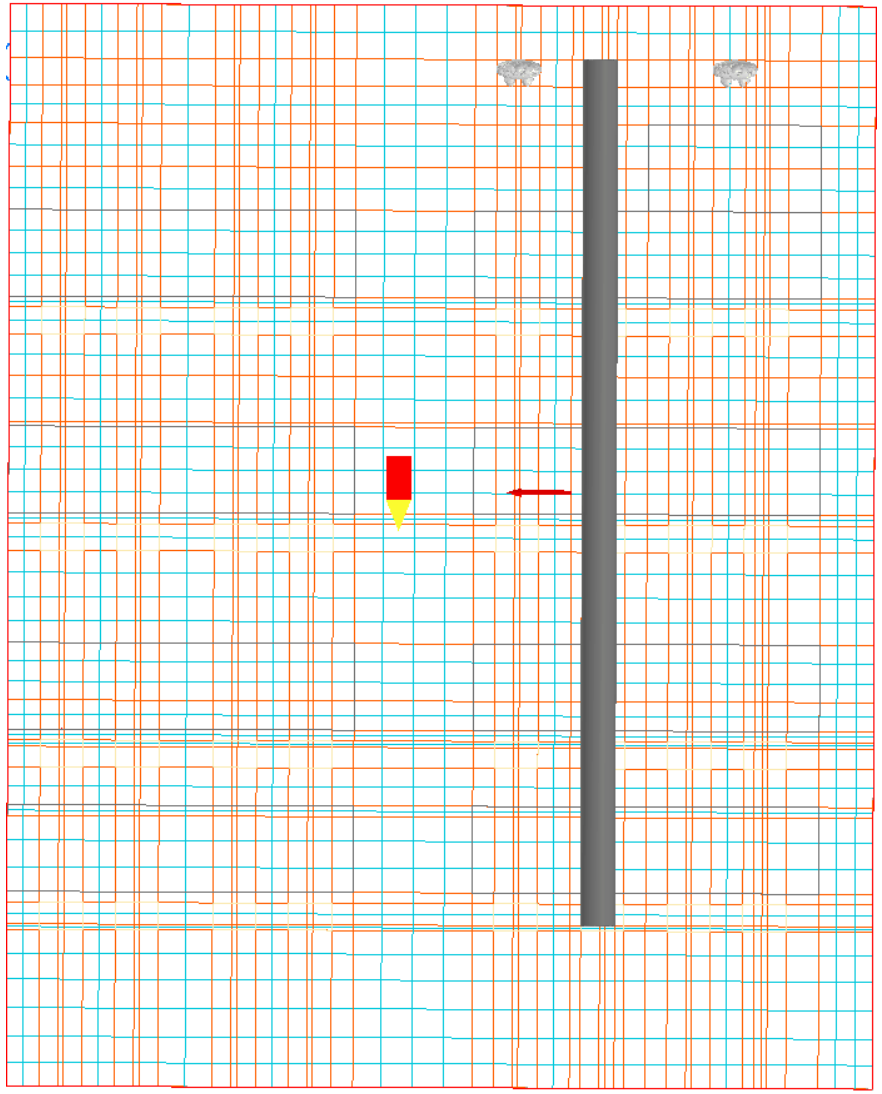
Pollutant settings — Previous panel

Pollutants are solved as the mass fraction of each species, with units kg/kg_mixture. Up to 5 species can be defined here.

ID	Status	Name	Molecular weight
0	ON	Carrier	28.97007
1	ON	CO2	44.00950
2	OFF	C2	28.97007
3	OFF	C3	28.97007
4	OFF	C4	28.97007
5	OFF	C5	28.97007

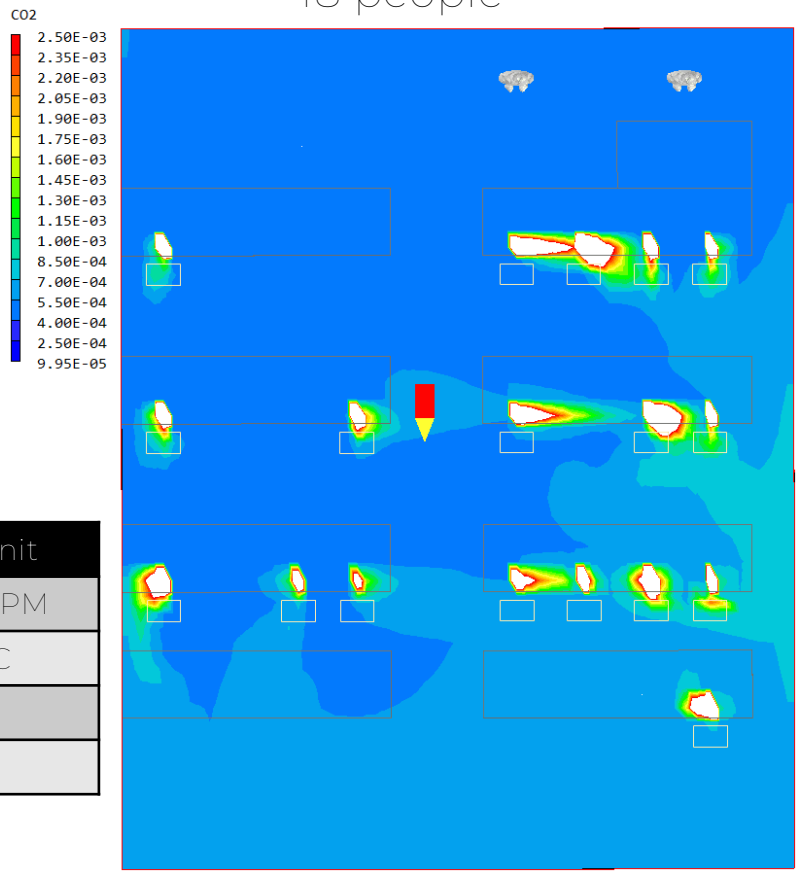
Include in gas density calculation: ON

Detailed solution control settings for these variables can be made from 'Models - Solution control / Extra variables'. More pollutant species can be added there.



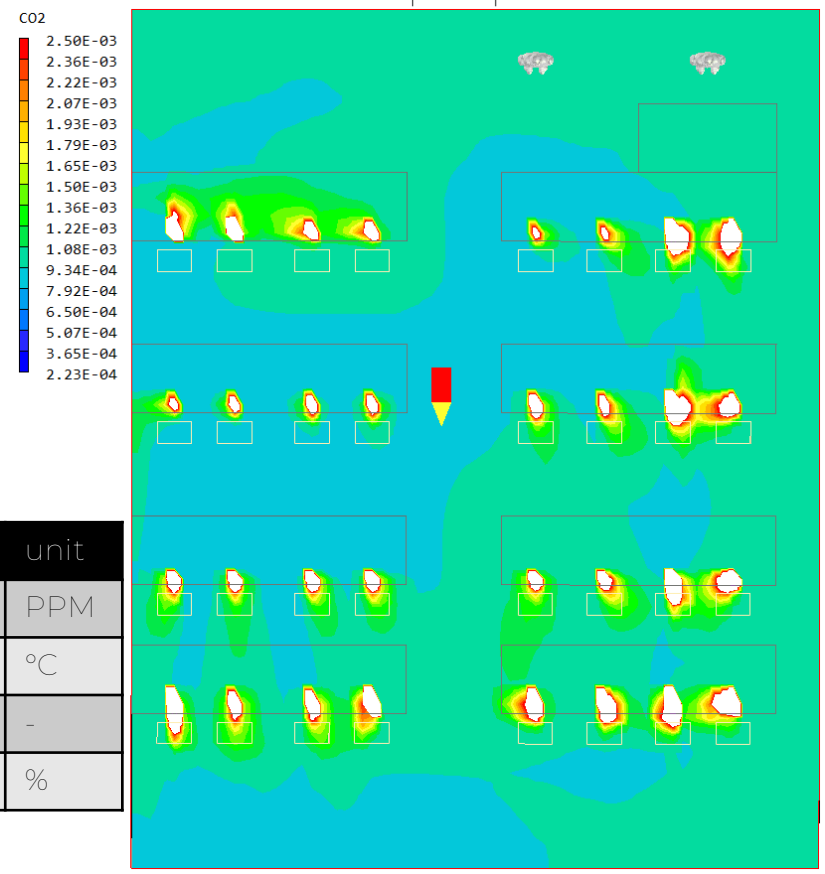
Simulation results

18 people



Parameters	Value	unit
CO2 (18 p)	871	PPM
Temperature	20,2	°C
PMV	-1,40	-
PPD	45	%

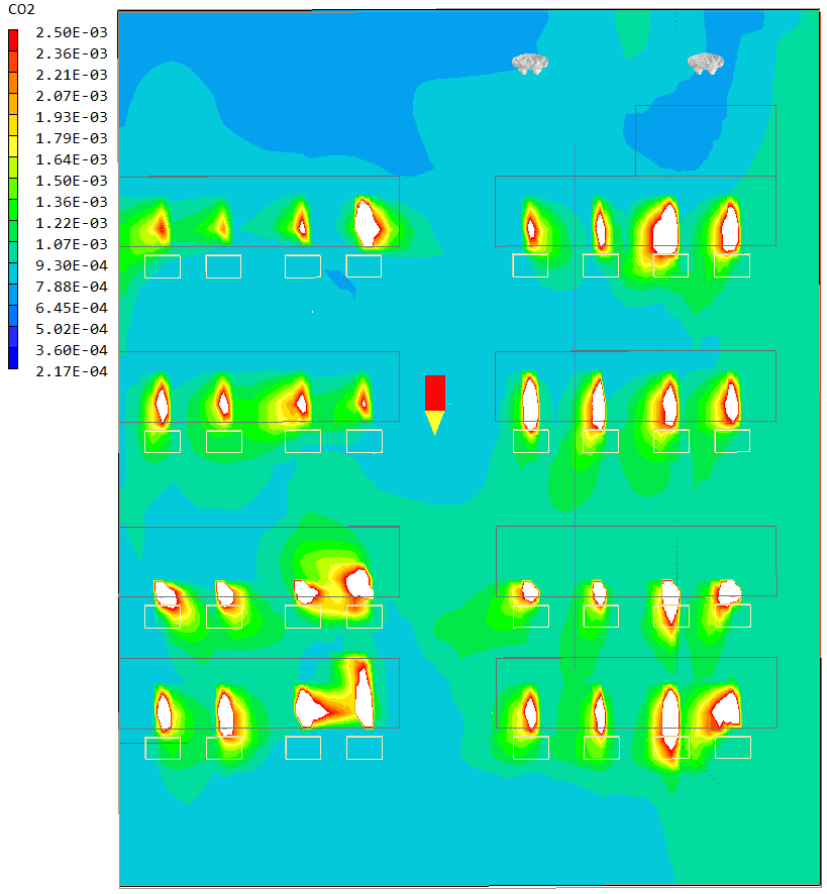
32 people



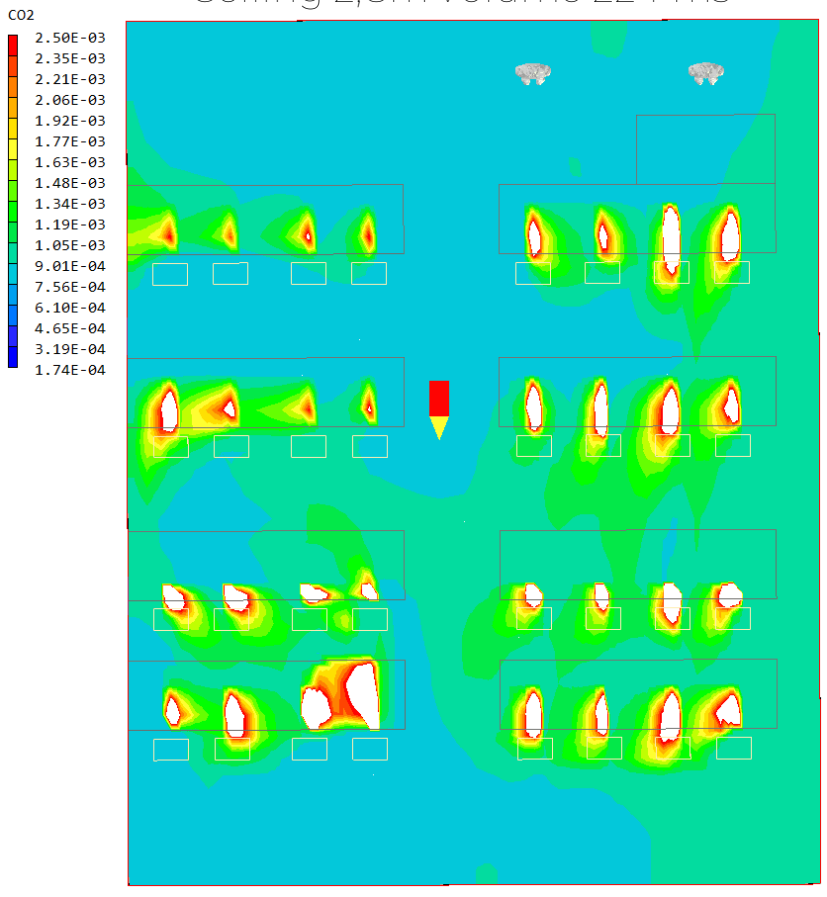
Parameters	Value	unit
CO2 (32 p)	1156	PPM
Temperature	21,9	°C
PMV	-1,07	-
PDD	29,8	%

Parametric research - volume

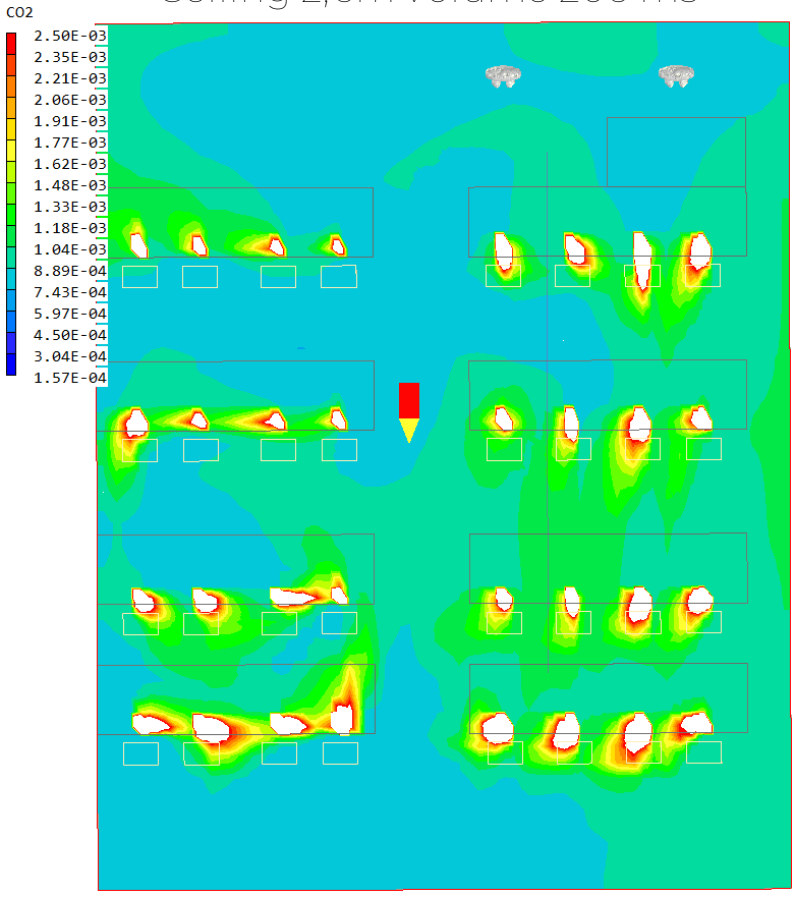
Ceiling 3,2m volume 256 m3



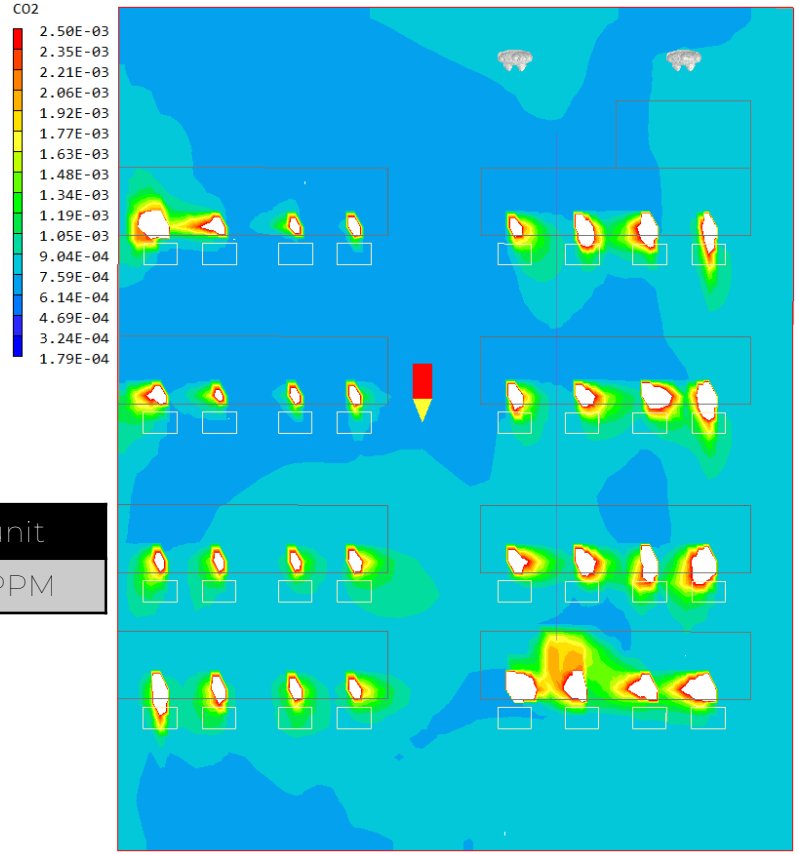
Ceiling 2,8m volume 224 m3



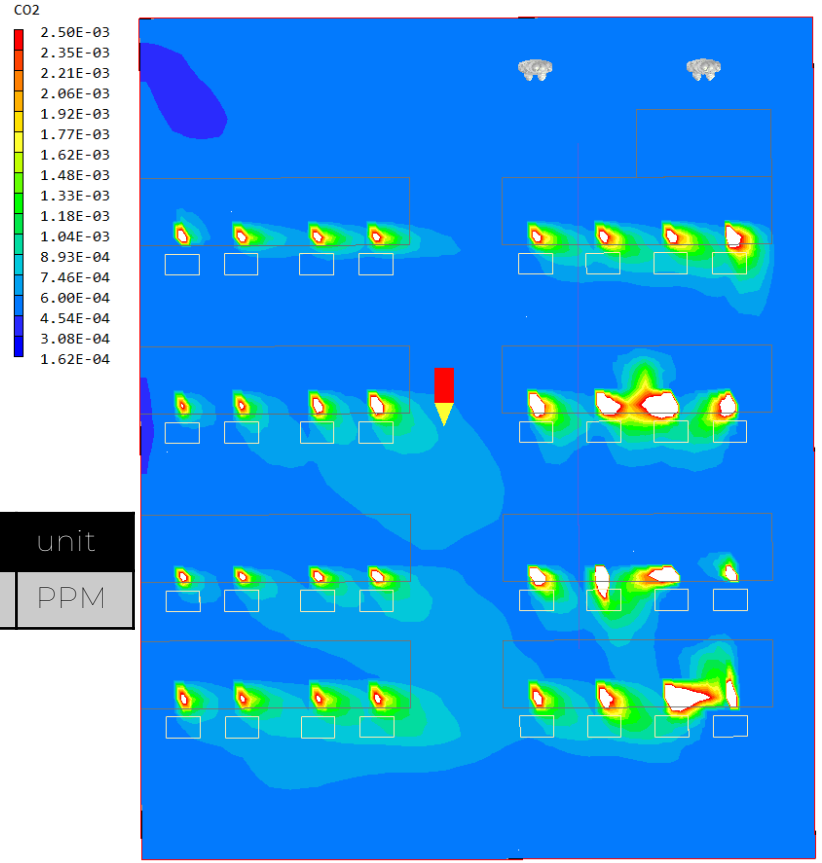
Ceiling 2,6m volume 206 m3



Parametric research - ventilation rate



Parameters	Value	unit
CO2 (10 l/s)	1057	PPM



Parameters	Value	unit
CO2 (15 l/s)	881	PPM

Infection risk

Rudnick en Milton - Infection risk - Baseline measurement			
	Sensor 4 (highest values at peak)	Sensor 8 (Lowest values at peak)	Average CO2 concentration
	883 PPM	765 PPM	813 PPM
	Quanta	Quanta range	
	Alfa	89 - 165	
	Delta	312 - 935	
	Omicron	725 - 2345	
	Fraction of inhaled breath	Fraction of inhaled breath	Fraction of inhaled breath
C	0,000883	0,000765	0,000813
C0	0,00046	0,00046	0,00046
Ca	0,05	0,05	0,05
f	0,0085	0,0061	0,0071
	ALFA VARIANT		
	Sensor 4 (highest values at peak)	Sensor 8 (Lowest values at peak)	Average CO2 concentration
I	1	1	1
f	0,0085	0,0061	0,0071
q	89 and 165	89 and 165	89 and 165
t	4	4	4
n	18	18	18
P	15% 27%	11% 20%	13% 23%
	DELTA VARIANT		
q	312 and 935	312 and 935	312 and 935
P	45% 83%	34% 72%	39% 77%
	OMICRON VARIANT		
q	725 and 2345	725 and 2345	725 and 2345
P	75% 99%	63% 96%	68% 98%

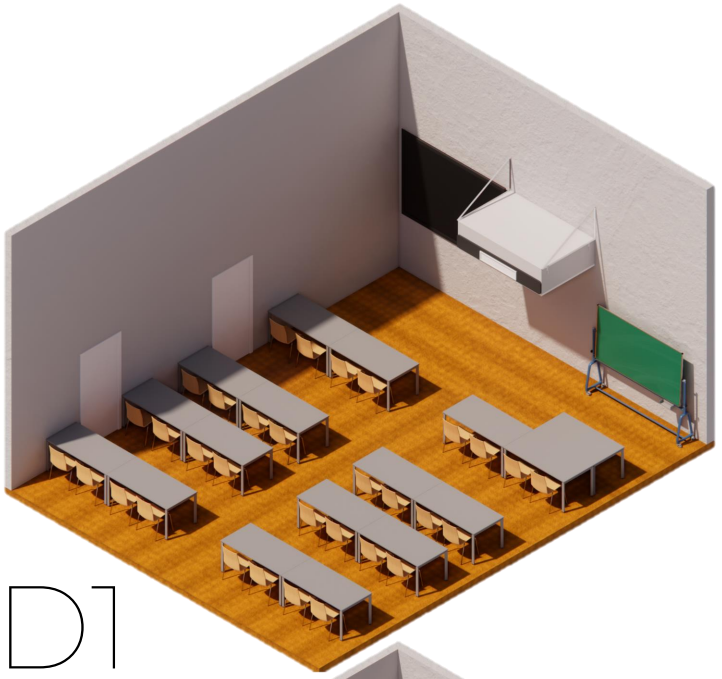
Rudnick en Milton - Infection risk - Simulation						
	Simulation 18 people - average	Simulation 18 people - peak	Simulation 32 people - average	Simulation 32 people - peak	10 l/s	15 l/s
	871 PPM	936 PPM	1156 PPM	1292 PPM	1057 PPM	881 PPM
	Quanta	Quanta range				
	Alfa	89 - 165				
	Delta	312 - 935				
	Omicron	725 - 2345				
	Fraction of inhaled breath	Fraction of inhaled breath	Fraction of inhaled breath	Fraction of inhaled breath	Fraction of inhaled breath	Fraction of inhaled breath
C	0,000871	0,000936	0,001156	0,001292	0,001057	0,000881
C0	0,00046	0,00046	0,00046	0,00046	0,00046	0,00046
Ca	0,05	0,05	0,05	0,05	0,05	0,05
f	0,0082	0,0095	0,0139	0,0166	0,0119	0,0084
	ALFA VARIANT		ALFA VARIANT		ALFA VARIANT	
I	1	1	1	1	1	1
f	0,0082	0,0095	0,0139	0,0166	0,0119	0,0084
q	89 and 165	89 and 165	89 and 165	89 and 165	89 and 165	89 and 165
t	4	4	4	4	4	4
n	18	18	32	32	32	32
P	15% 26%	17% 29%	14% 25%	17% 29%	12% 22%	9% 16%
	DELTA VARIANT		DELTA VARIANT		DELTA VARIANT	
q	312 and 935	312 and 935	312 and 935	312 and 935	312 and 935	312 and 935
P	43% 82%	48% 86%	42% 80%	48% 86%	37% 75%	28% 63%
	OMICRON VARIANT		OMICRON VARIANT		OMICRON VARIANT	
q	725 and 2345	725 and 2345	725 and 2345	725 and 2345	725 and 2345	725 and 2345
P	73% 99%	78% 99%	72% 98%	78% 99%	66% 97%	53% 91%

Results baseline

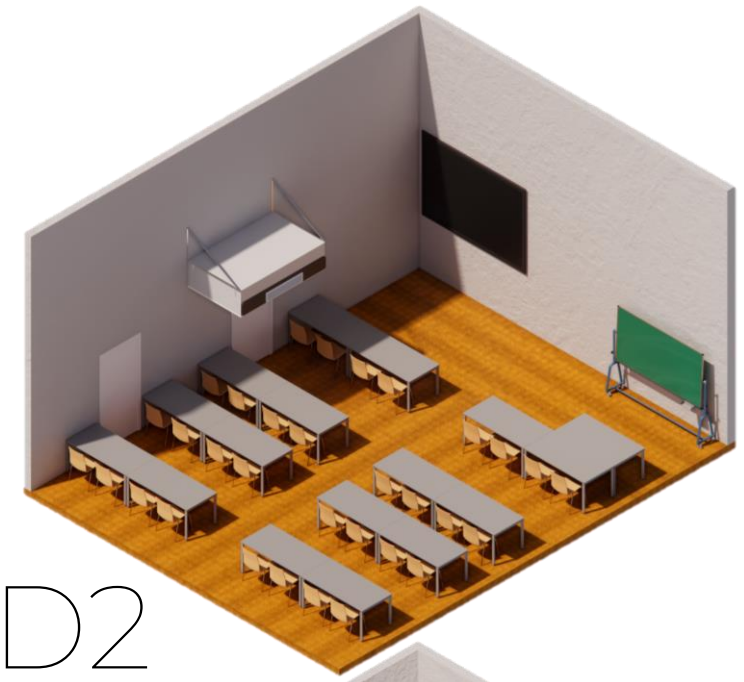
	Covid -19	Comfort	Costs
Baseline	14 – 25 %	PPD; 29,8% PMV; -1,07	No additional costs
Decentral			
SMART			
Personal ventilation			

The designs

D = Decentralised
S = SMART
PV = Personalised



D1



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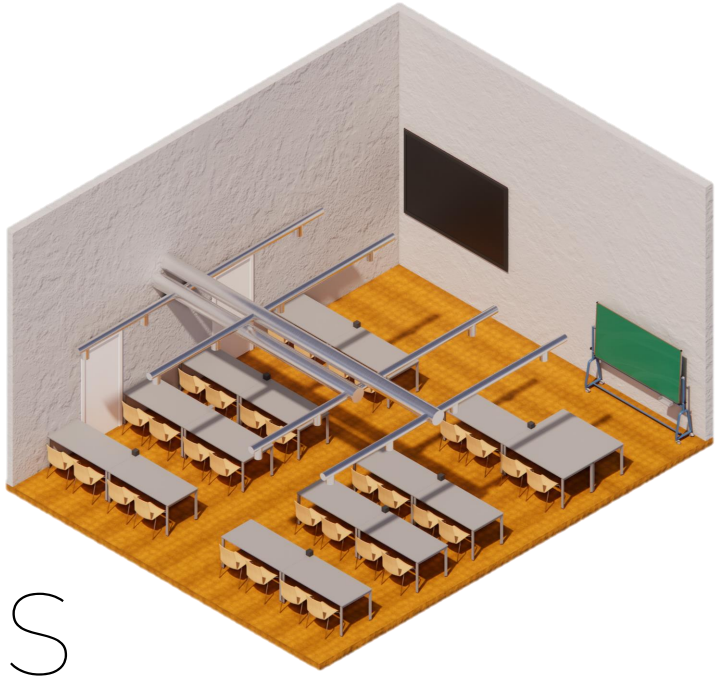

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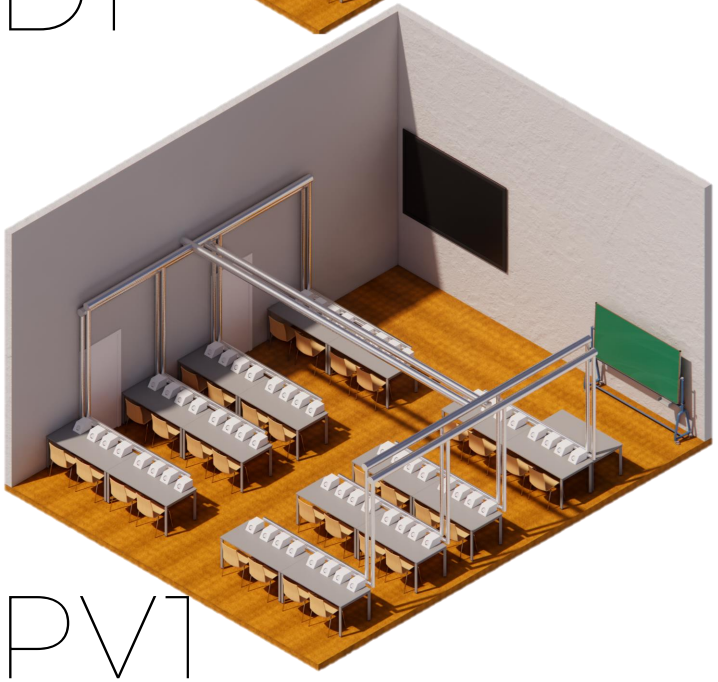
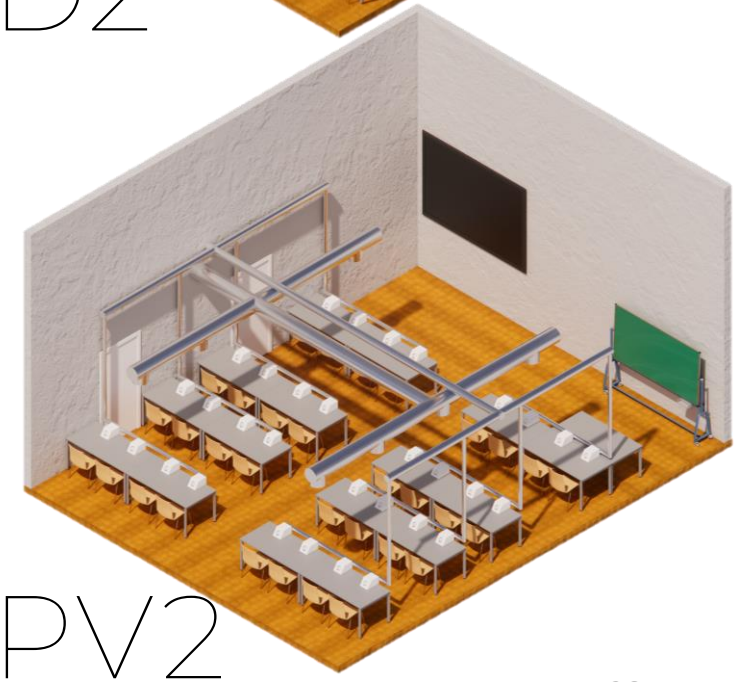
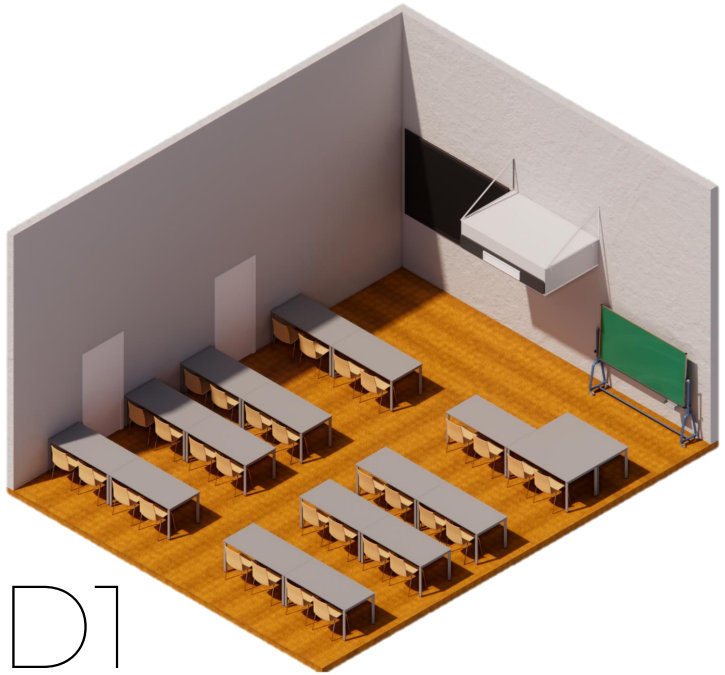


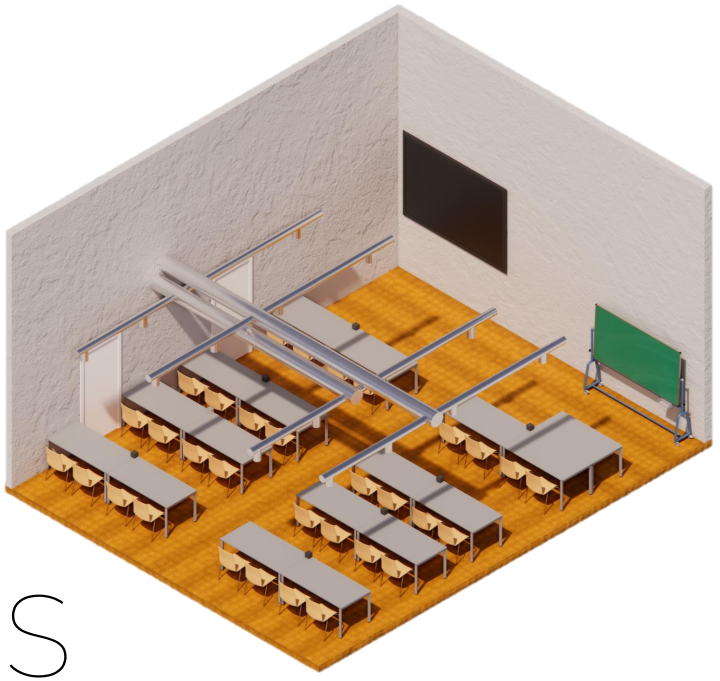
PV1



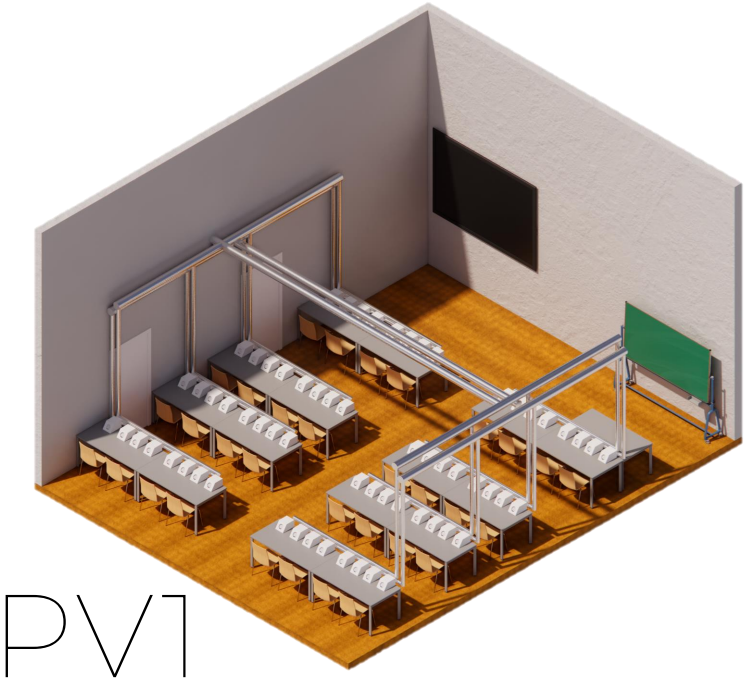
PV2



D1



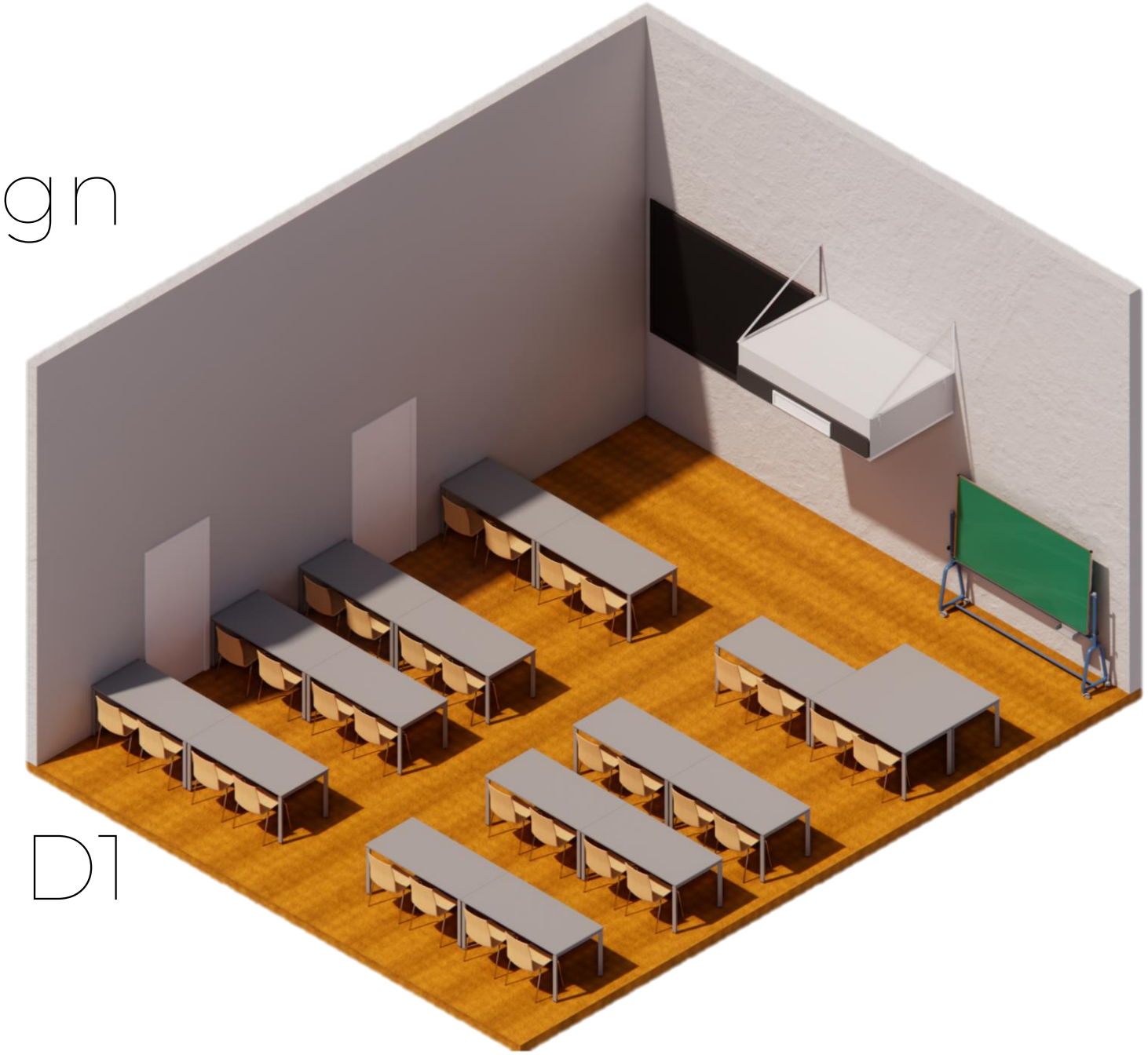
S



PV1

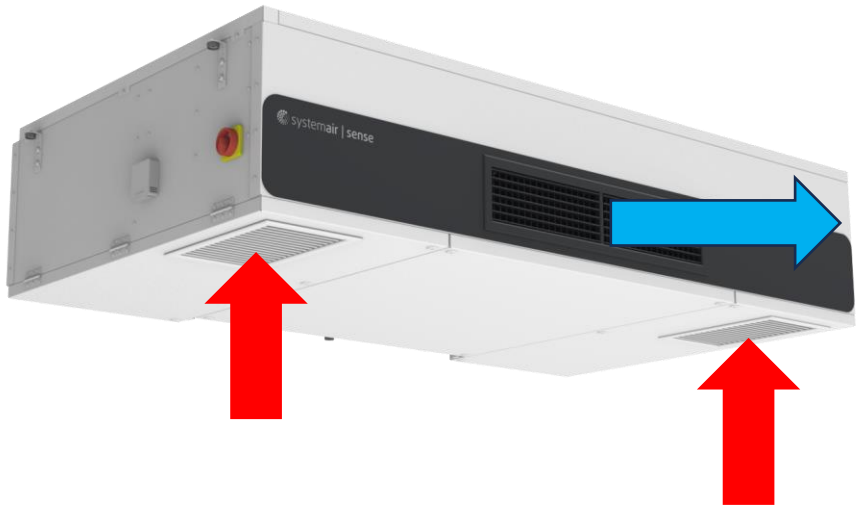
Decentralised ventilation design

- Unit in the front
- Both supply and exhaust located at the front of the room

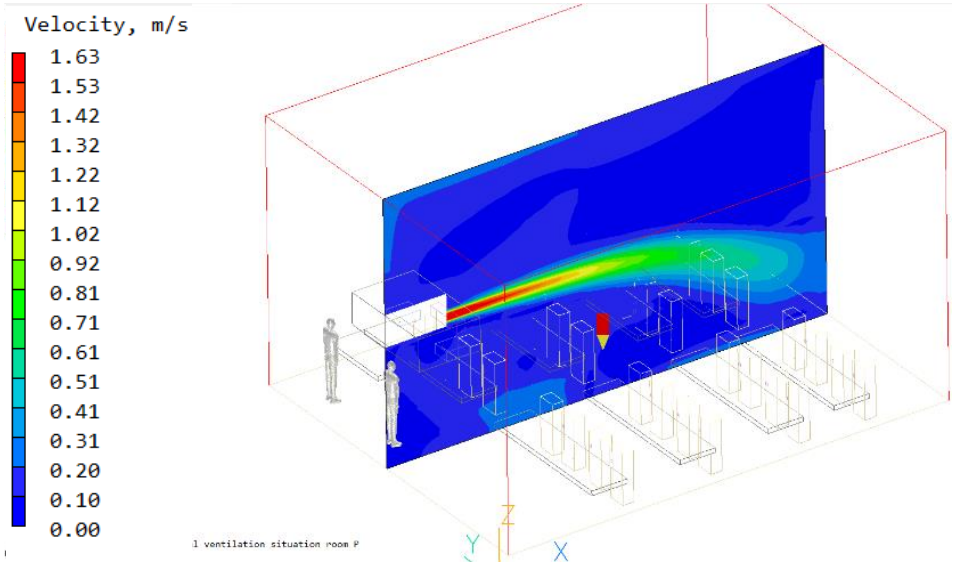


D1

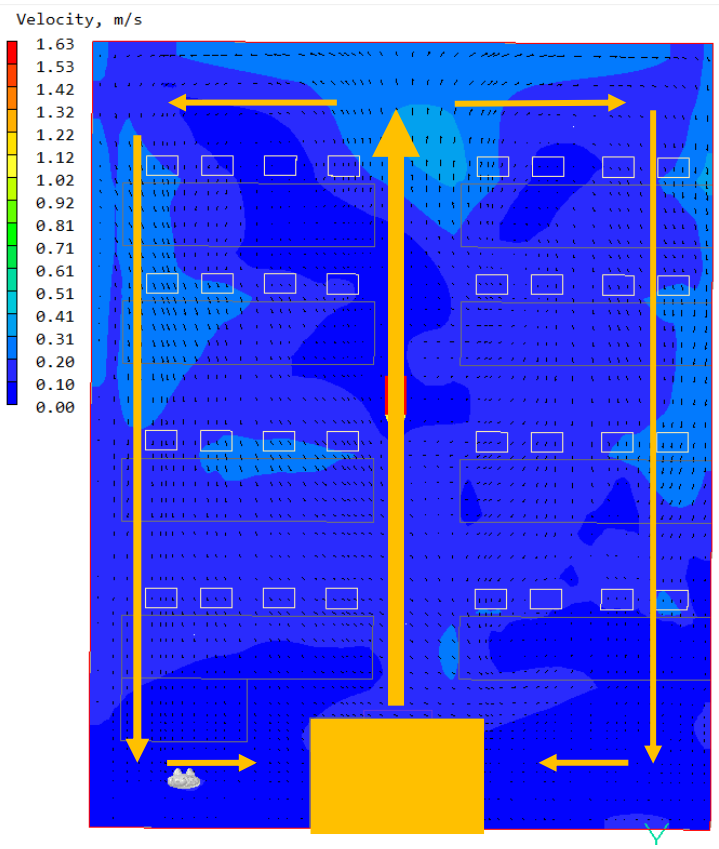
The unit

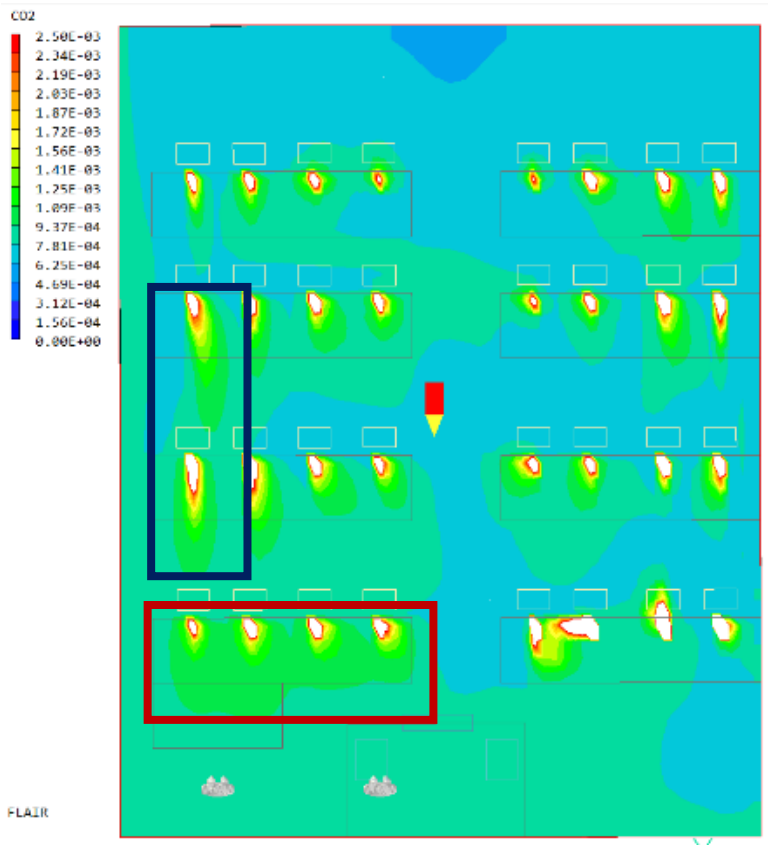


Simulation results



Parameters	Value	Unit
CO2 (32 p)	1033 / 1134 (peak)	PPM
Temperature	21,7	°C
PMV	-1,13	-
PPD	32	%



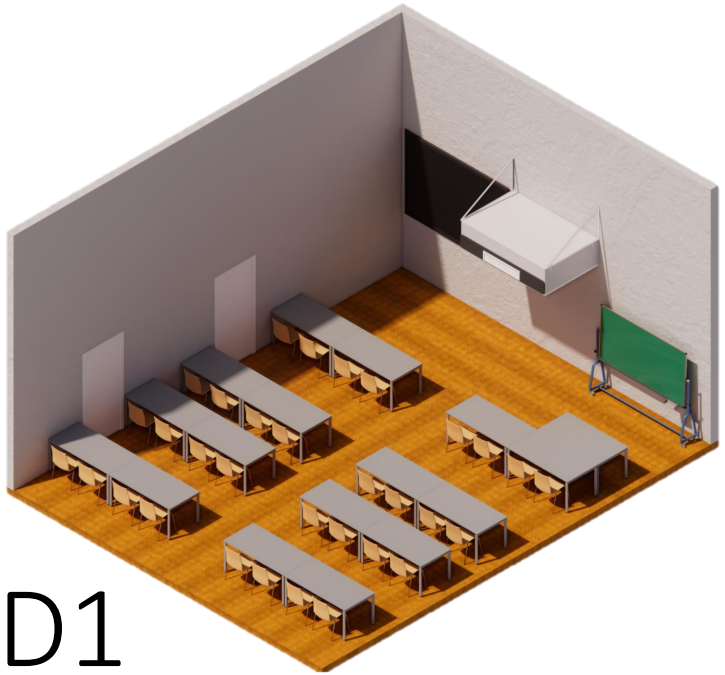


Risk of infection

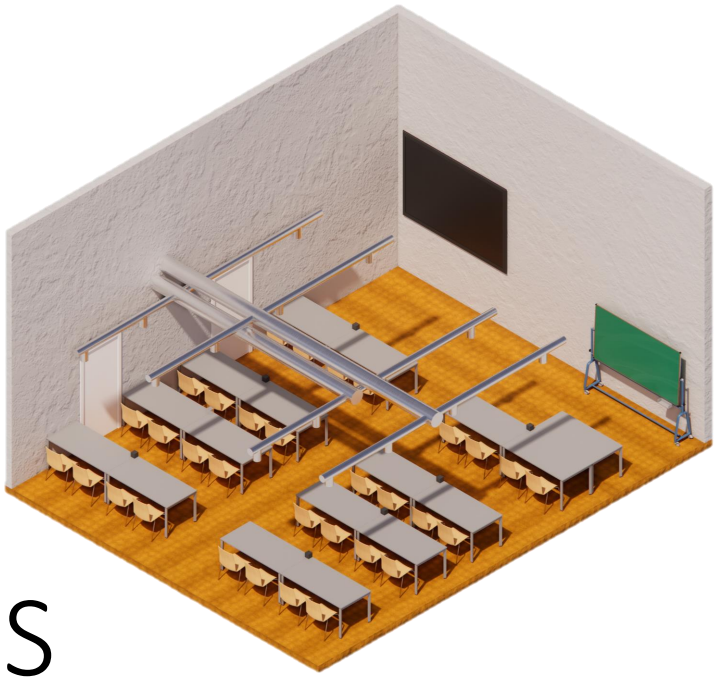
Rudnick en Milton - Infection risk - Decentral simulation		
	Front - Average	Front - Peak
	1033 PPM	1134 PPM
	Quanta	Quanta range
	Alfa	89 - 165
	Delta	312 - 935
	Omicron	725 - 2345
	Fraction of inhaled breath	Fraction of inhaled breath
C	0,001033	0,001134
C0	0,00046	0,00046
Ca	0,05	0,05
f	0,0115	0,0135
	ALFA VARIANT	
I	1	1
f	0,0115	0,0135
q	89 and 165	89 and 165
t	4	4
n	32	32
P	12% 21%	14% 24%
	DELTA VARIANT	
q	312 and 935	312 and 935
P	36% 74%	41% 79%
	OMICRON VARIANT	
q	725 and 2345	725 and 2345
P	65% 97%	71% 98%

Progression of results

	Covid -19	Comfort	Costs
Baseline	14 – 25 %	PPD; 29,8% PMV; -1,07	No additional costs
Decentral	12 – 21 %	PPD; 32% PMV; -1,13	€13000
SMART			
Personal ventilation			



D1



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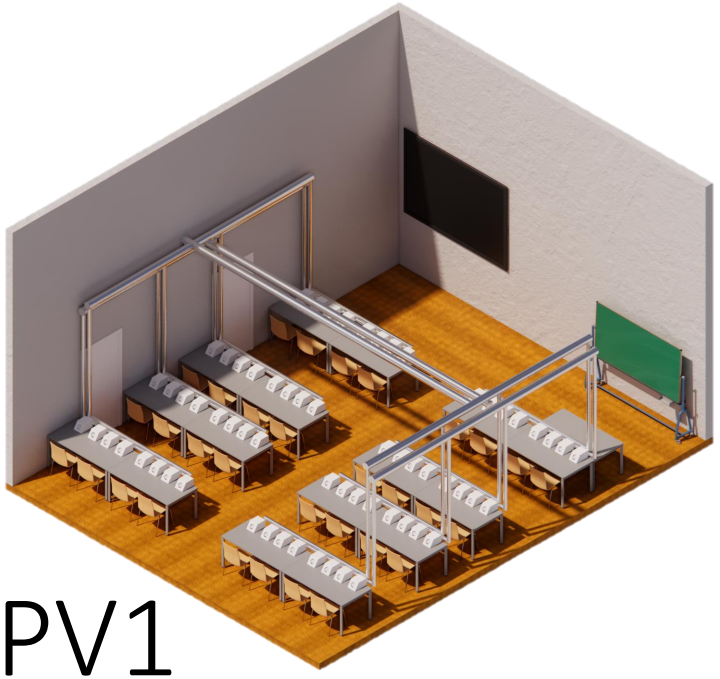
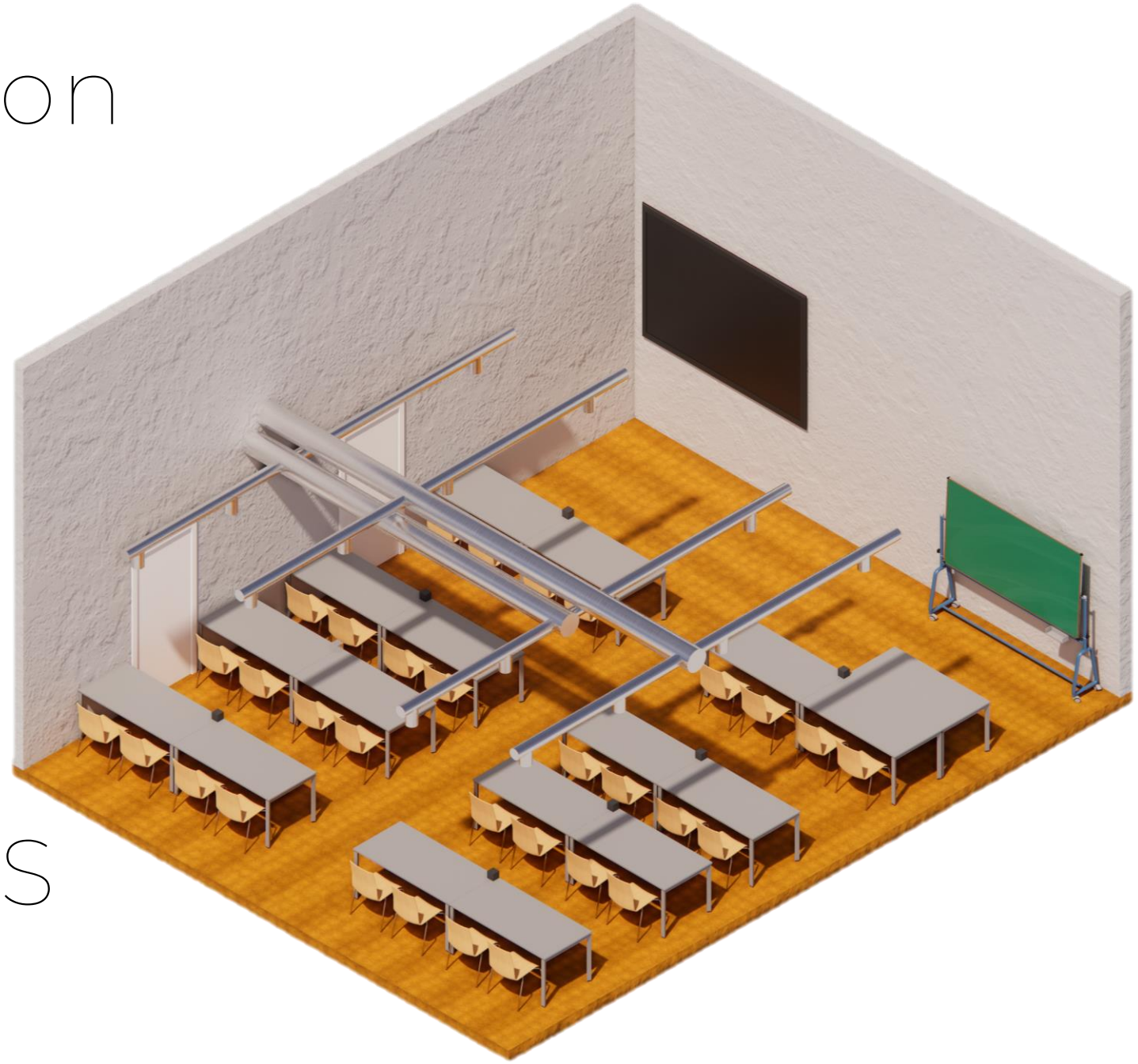


PV1

SMART ventilation design

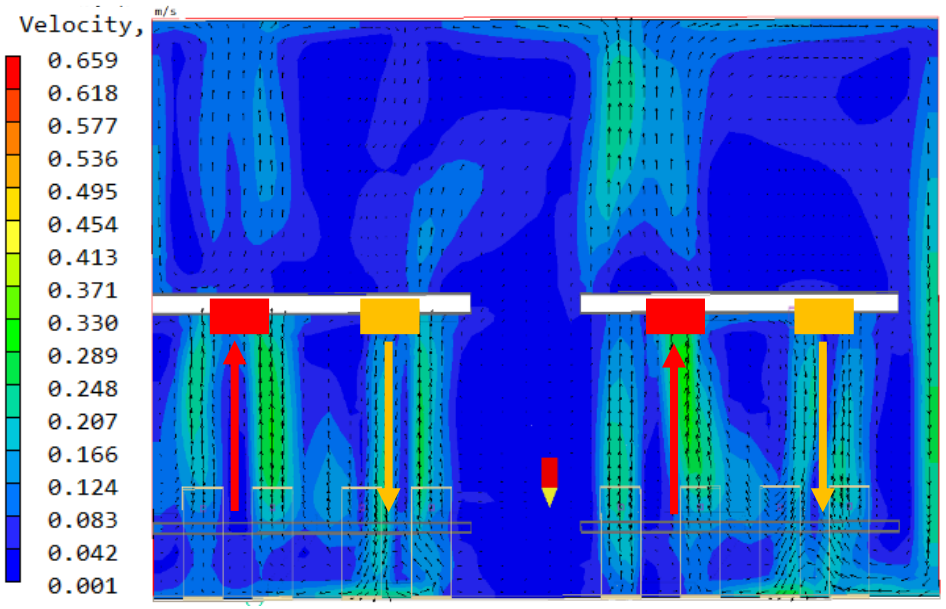
- Sensors for each table

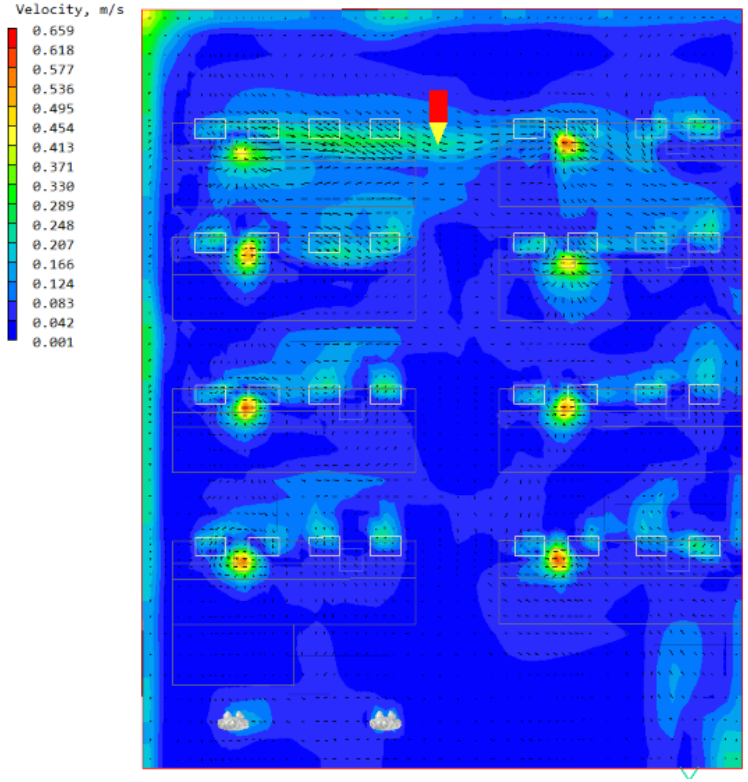
- Supply and exhaust directly above the source of contaminants

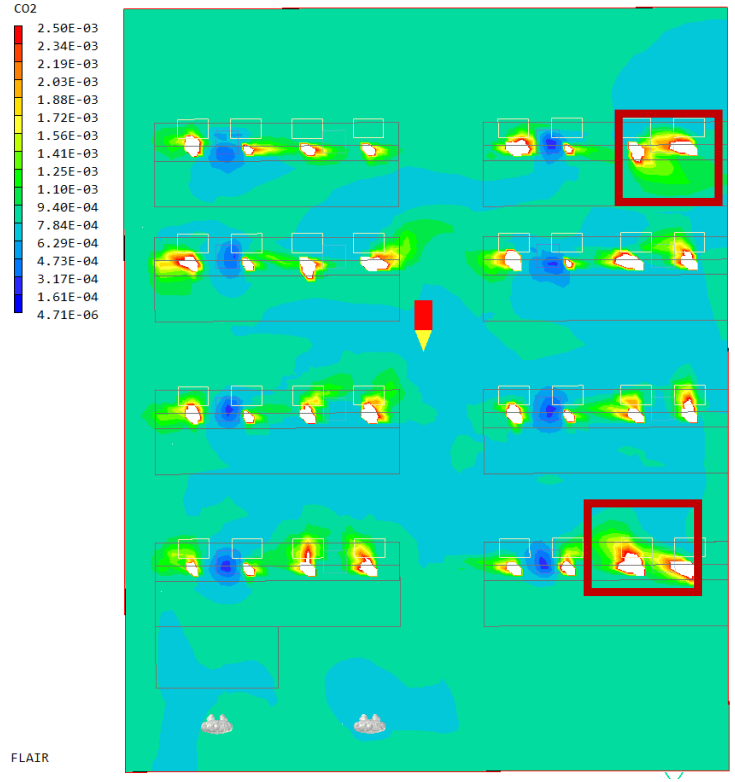


S

Simulation results

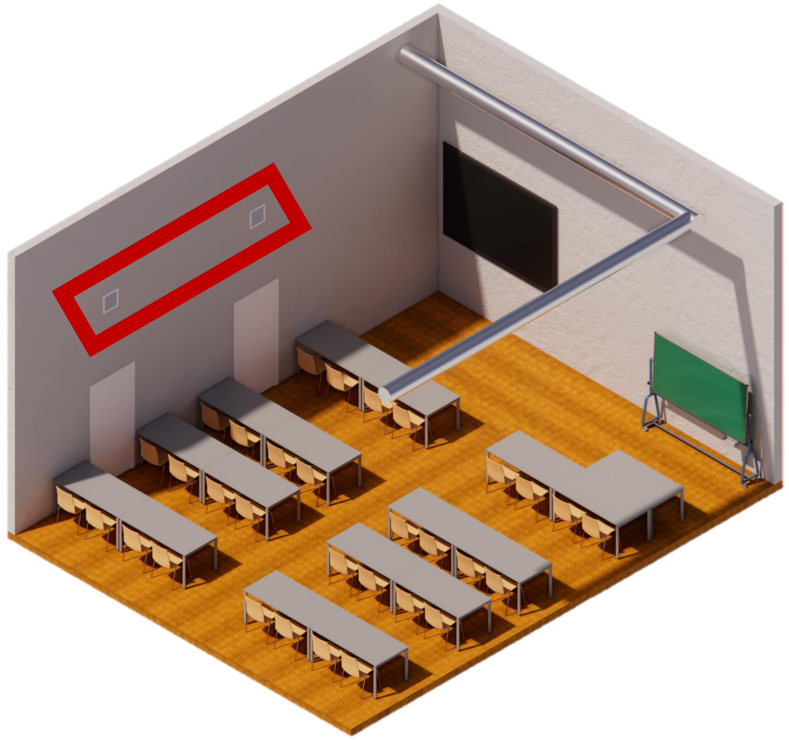


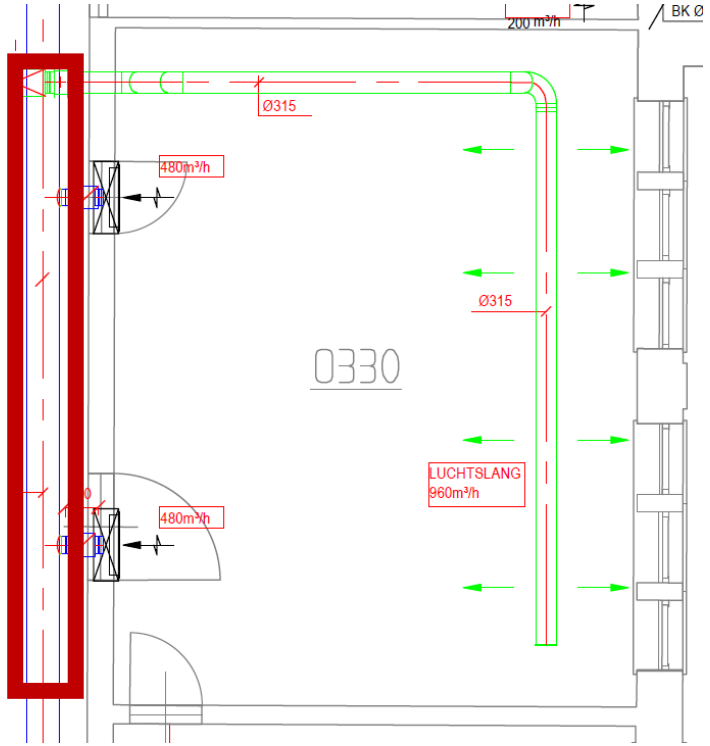


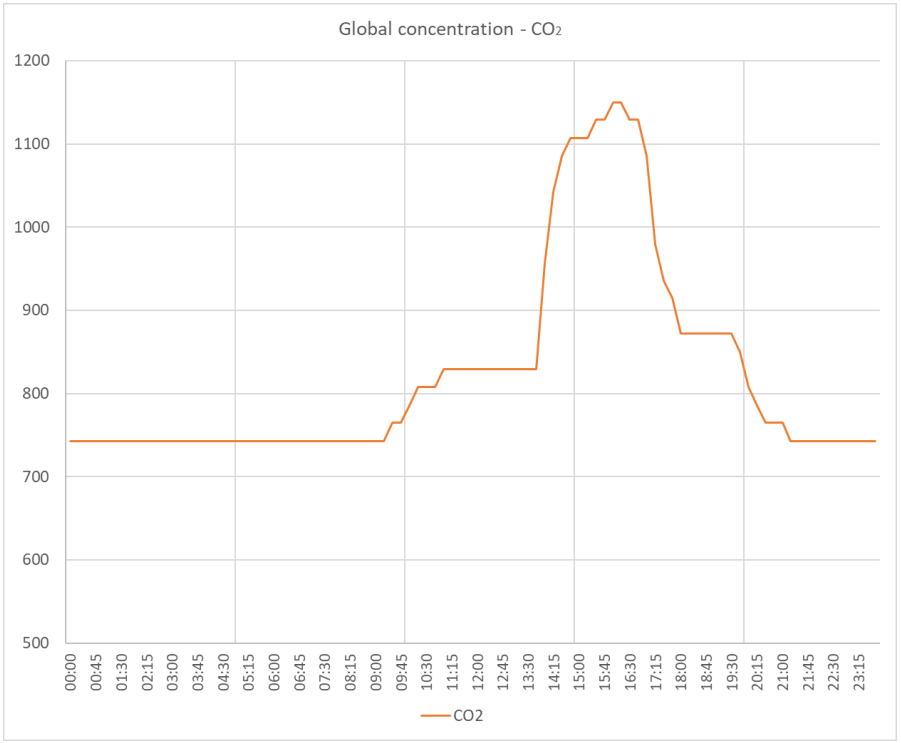


Parameters	Value	unit
CO2 (32 p)	1058 (1121)	PPM
Temperature	21,8	°C
PMV	-1,00	-
PPD	25	%

The current SMART system





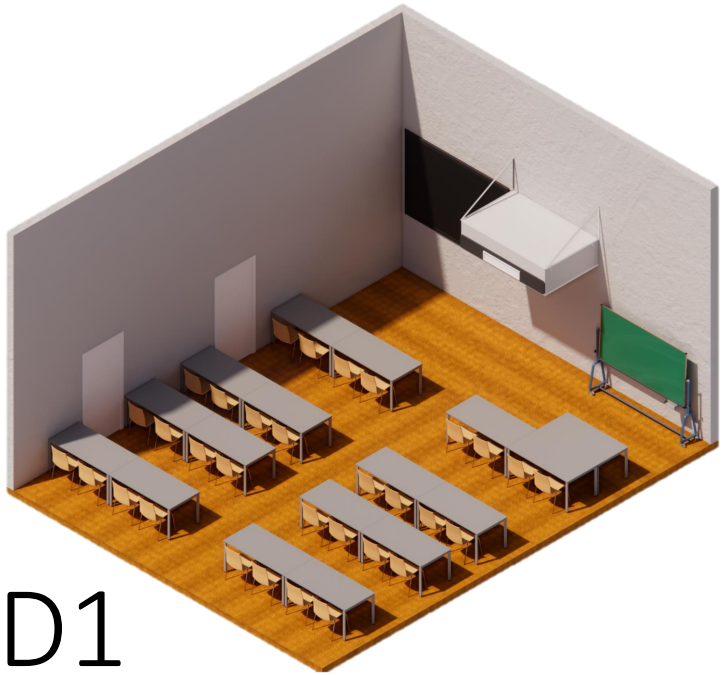


Risk of infection

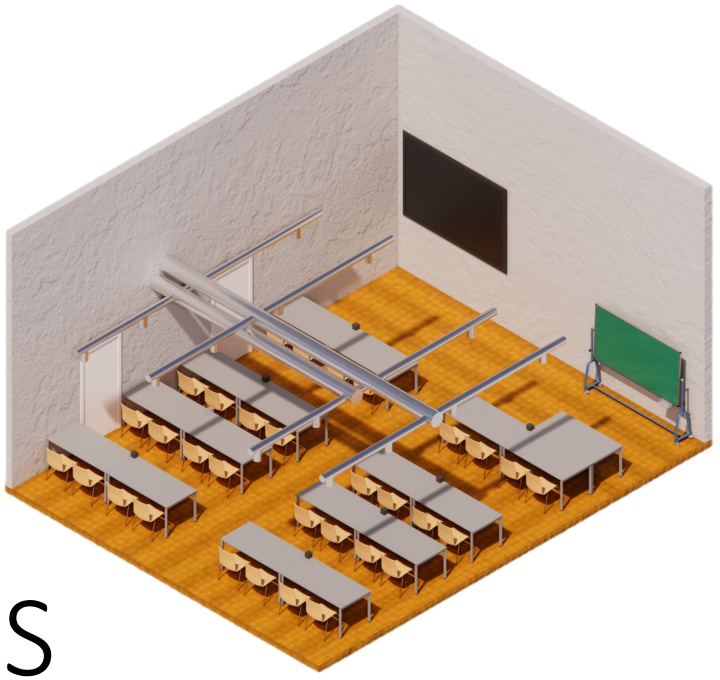
Rudnick en Milton - Infection risk - SMART simulation		
	Average	Peak
	1058 PPM	1121 PPM
	Quanta	Quanta range
	Alfa	89 - 165
	Delta	312 - 935
	Omicron	725 - 2345
	Fraction of inhaled breath	Fraction of inhaled breath
C	0,001058	0,001121
C0	0,00046	0,00046
Ca	0,05	0,05
f	0,012	0,0132
	ALFA VARIANT	
I	1	1
f	0,012	0,0132
q	89 and 165	89 and 165
t	4	4
n	32	32
P	12% 22%	14% 24%
	DELTA VARIANT	
q	312 and 935	312 and 935
P	37% 75%	40% 79%
	OMICRON VARIANT	
q	725 and 2345	725 and 2345
P	66% 97%	70% 98%

Progression of results

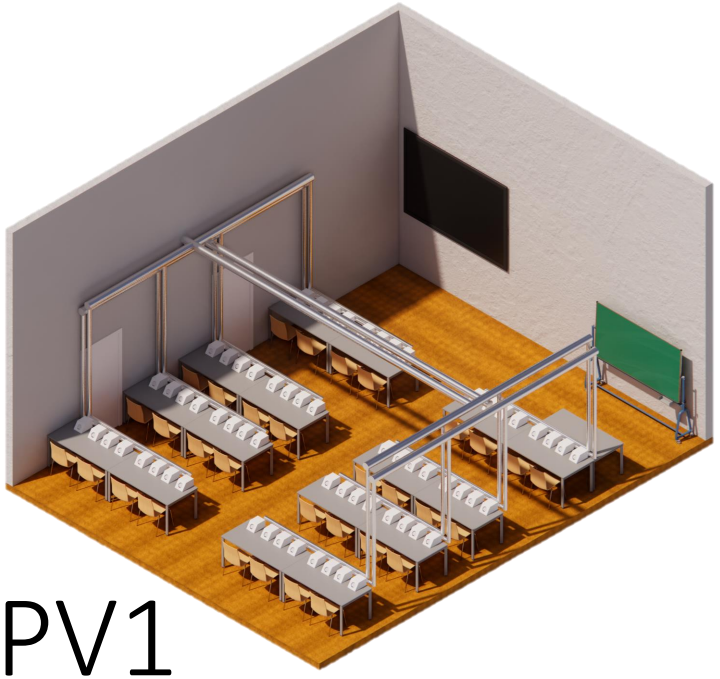
	Covid -19	Comfort	Costs
Baseline	14 – 25 %	PPD; 29,8% PMV; -1,07	No additional costs
Decentral	12 – 21 %	PPD; 32% PMV; -1,13	€13000
SMART	12 – 22 %	PPD; 25% PMV; -1,00	€4380 - 7740
Personal ventilation			



D1



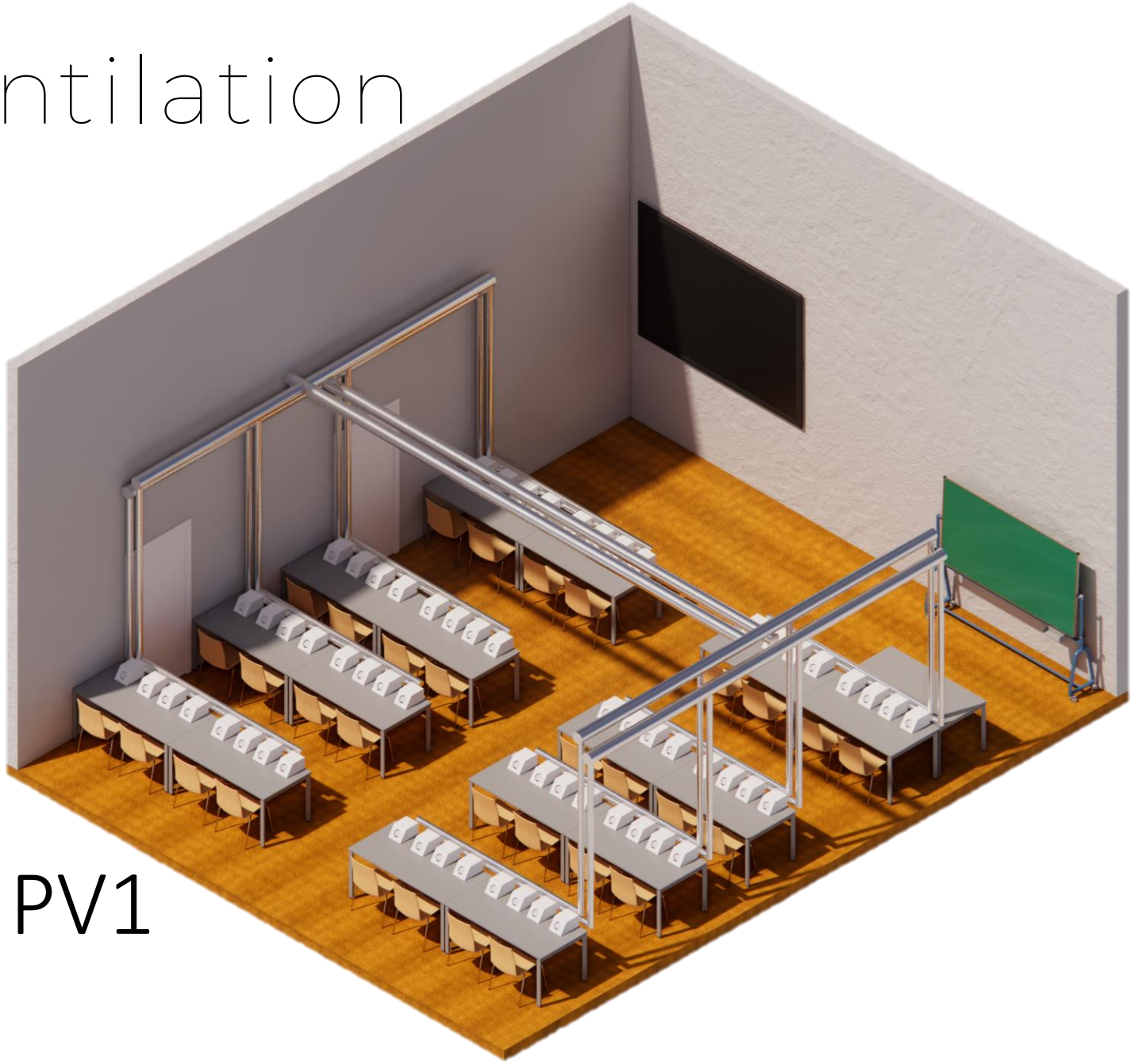
S



PV1

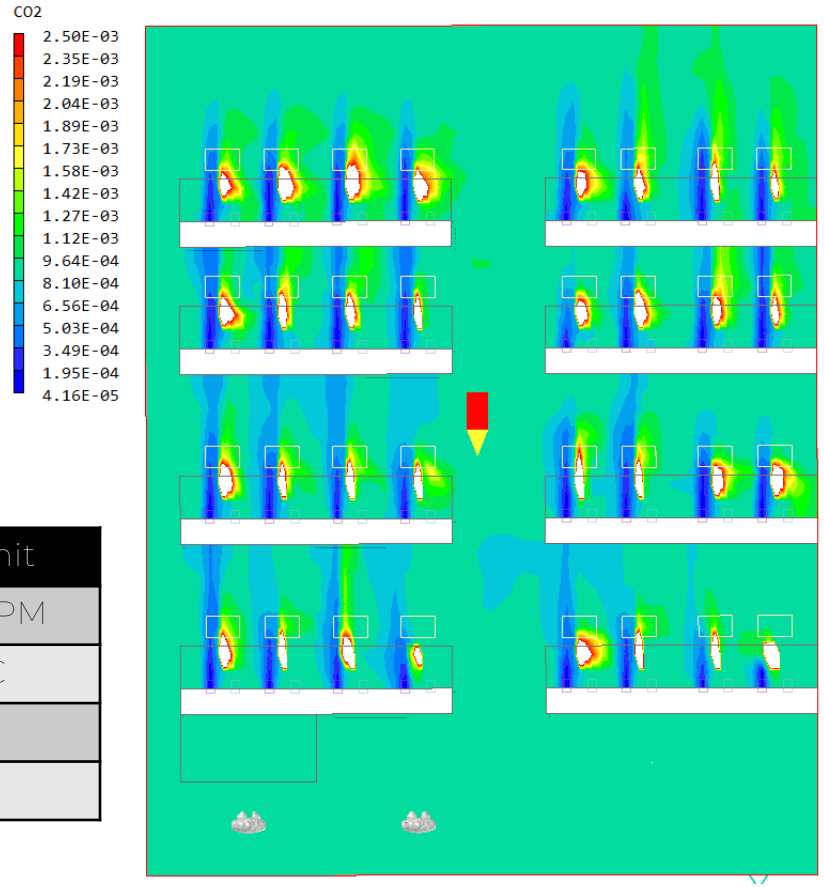
Personalised ventilation design

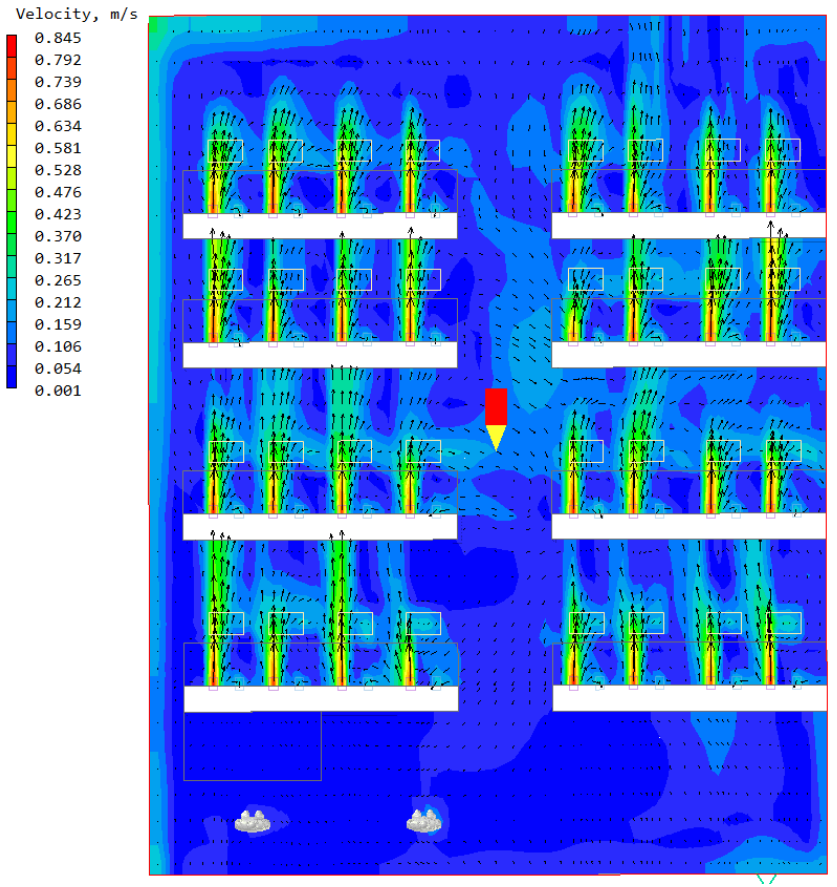
- Supply and exhaust close to the source of contaminants
- Large amount of ductwork is needed



PV1

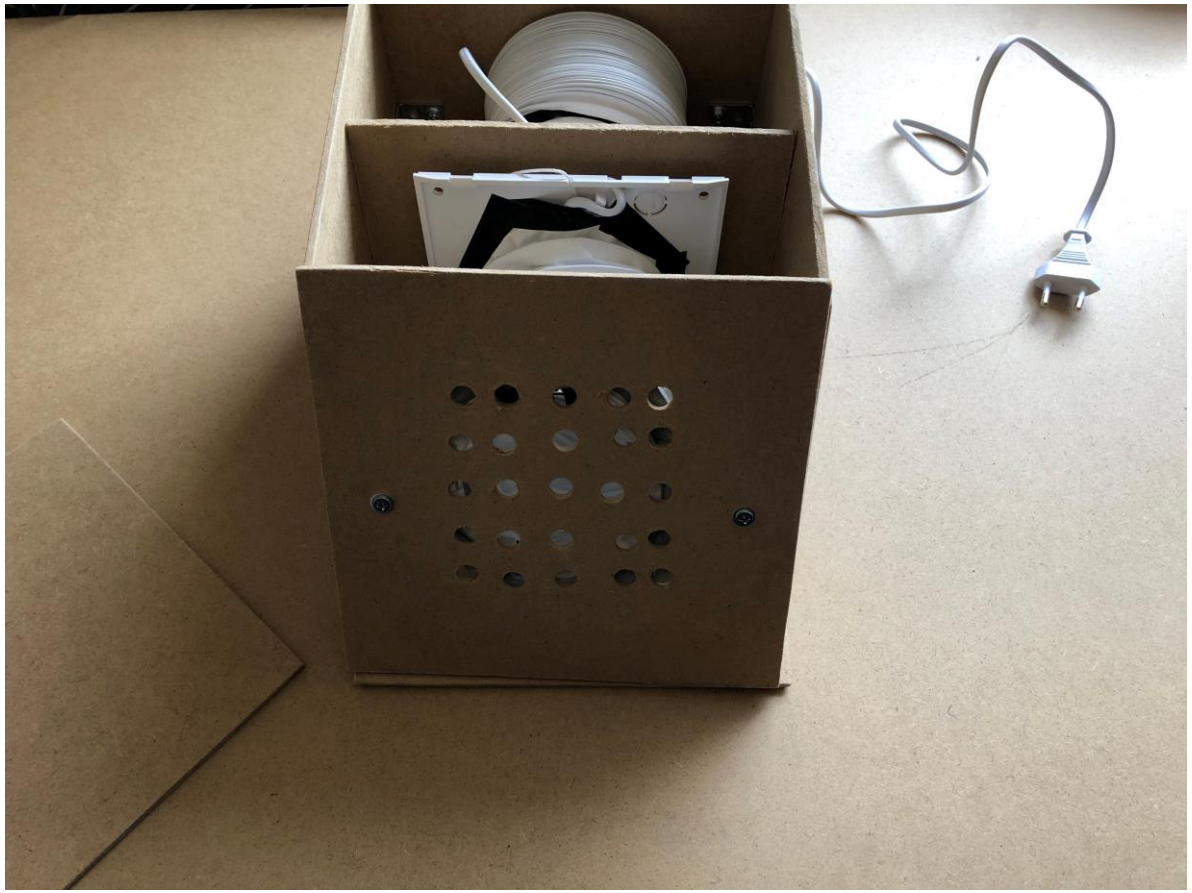
Simulation results



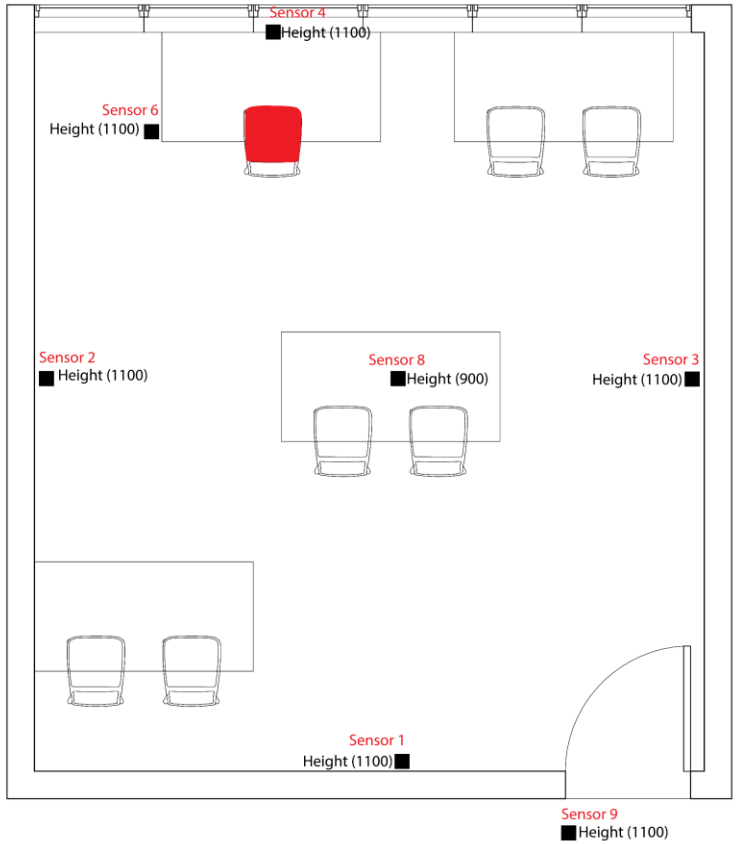


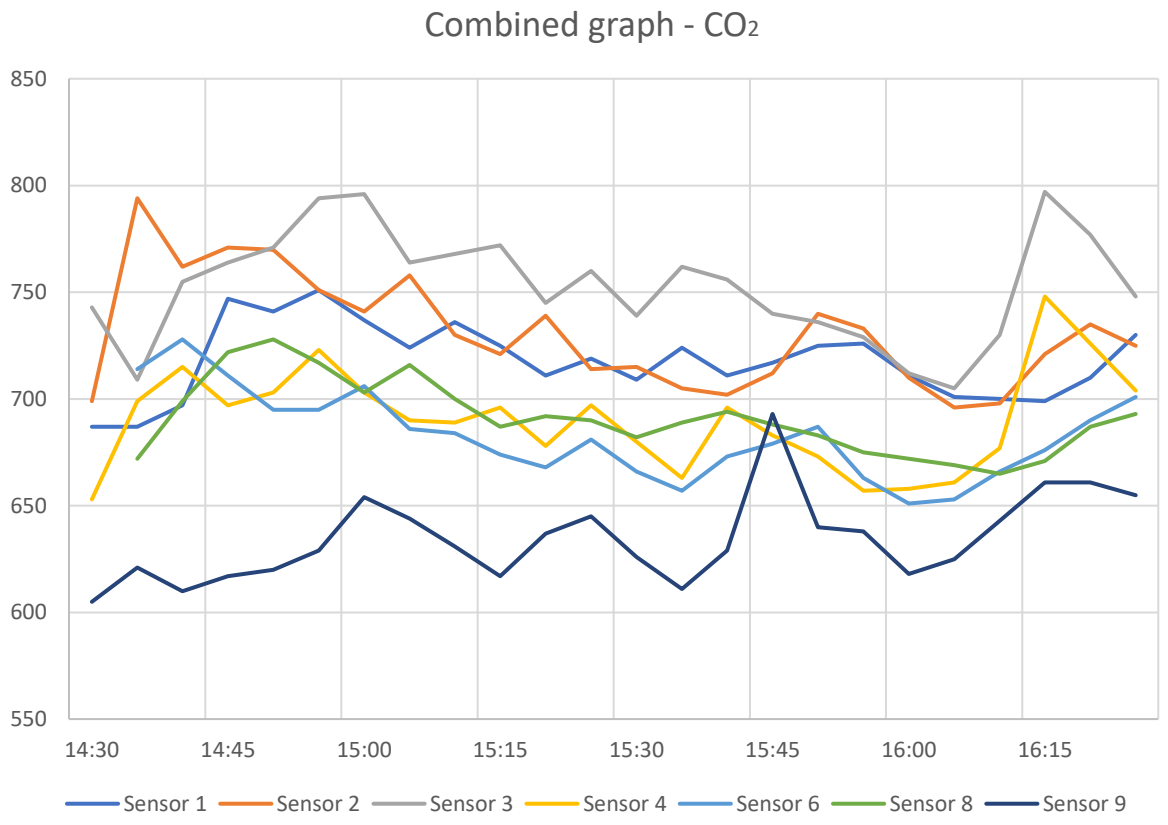
Parameters	Value	unit
CO2 (32p)	1032 (715)	PPM
Temperature	22,0	°C
PMV	-2,29	-
PPD	80	%

Individual unit



Individual unit – measurement





Comfort

Thermal sensation:

- *Cooling effect*
- *Uncomfortable due to airflow*

Indoor air quality:

- *Compared to the room, air quality was noticeable better in close proximity*

Risk of infection

Rudnick en Milton - Infection risk - PV simulation		
	Design 1 - Average	Design 1 - Close range
	1032 PPM	715 PPM
	Quanta	Quanta range
	Alfa	89 - 165
	Delta	312 - 935
	Omicron	725 - 2345
	Fraction of inhaled breath	Fraction of inhaled breath
C	0,001032	0,000715
C0	0,00046	0,00046
Ca	0,05	0,05
f	0,0114	0,0051
	ALFA VARIANT	
I	1	1
f	0,0114	0,0051
q	89 and 165	89 and 165
t	4	4
n	32	32
P	12% 21%	6% 10%
	DELTA VARIANT	
q	312 and 935	312 and 935
P	36% 74%	18% 45%
	OMICRON VARIANT	
q	725 and 2345	725 and 2345
P	64% 96%	37% 78%

The conclusion

The advice:

- Each design shows potential
- A more human centric design approach
- Higher ventilation rate in combination with the designs

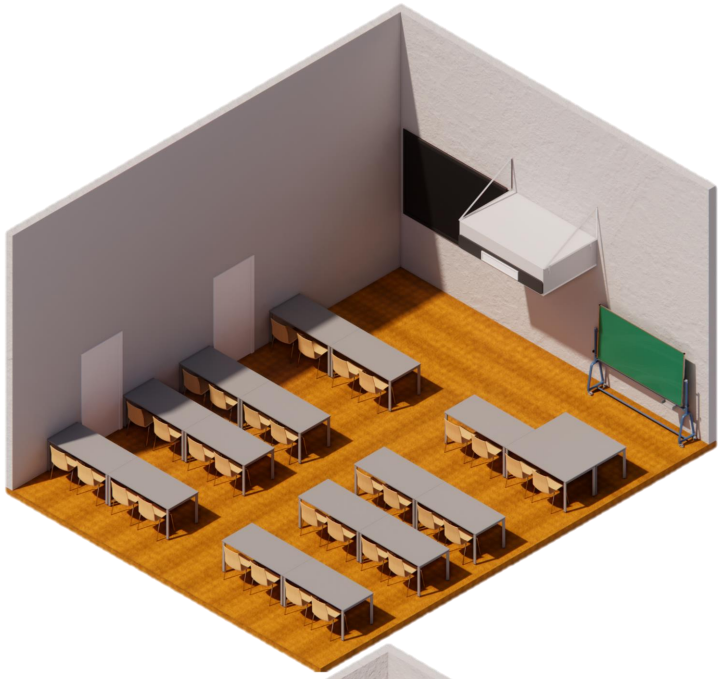
	Covid -19	Comfort	Costs
Baseline	14 – 25 %	PPD; 29,8% PMV; -1,07	No additional costs
Decentral	14 – 24 %	PPD; 32% PMV; -1,13	~ €13000
SMART	12 – 22 %	PPD; 25% PMV; -1,00	~ €4380 - 7740
Personal ventilation	6 – 10 %	PPD; 80% PMV; -2,29	~ €6000

Limitations

- Depends on the context; what, where and how
- Accuracy of the models is still an issue
- Costs; marginal improvements for large costs
- Practicality; impact on the room

Future research

- Integrating with the other measures
- The exact values recommended for ventilation rates
- Cost reduction research
- Better integrated design choices



Thank you