

# FIELD STUDY

## Inroom Air Quality Assessment in Primary School Hainfeld in Lower Austria

Real Environment complex fieldstudy for improvement of inroom air quality with use of passive air filter technology and assessment of the Austrian Government mandate to open classroom windows in regular terms as preventive measure conducted under scientific supervision of **IBO Innenraumanalytik OG**



in cooperation with



# The Primary School classroom



# Baseline initial situation

The Covid19 pandemic has created increased awareness of the **indoor risk of infection** through airborne pathogens & aerosols (droplet infection).

Existing heating systems (**convection heat radiators**) contribute significantly to the distribution of fine particles (PM Particle Matter) in the room.

Radiators suck in cool air at the bottom and release heated air at the top, creating the typical **convection air circulation**.

This convection (circulation of the air) is also responsible for the fact that normal **flu epidemics** occur more frequently in the cold season.

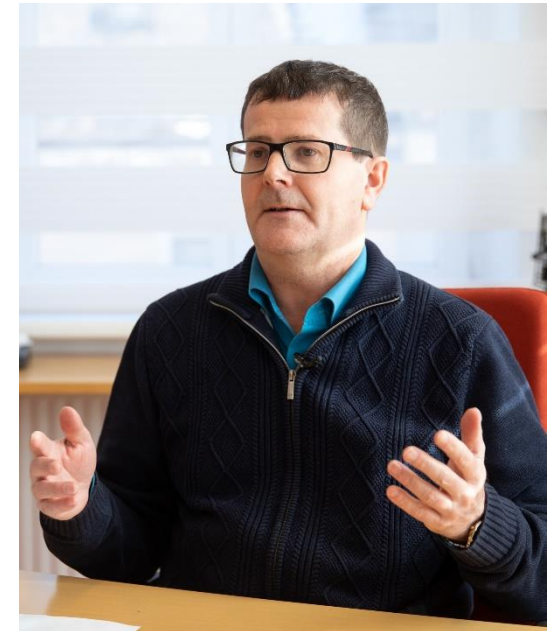


# Politics called for

The US-Austrian technology company Dexwet has developed and patented the world's first passive indoor air filter system with state support (AWS) in 2015 and successfully brought it to market.

The filters are **highly air-permeable** and are able to **preventively and effectively** clean the soft convection air flow of the heat radiators from fine dust particles.

Hainfeld's mayor, Albert Pitterle, wants to use this **noiseless filter solution** as an effective preventive measure for the **health protection** of his community and thus to reduce the high costs associated with flu epidemics in the long term.



# Scientific knowledge creates trust

The municipality of Hainfeld has therefore decided to conduct a worldwide unique field study under real conditions in the primary school Hainfeld under the scientific direction of the **Air Quality Expert DI Peter Tappler** (Institute for Interior Analysis OG).

In addition to the effectiveness of the preventive filter solution, the effect of the government regulation (**ventilate every 20 minutes**) on its effectiveness with regard to air quality shall be assessed.

The focus of interest is also on **behavioral and psychological aspects** with regard to the children's ability to learn and concentrate under the prescribed conditions.



# The Field Study in class 1A

**Duration:** 3 school weeks with 3 different experimental arrangements (2/15/2021 – 3/15/2021).

Support from **School Headmaster Herta Smetana** and **Teacher Romina Wais**. Participation of **26 kids** under extraordinary conditions (Cov19 tests).

## Test-Settings:

**Week1:** Filters installed, and windows opened only during breaks

**Week2:** Filter installed, plus active fan support for test outside the heating season, window opening 20min, + 5min ventilation

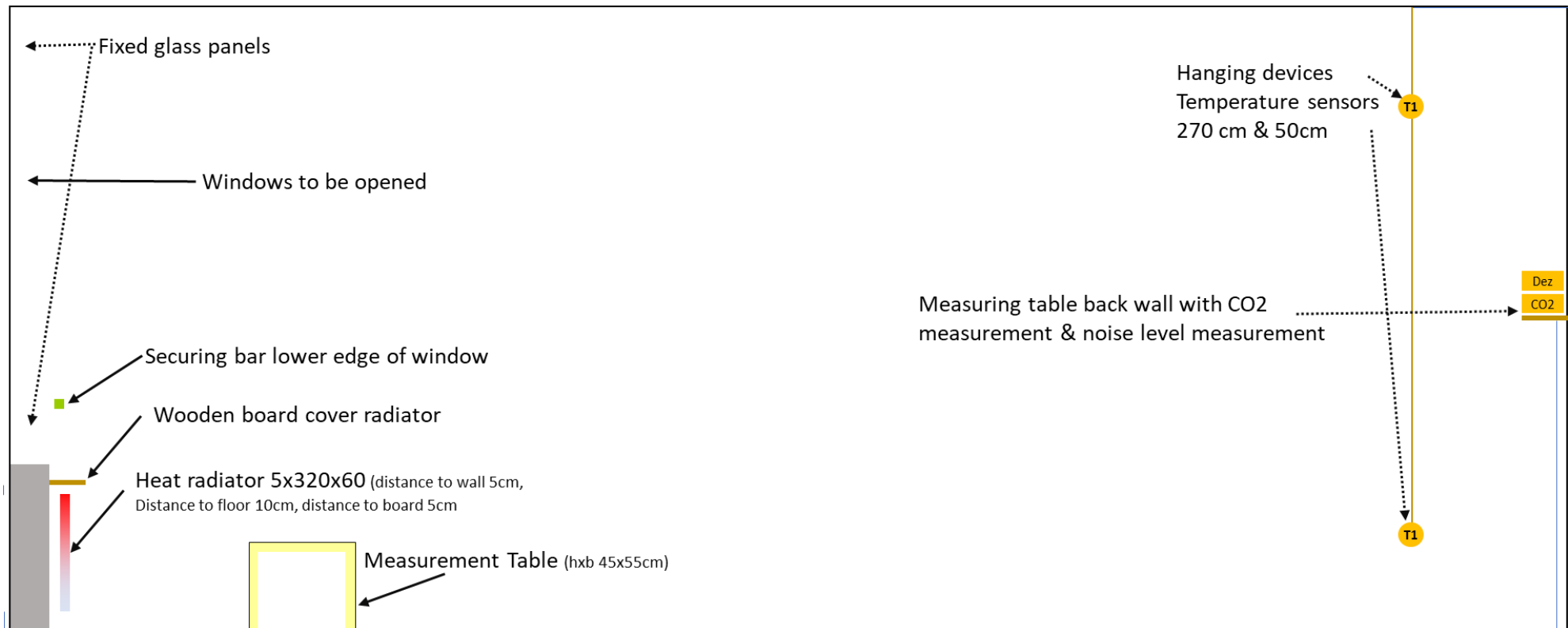
**Week3:** only window opening 20min + 5min ventilation, no filter

Installation of 17 (!) scientific measuring devices in the class + **gravimetric fine dust measuring device** in the AULA for the scientific analysis of the composition of the detected particles (weekly sampling => electro-microscopy for morphology of PM).



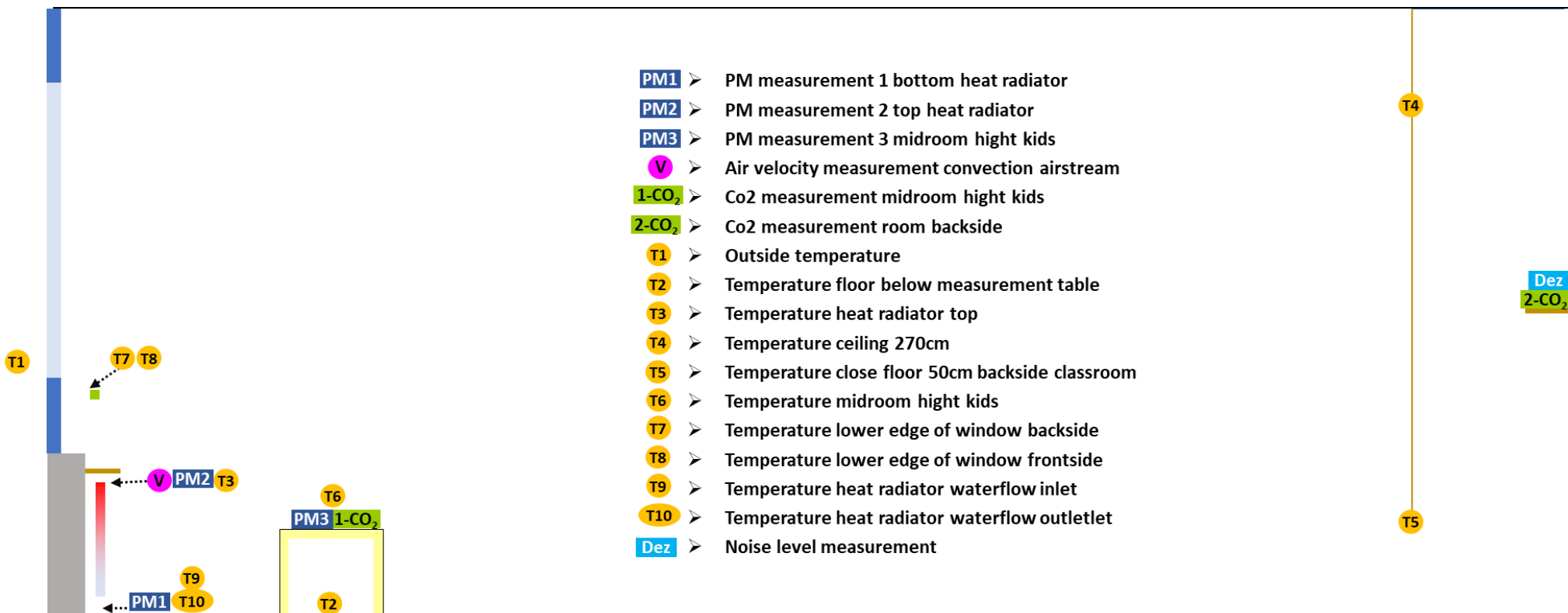
# Experimental scheme

Cross-section class 1A: room cubature  $10\text{m} \times 8\text{m} \times 3.2\text{m} = 256\text{m}^3$



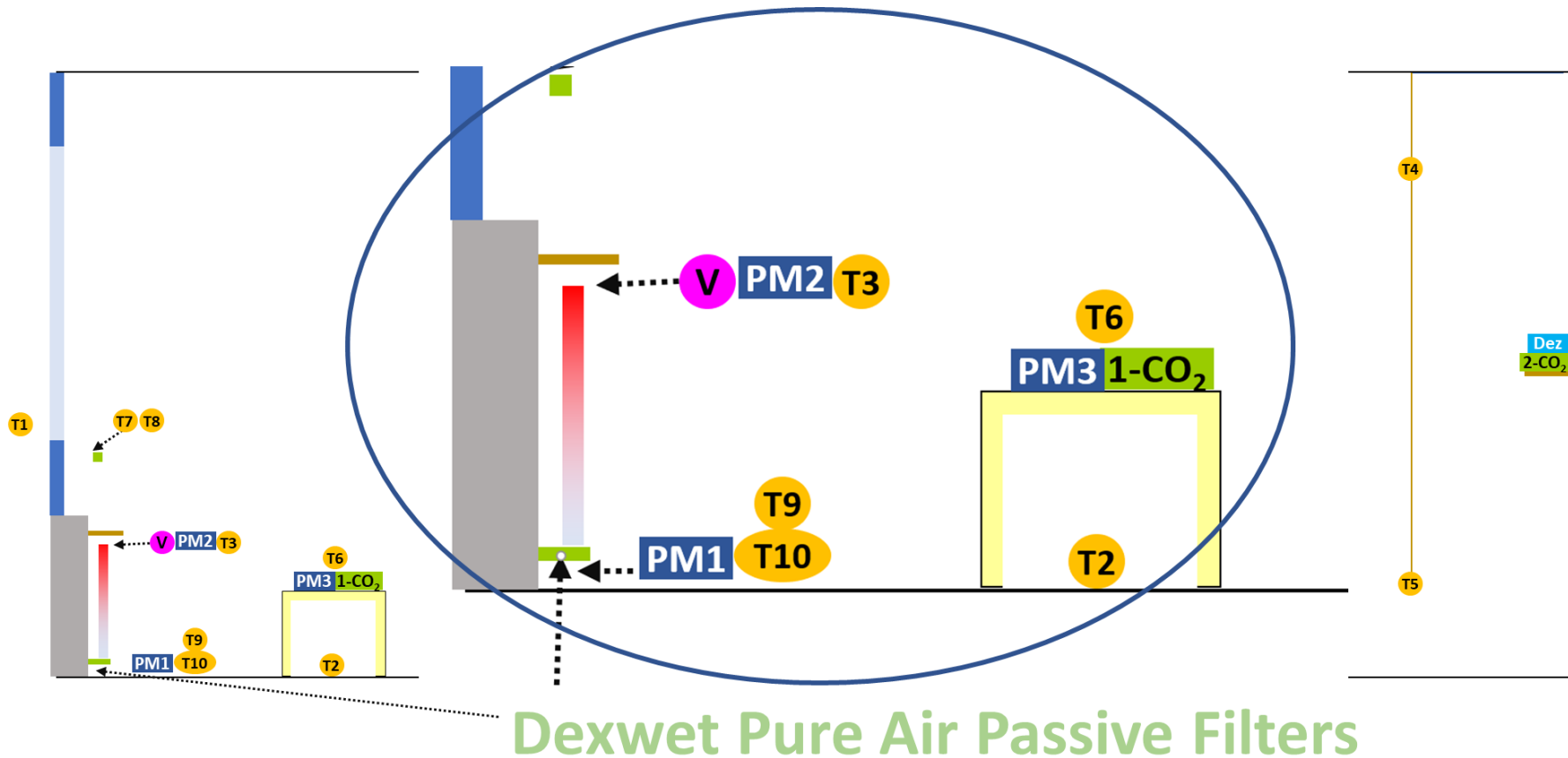
# Measurement points

## 17 Sensors for temperature, CO<sub>2</sub>, air velocity and finedust PM measurement



# Passive Air Purification

Air Filters on the bottom of the heat radiators purify convection airflow



# Definitions

**PM = Particulate Matter** (finedust) is measured in microgramms ( $\mu\text{g}$ =weight) and micrometer ( $\mu\text{m}$ =size).

**PM10** = 10 micrometer diameter ( $10\mu\text{m}$ ) or smaller = finedust of  $1/100\text{mm} \rightarrow 1/400\text{mm}$  size (**PM2.5**), are called microparticles, they sink/fall down with app. 10 cm per hour

**PM1** = 1 micrometer ( $1\mu\text{m}$  and smaller) = Ultrafinedust of  $1/1000 \rightarrow 1/\text{ppm mm}$  size, are called nanoparticles (hovering dust), do not sink down due to small weight

**Van-da-Waals-principle:** The smaller the particles the more they torkle within the airstream – this swirling effect is utitized/functionalized by Dexwet Filters

**Gravitation principle:** nanoparticles are so light in mass that they stand in the air because earth gravity can hardly attract them, they stand in the air and are only moved by airstreams. Furtheron, nanoparticles get distracted gravitationally by larger, higher-mass microparticles

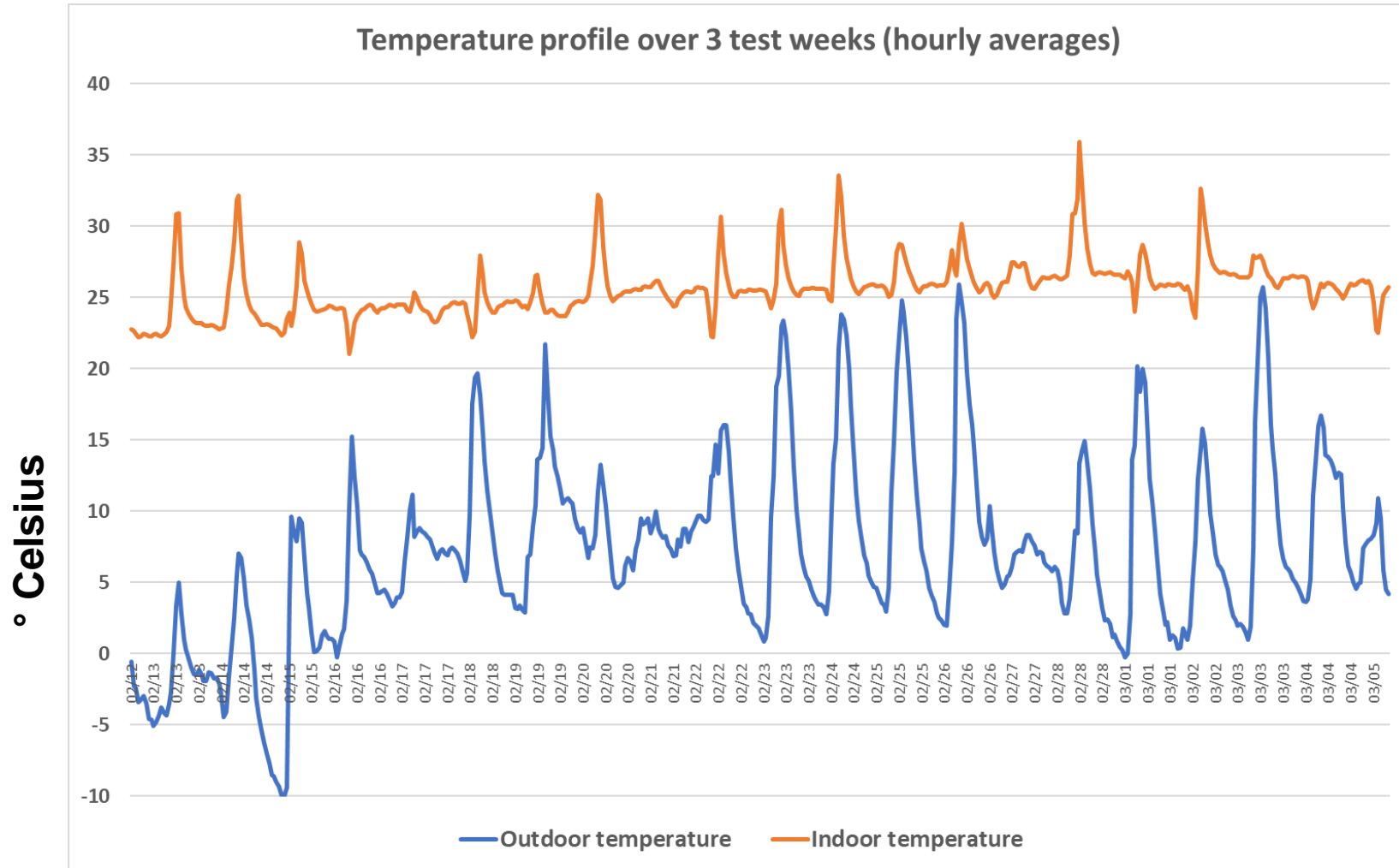
**Degree of seperation:** describes the effectiveness of a separation or purification process (= filtration-effect, filter effectiveness).

# Measurements over testing period

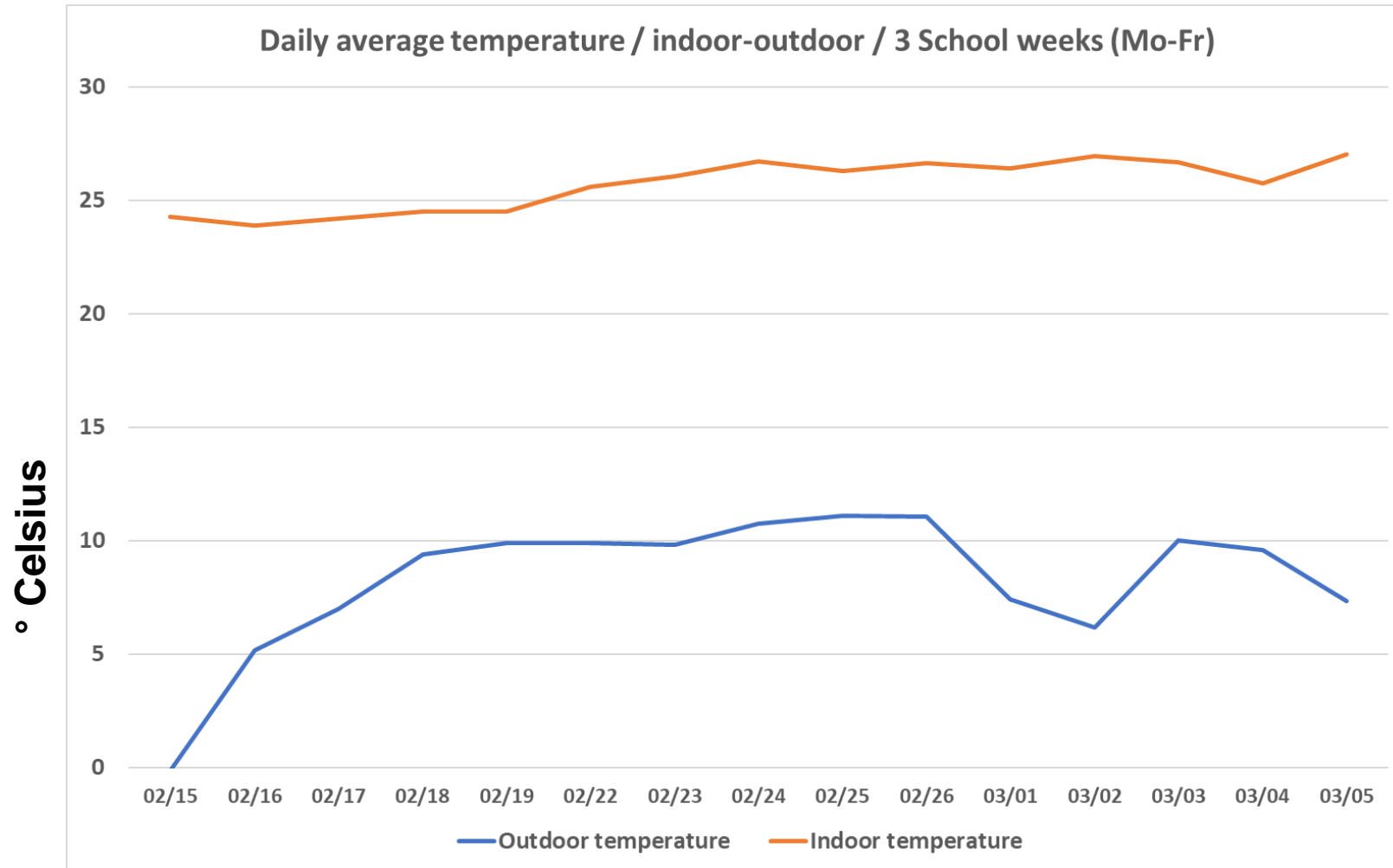
Project overview in time with different settings and permanent data capturing

		hour	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24		
		hour start	00:00	01:00	02:00	03:00	04:00	05:00	06:00	07:00	08:00	09:00	10:00	11:00	12:00	13:00	14:00	15:00	16:00	17:00	18:00	19:00	20:00	21:00	22:00	23:00		
		hour end	01:00	02:00	03:00	04:00	05:00	06:00	07:00	08:00	09:00	10:00	11:00	12:00	13:00	14:00	15:00	16:00	17:00	18:00	19:00	20:00	21:00	22:00	23:00	00:00		
Pre-Phase	02/12	Friday																										T1
Pre-Phase	02/13	Saturday																										T2
Pre-Phase	02/14	Sunday																										T3
Setting1	02/15	Monday																										A1 T4
Setting1	02/16	Tuesday																										B2 T5
Setting1	02/17	Wednesday																										C3 T6
Setting1	02/18	Thursday																										D4 T7
Setting1	02/19	Friday																										E5 T8
Pre-Phase2	02/20	Saturday																										T9
Pre-Phase3	02/21	Sunday																										T10
Setting2	02/22	Monday																										F6 T11
Setting2	02/23	Tuesday																										G7 T12
Setting2	02/24	Wednesday																										H8 T13
Setting2	02/25	Thursday																										I9 T14
Setting2	02/26	Friday																										J10 T15
Pre-Phase3	02/27	Saturday																										T16
Pre-Phase4	02/28	Sunday																										T17
Setting3	03/01	Monday																										K11 T18
Setting3	03/02	Tuesday																										L12 T19
Setting3	03/03	Wednesday																										M13 T20
Setting3	03/04	Thursday																										N14 T21
Setting3	03/05	Friday																										O15 T22

# Temperature profile 3 test weeks



# Average daily temperatures



# Hainfeld

**GESUNDE GEMEINDE**

HAINFELD



# 1<sup>st</sup> test week - winter conditions

**winter conditions: very cold temperatures**  
ventilating only in the pauses (30 minuten total)

**Good natural convection performance** of the heat radiators,  
**430 m<sup>3</sup> per hour** results in factor 1,7 >> i.e. 1,7 times per  
hour the whole room air volume is sucked through the filter –  
results in **high degree of separation**

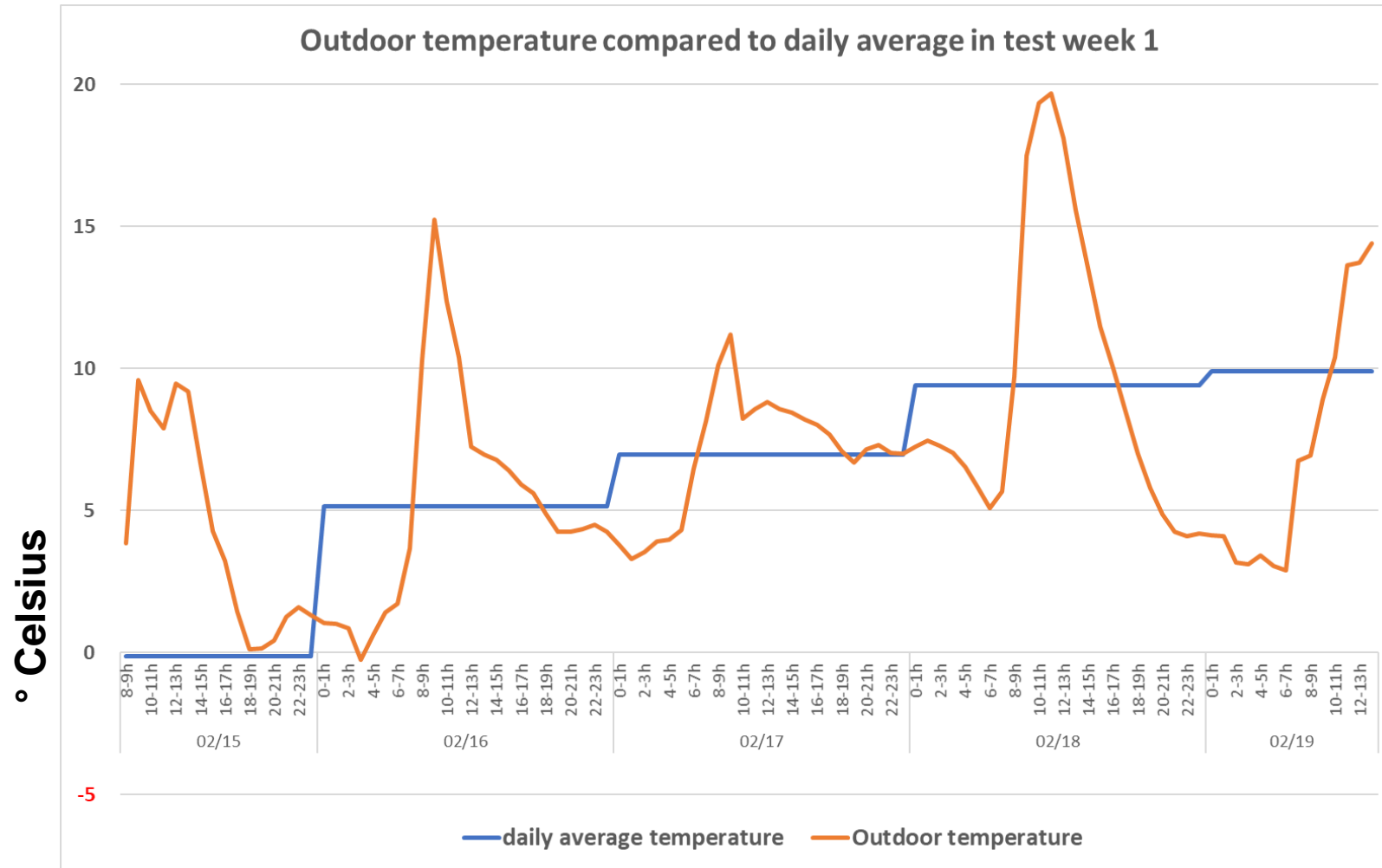
**Lowest average particle concentration**  
of all three test weeks:

**PM10=39µg/m<sup>3</sup> - PM2.5=9.5µg/m<sup>3</sup> - PM1=5.1µg/m<sup>3</sup>**

Gravimetric finedust measurement shows **lowest particle imission from the outside (17 µg/m<sup>3</sup>)** to the School Aula in the center of the building



# 1<sup>st</sup> test week - winter conditions



# 2<sup>nd</sup> test week - Sahara-high

**Spring conditions: very warm temperatures.**

Ventilate all 20 Minutes for 5 Minutes (11 x 5 = 55 min total)

Reduced convection performance was leveled by **active fan support** of the heat radiators. **410m<sup>3</sup> per hour** results in faktor 1.6 >> i.e. 1.6 times per hour the whole room air volume is sucked through the filter

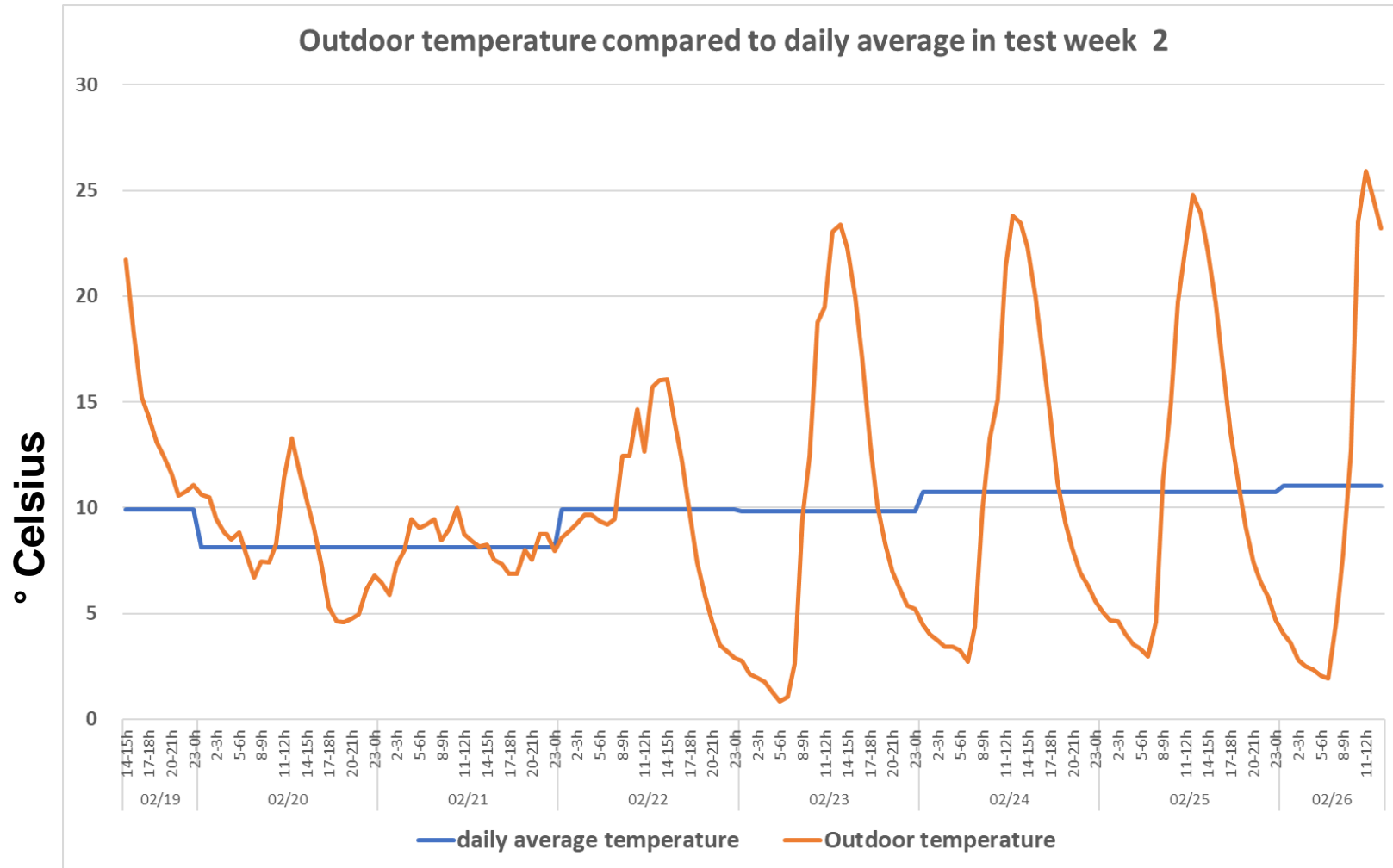
**Highest average particle pollution** of all three test weeks:  
**PM10=48µg/m<sup>3</sup> - PM2.5=19µg/m<sup>3</sup> - PM1=11µg/m<sup>3</sup>**

Gravimetric finedust measurement shows **nearly double value and highest particle imission\*** (32 µg/m<sup>3</sup>) in School central aula.

\* **Sahara-Sand** was detected in gravimetric fine dust weekly sample with the help of electron microscopy in morphologic assessment.



# 2<sup>nd</sup> test week - Sahara-High



# 3<sup>rd</sup> test week - Spring

## Spring conditions: Cooler temperatures

Ventilate all 20 Minutes for 5 Minutes (11 x 5 = 55 min total)

Good natural convection performance of the heat radiators.  
**490 m<sup>3</sup> per hour Stunde** results in Faktor 1,8 >> 1,8 times  
per hour the whole room air volume is sucked through the  
filter

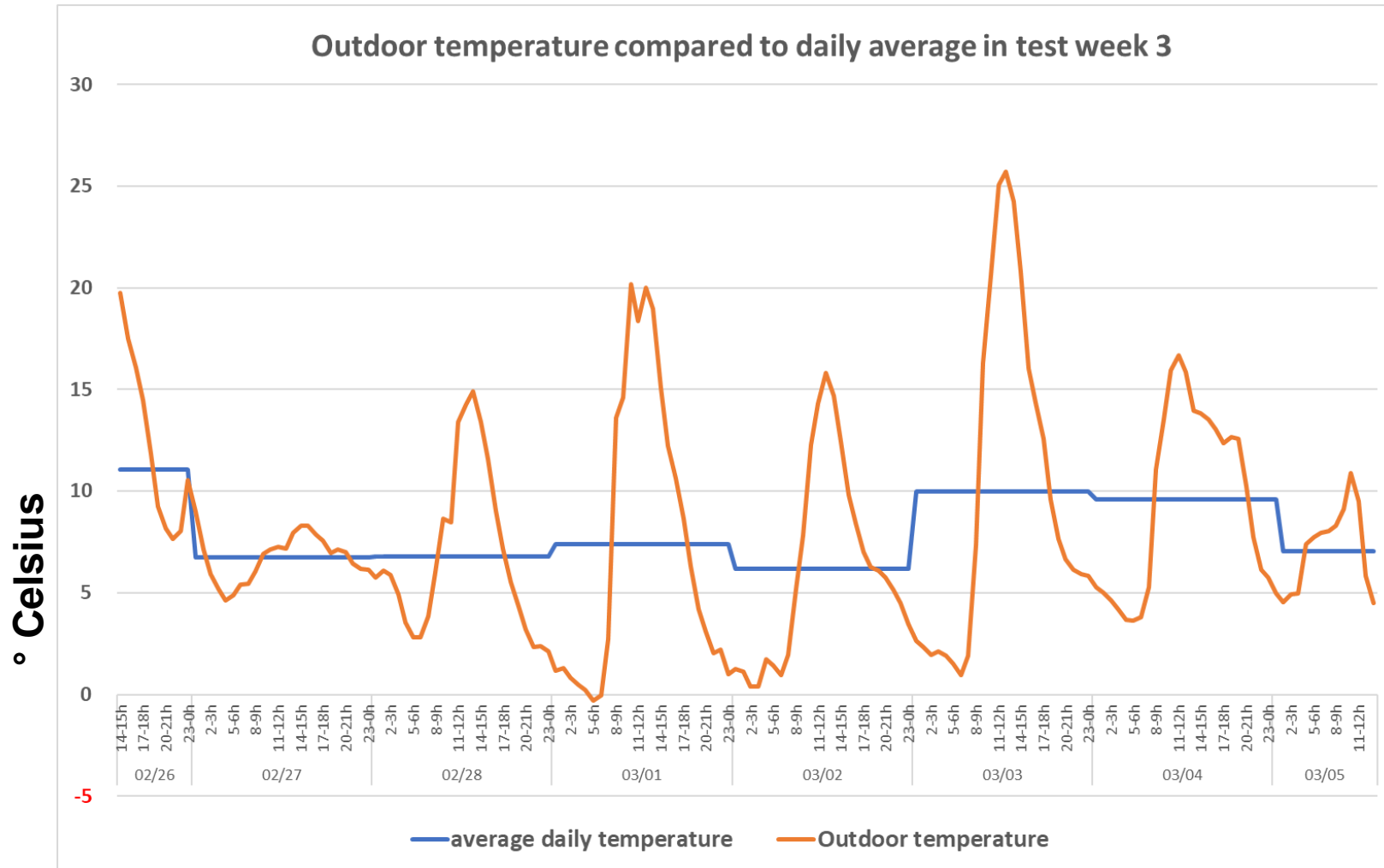
**Second highest average particle pollution**  
of all three test weeks

**PM10=39µg/m<sup>3</sup> - PM2.5=14µg/m<sup>3</sup> - PM1=10µg/m<sup>3</sup>**

Gravimetric finedust measurement shows **reduced particle imission from outdoors** similar like in first week (19 µg/m<sup>3</sup>).

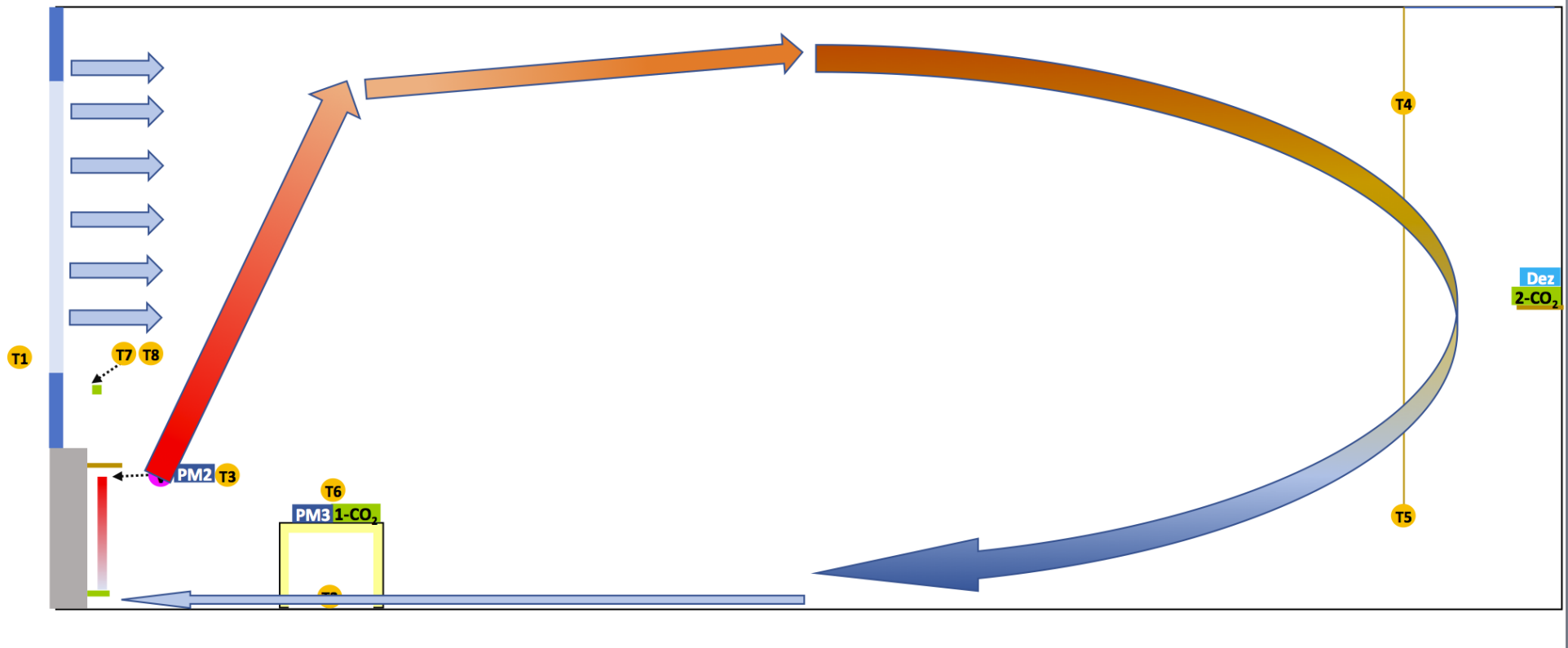


# 3<sup>rd</sup> test week - Spring



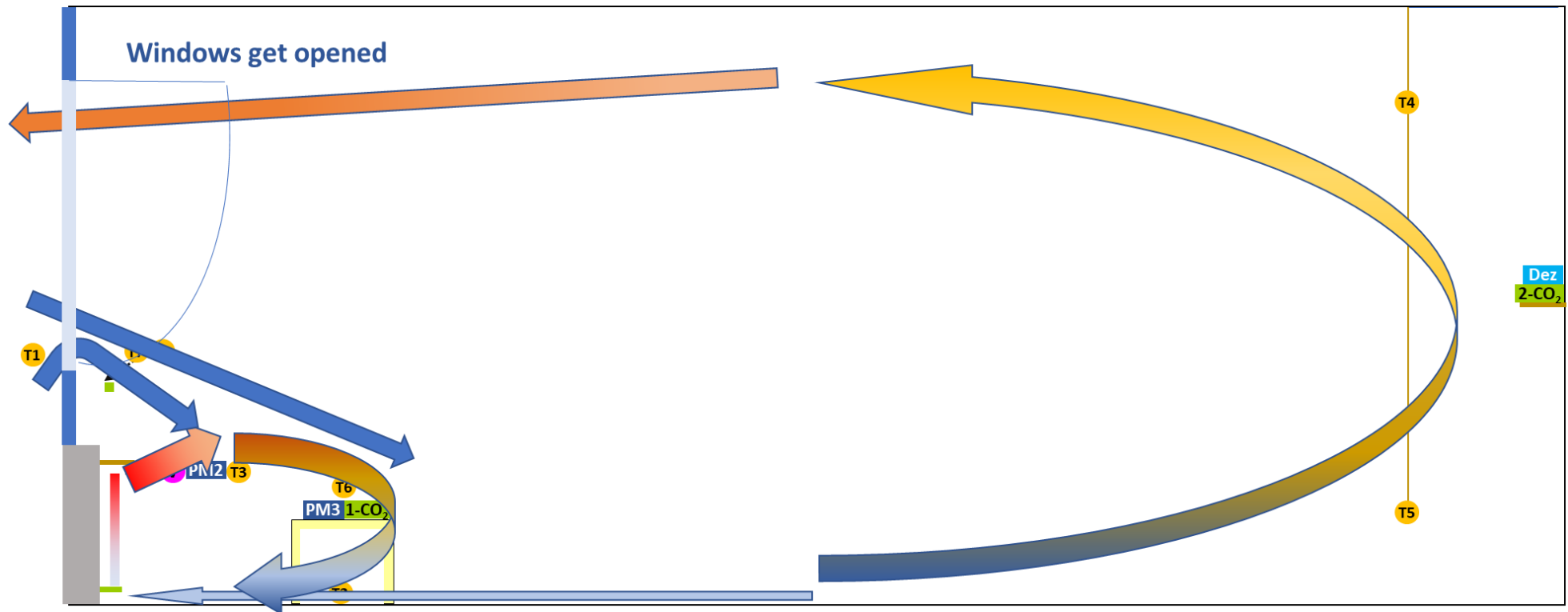
# Normal heating convection airstream

Soft & noiseless airstream, generated by the radiators, circulates through the whole room

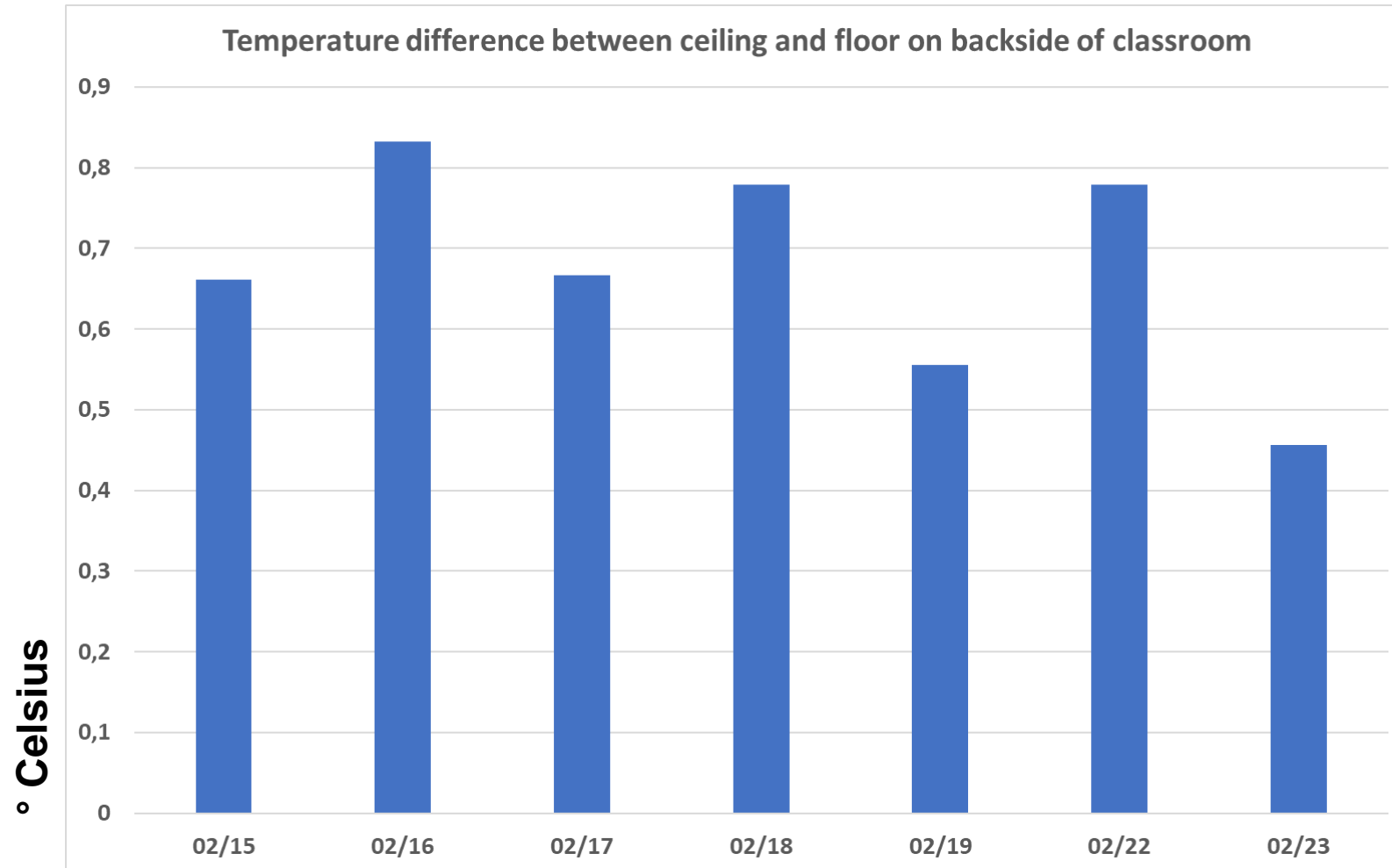


# Reversal of airflow

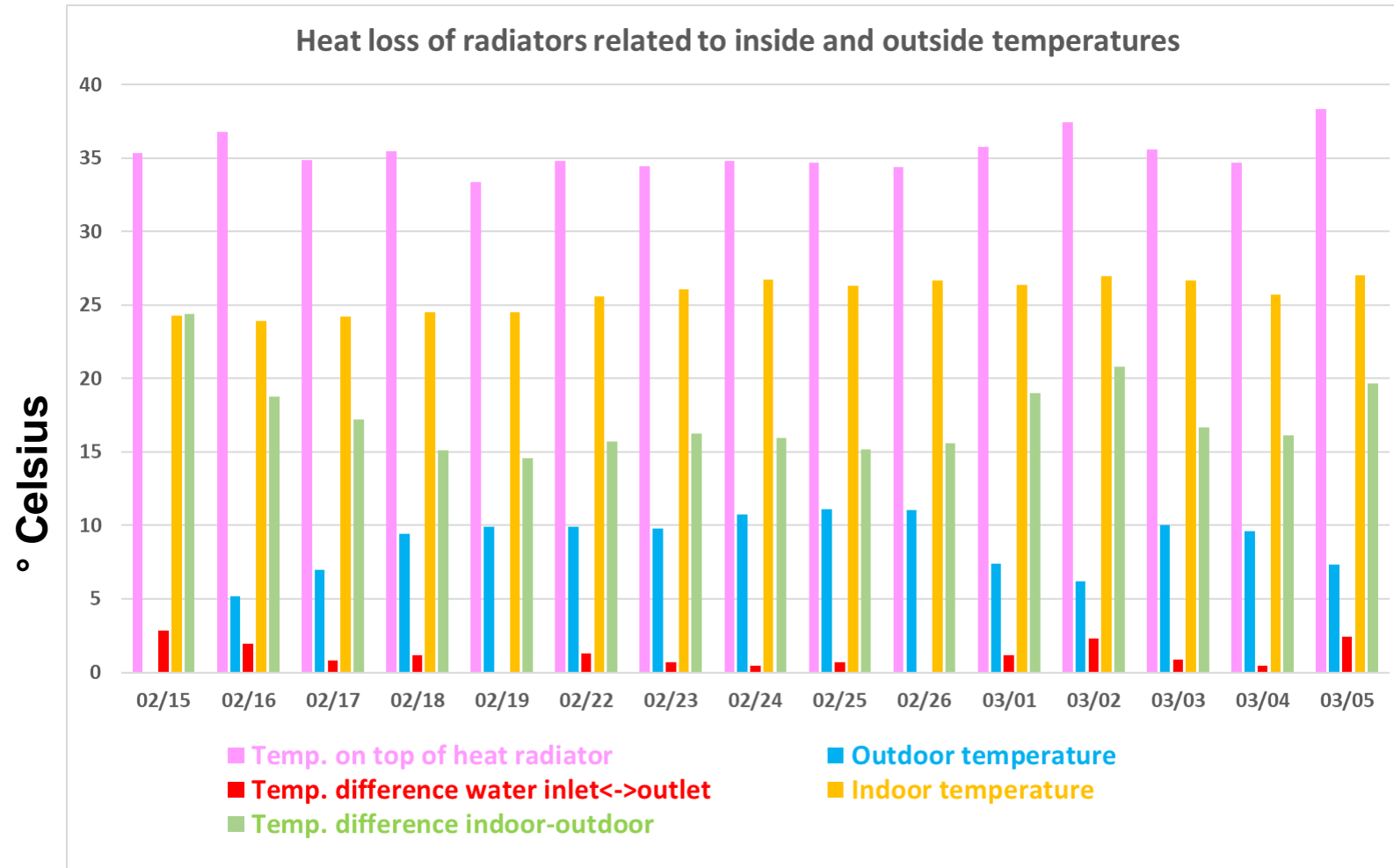
When windows get opened the convection **airstream is reversed** and **increases the particle imission into the room**, while diluting CO<sub>2</sub> concentration and particle concentration from indoor sources with outside particle imissions



# Proof of convection airstream

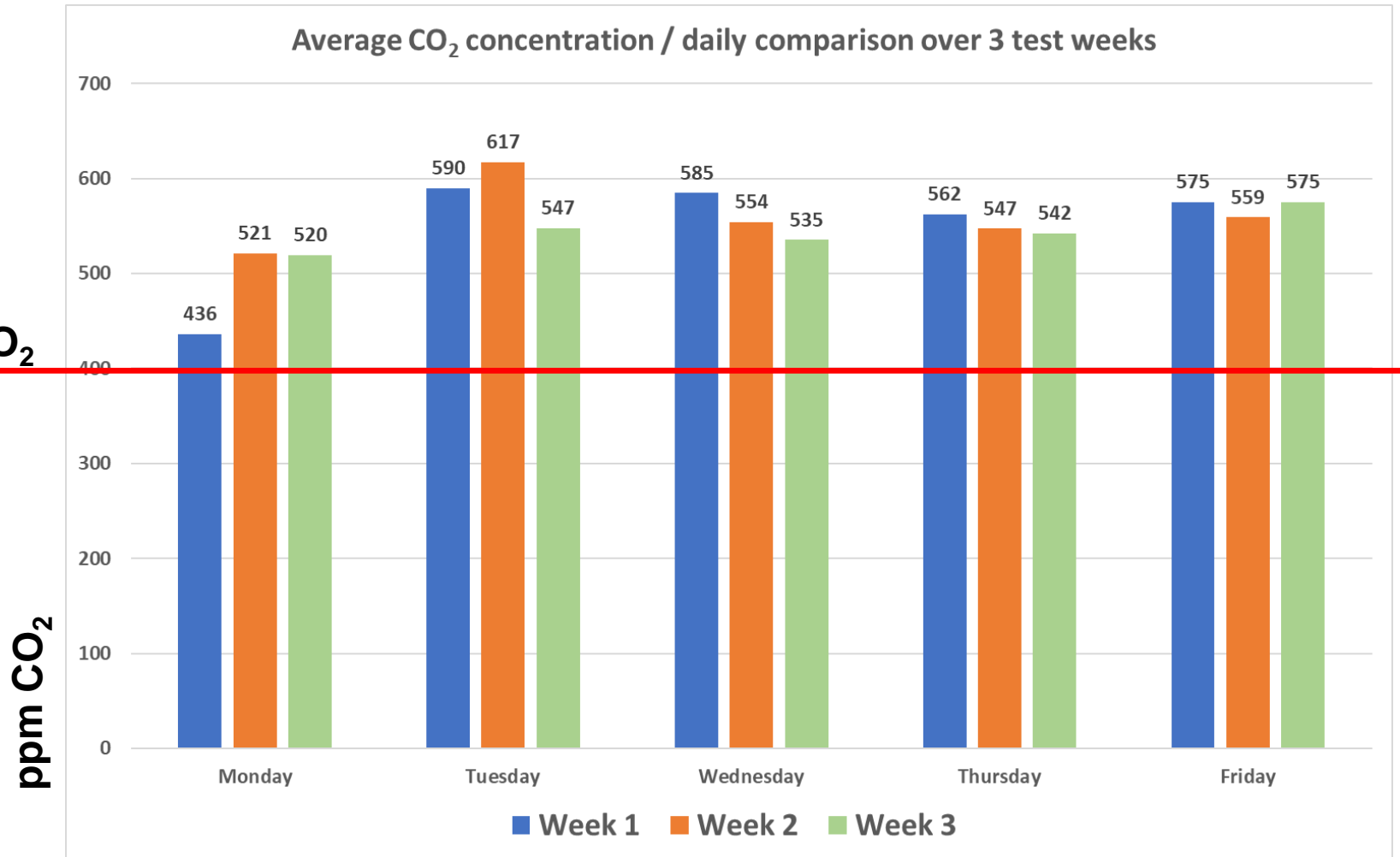


# Energy loss due to ventilation

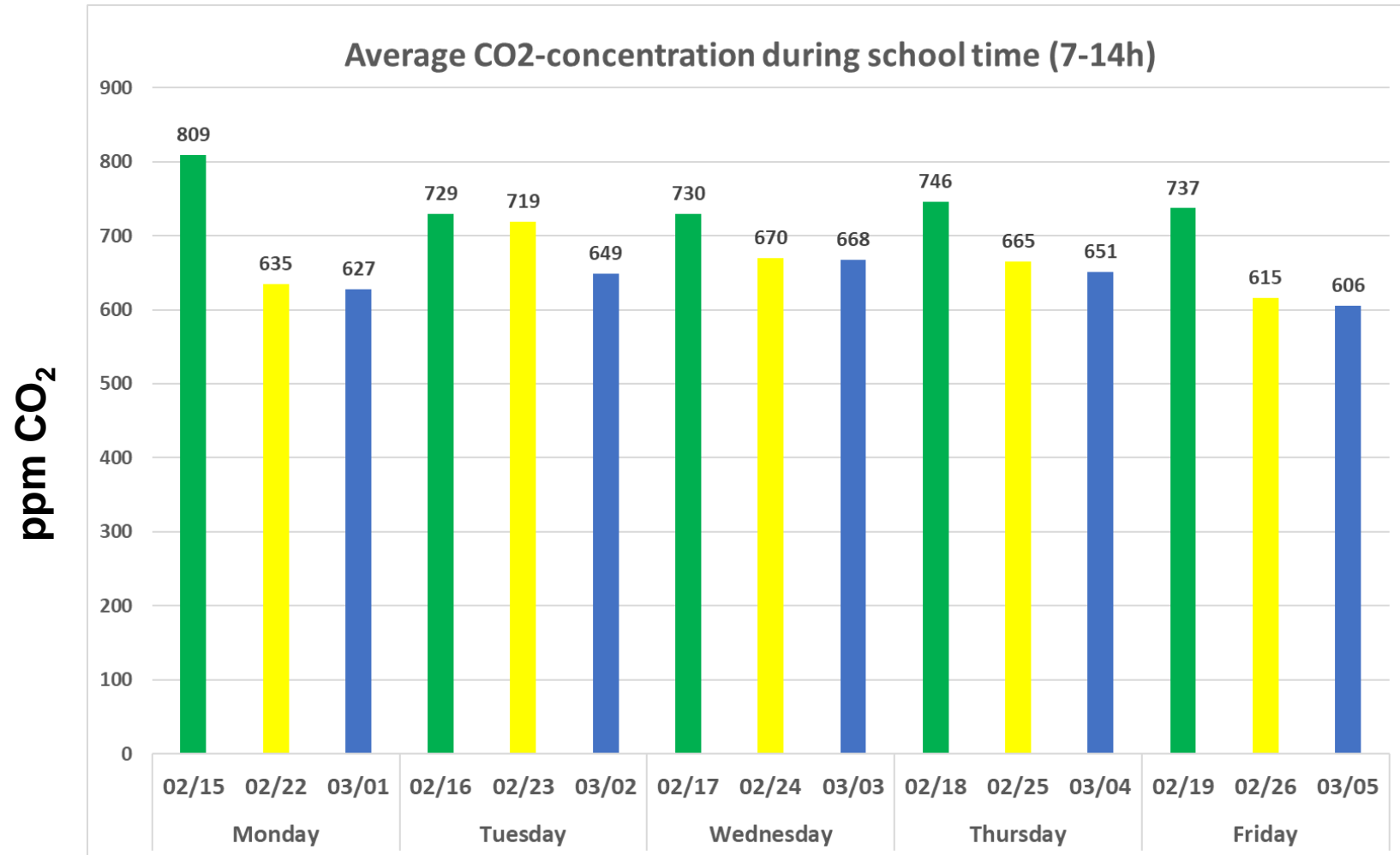


# CO<sub>2</sub>-concentration analysis

Outdoor air CO<sub>2</sub>  
concentration

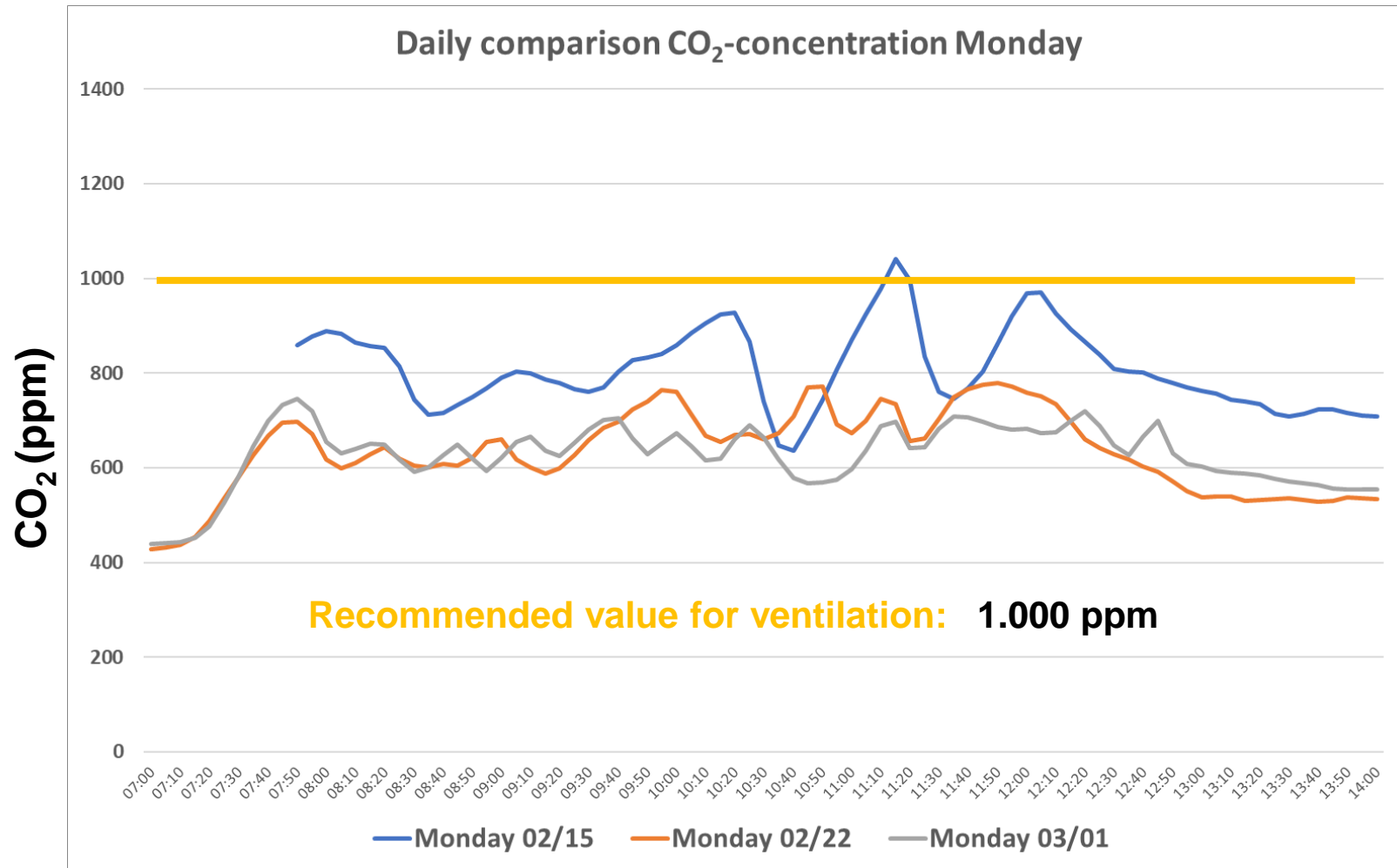


# CO<sub>2</sub>-concentration analysis

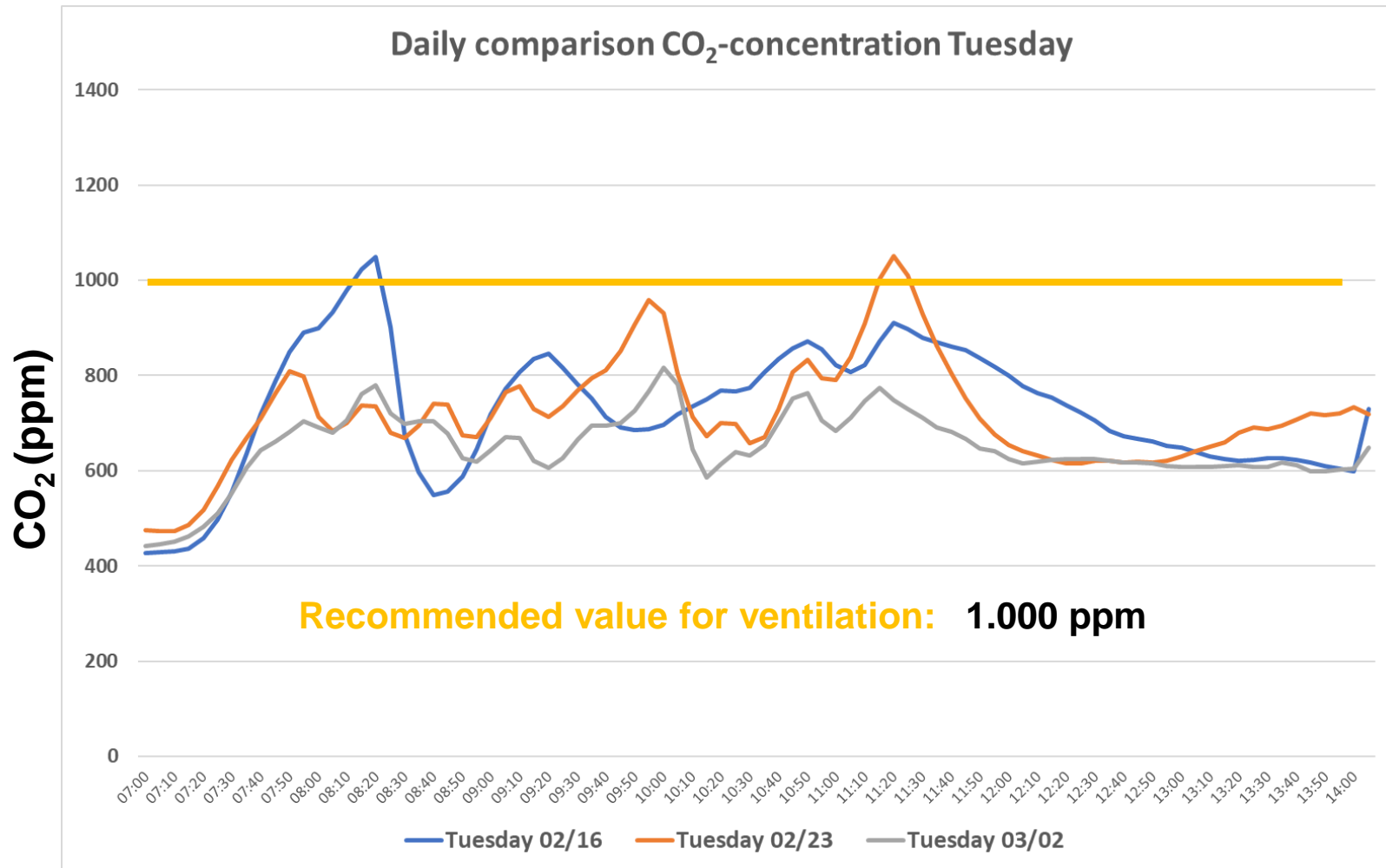


■ Week 1   ■ Week 2   ■ Week 3

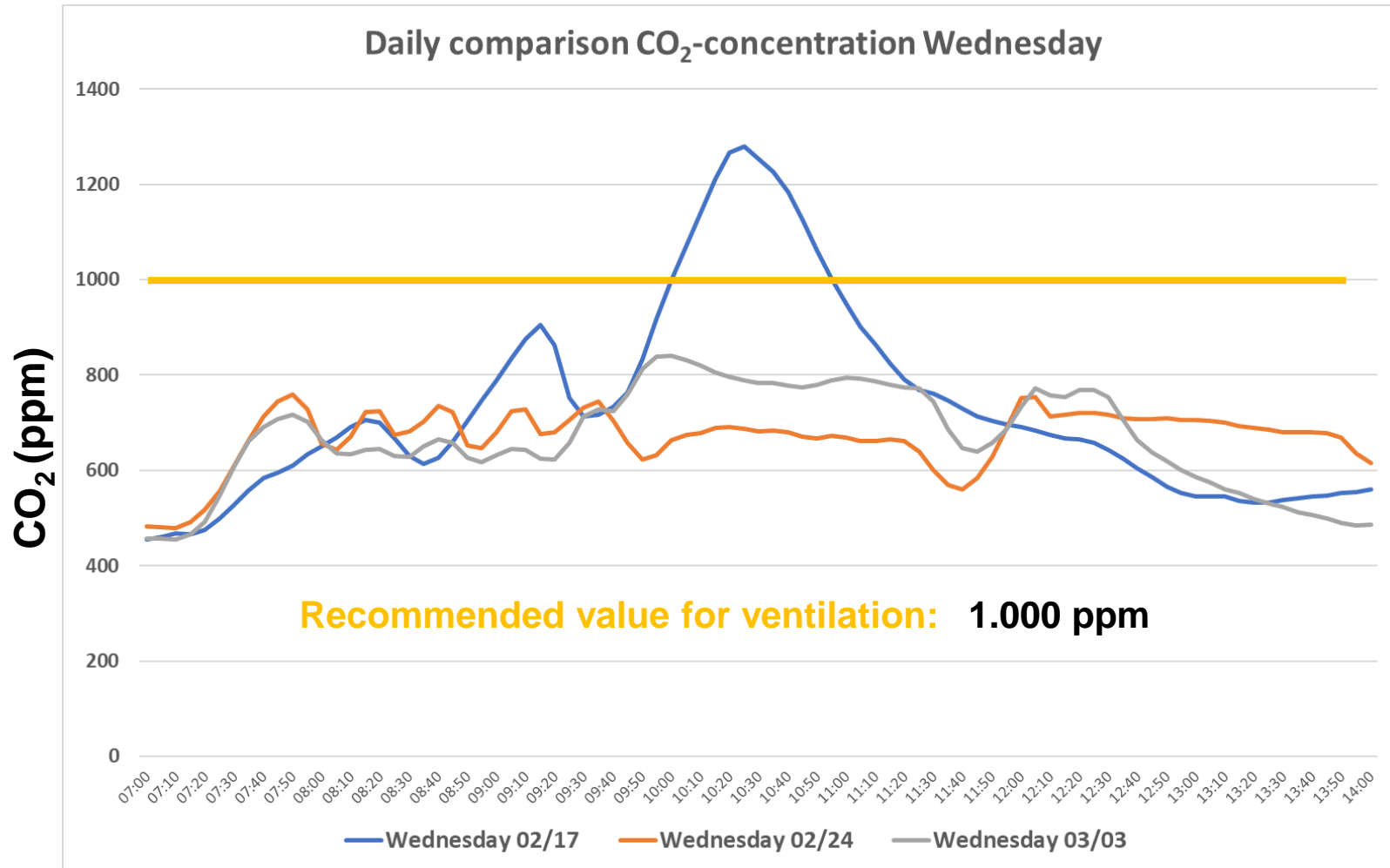
# CO<sub>2</sub>-concentration analysis



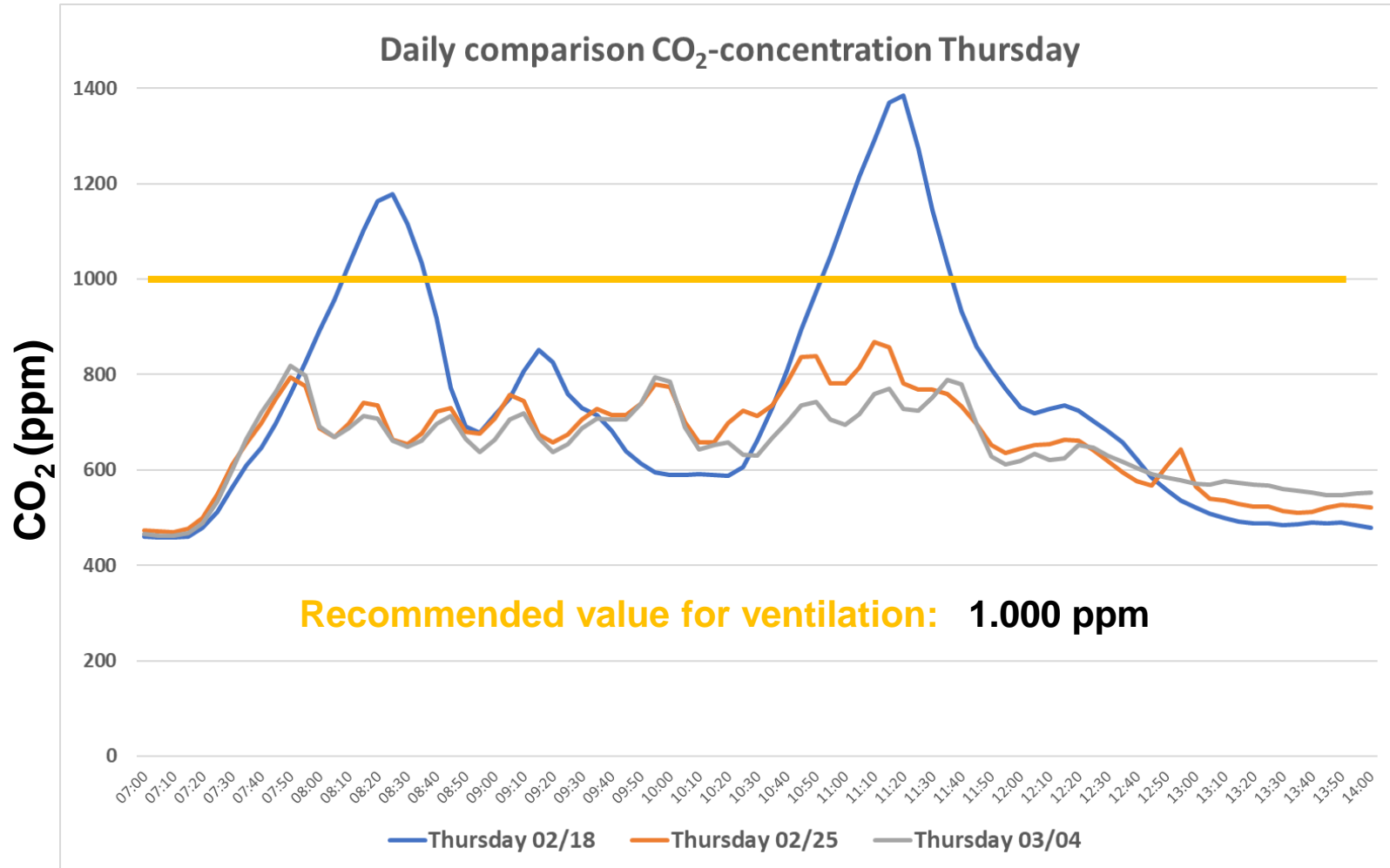
# CO<sub>2</sub>-concentration analysis



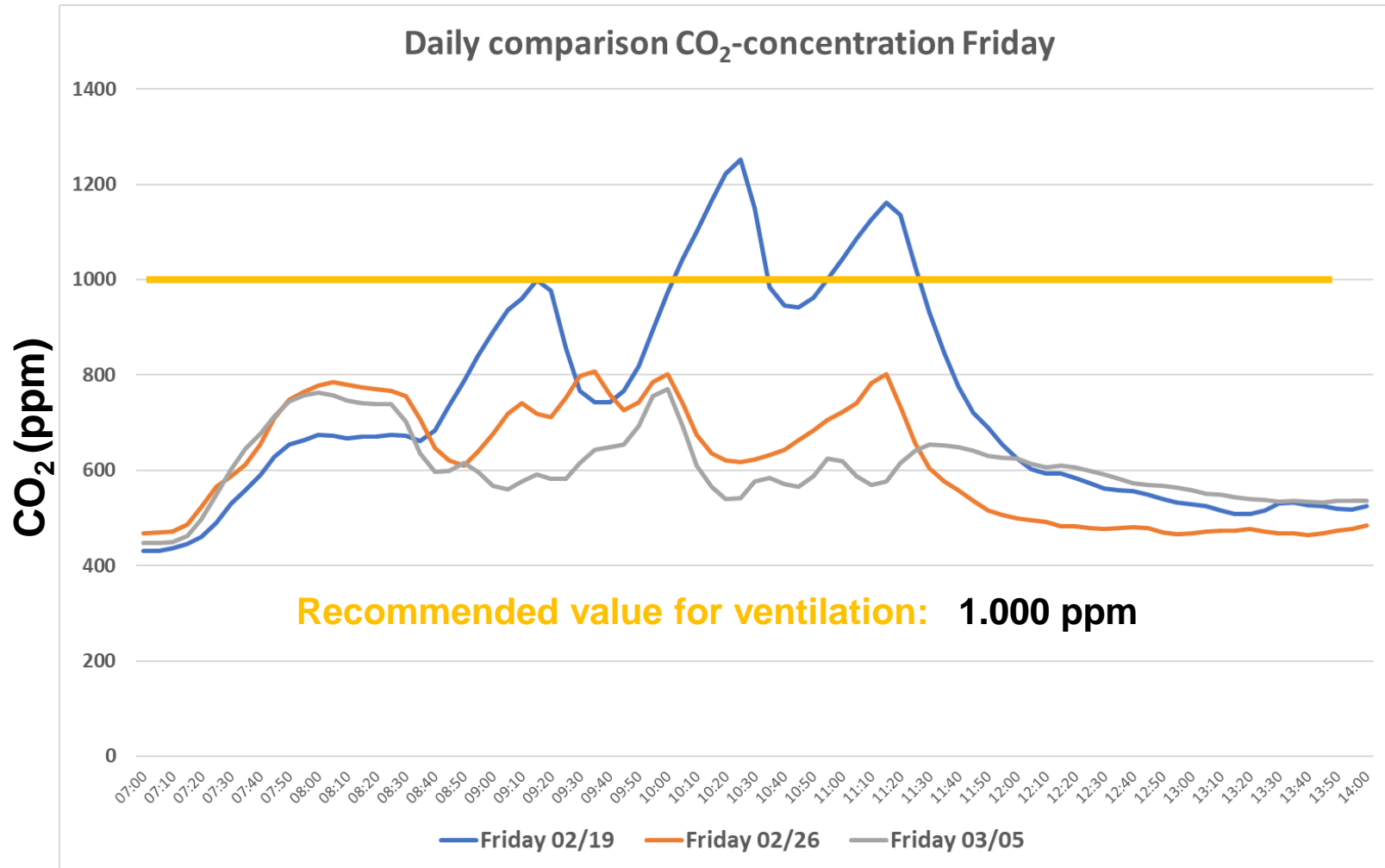
# CO<sub>2</sub>-concentration analysis



# CO<sub>2</sub>-concentration analysis



# CO<sub>2</sub>-concentration analysis



# Quality of weekly PM samples

Scientific proof that the recommended window opening practise led to a high level of imission of environmental fine dust into the classroom and school

Sahara- fine sand particles captured in the core of the school (Aula)

	Test week 1		Test week 2		Test week 3	
sample number	Z0072-1	in % of sample	Z0072-3	in % of sample	Z0072-5	in % of sample
Silicates (fine sand)	55	17%	166	46%	72	22%
Carbonates	68	21%	51	14%	58	17%
Sulphurous Particles	4	1%	8	2%	5	2%
Chlorous Particles	55	17%	16	4%	10	3%
Phosphorous Particles	4	1%	0	0%	3	1%
Carbon & Organic Particles	86	27%	69	19%	127	38%
Other Particles	12	4%	8	2%	19	6%
Non-attributable Particles	33	10%	45	12%	38	11%
Average Particle concentration	17 µg/m <sup>3</sup>		32 µg/m <sup>3</sup>		19 µg/m <sup>3</sup>	

Highest particle imission from environment in 2<sup>nd</sup> test week

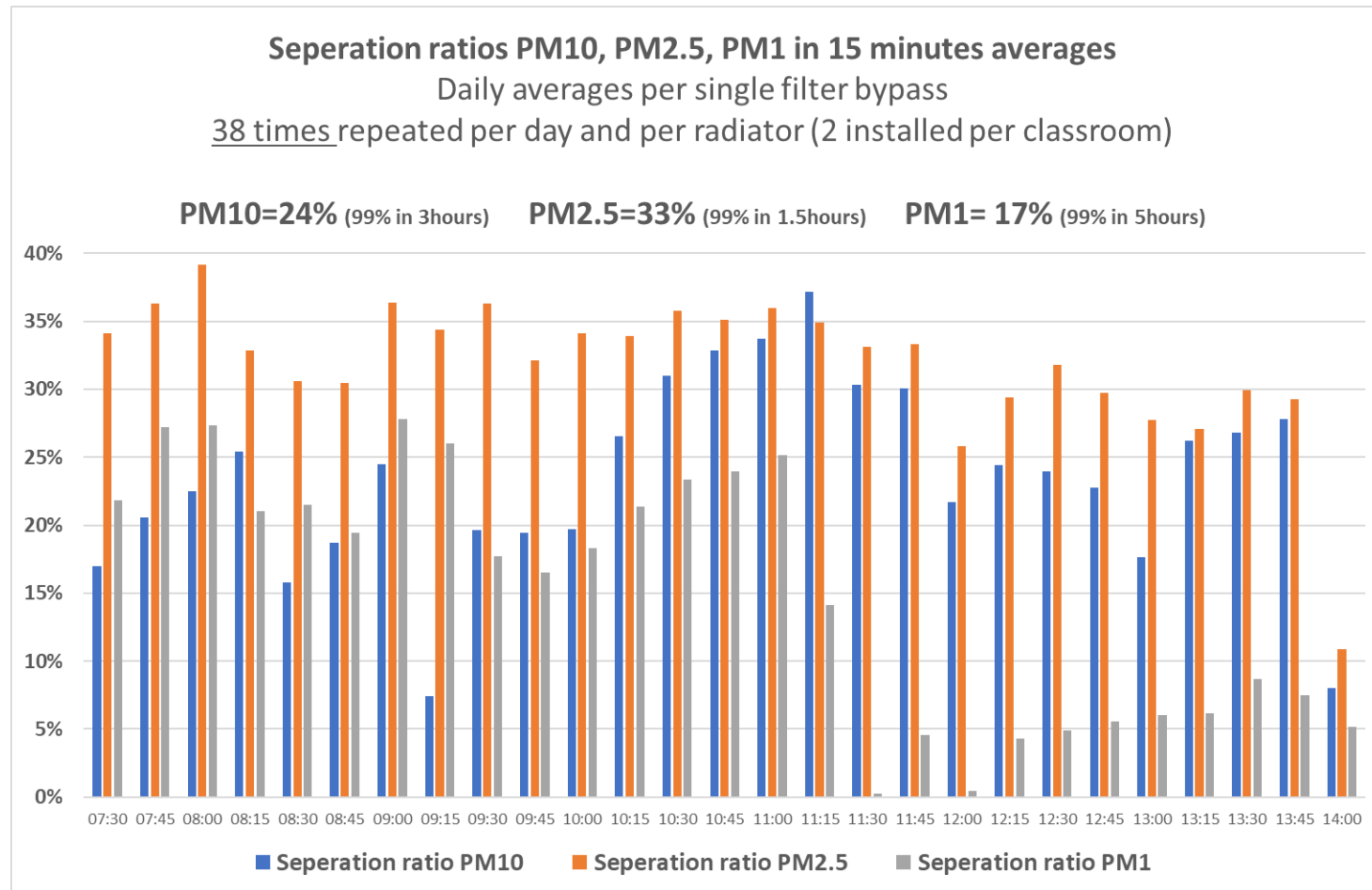
# particle pollution of one test day

test day H8 (Wednesday 24th February) is subjected to a detailed analysis of the data

		above radiator	below filter	mid room		above radiator	below filter	mid room		above radiator	below filter	mid room	
		PM10 [ $\mu\text{g}/\text{m}^3$ ]	PM10 [ $\mu\text{g}/\text{m}^3$ ]	PM10 [ $\mu\text{g}/\text{m}^3$ ]	Av	PM2.5 [ $\mu\text{g}/\text{m}^3$ ]	PM2.5 [ $\mu\text{g}/\text{m}^3$ ]	PM2.5 [ $\mu\text{g}/\text{m}^3$ ]	Av	PM1.0 [ $\mu\text{g}/\text{m}^3$ ]	PM1.0 [ $\mu\text{g}/\text{m}^3$ ]	PM1.0 [ $\mu\text{g}/\text{m}^3$ ]	Av
02/15	A1	42,73		43,47	<b>43,10</b>	7,42		11,10	<b>9,26</b>	4,13		6,39	<b>5,26</b>
02/16	B2	28,59		29,40	<b>28,99</b>	5,14		8,45	<b>6,80</b>	2,85		5,10	<b>3,97</b>
02/17	C3	36,11		37,83	<b>36,97</b>	4,46		7,66	<b>6,06</b>	1,89		3,50	<b>2,70</b>
02/18	D4	36,46		44,46	<b>40,46</b>	5,45		9,13	<b>7,29</b>	2,33		3,69	<b>3,01</b>
02/19	E5	30,76		38,47	<b>34,61</b>	6,45		11,02	<b>8,74</b>	3,79		6,76	<b>5,28</b>
		<b>34,93</b>		<b>38,73</b>	<b>36,83</b>	<b>5,79</b>		<b>9,47</b>	<b>7,63</b>	<b>3,00</b>		<b>5,09</b>	<b>4,04</b>
02/22	F6	33,84		43,93	38,88	11,29		15,05	13,17	8,56		11,20	9,88
02/24	H8	<b>32,33</b>	<b>42,42</b>	<b>84,36</b>	<b>53,04</b>	<b>10,81</b>	<b>16,16</b>	<b>20,13</b>	<b>15,70</b>	<b>5,51</b>	<b>6,68</b>	<b>8,30</b>	<b>6,83</b>
02/25	I9	45,64	57,33	111,49	71,49	15,19	22,11	27,10	21,47	8,72	10,87	12,83	10,81
02/26	J10		49,64	99,08	74,36		20,53	26,52	23,52		7,66	10,34	9,00
		<b>37,27</b>	<b>49,80</b>	<b>84,72</b>	<b>59,44</b>	<b>12,43</b>	<b>19,60</b>	<b>22,20</b>	<b>18,46</b>	<b>7,60</b>	<b>8,40</b>	<b>10,67</b>	<b>9,13</b>
03/01	K11	30,22	30,27	73,49	44,66	8,82	12,71	13,03	11,52	6,09	9,42	8,38	7,96
03/02	L12	29,84	28,81	71,37	43,34	8,76	12,24	14,89	11,96	6,12	8,89	10,17	8,39
03/03	M13	29,41	30,01	73,25	44,22	6,94	12,10	13,12	10,72	4,45	8,68	8,37	7,17
03/04	N14	36,87	34,57	83,95	51,80	8,12	12,68	13,06	11,29	4,76	8,30	7,40	6,82
		<b>31,58</b>	<b>30,92</b>	<b>75,52</b>	<b>46,01</b>	<b>8,16</b>	<b>12,43</b>	<b>13,53</b>	<b>11,37</b>	<b>5,36</b>	<b>8,82</b>	<b>8,58</b>	<b>7,59</b>

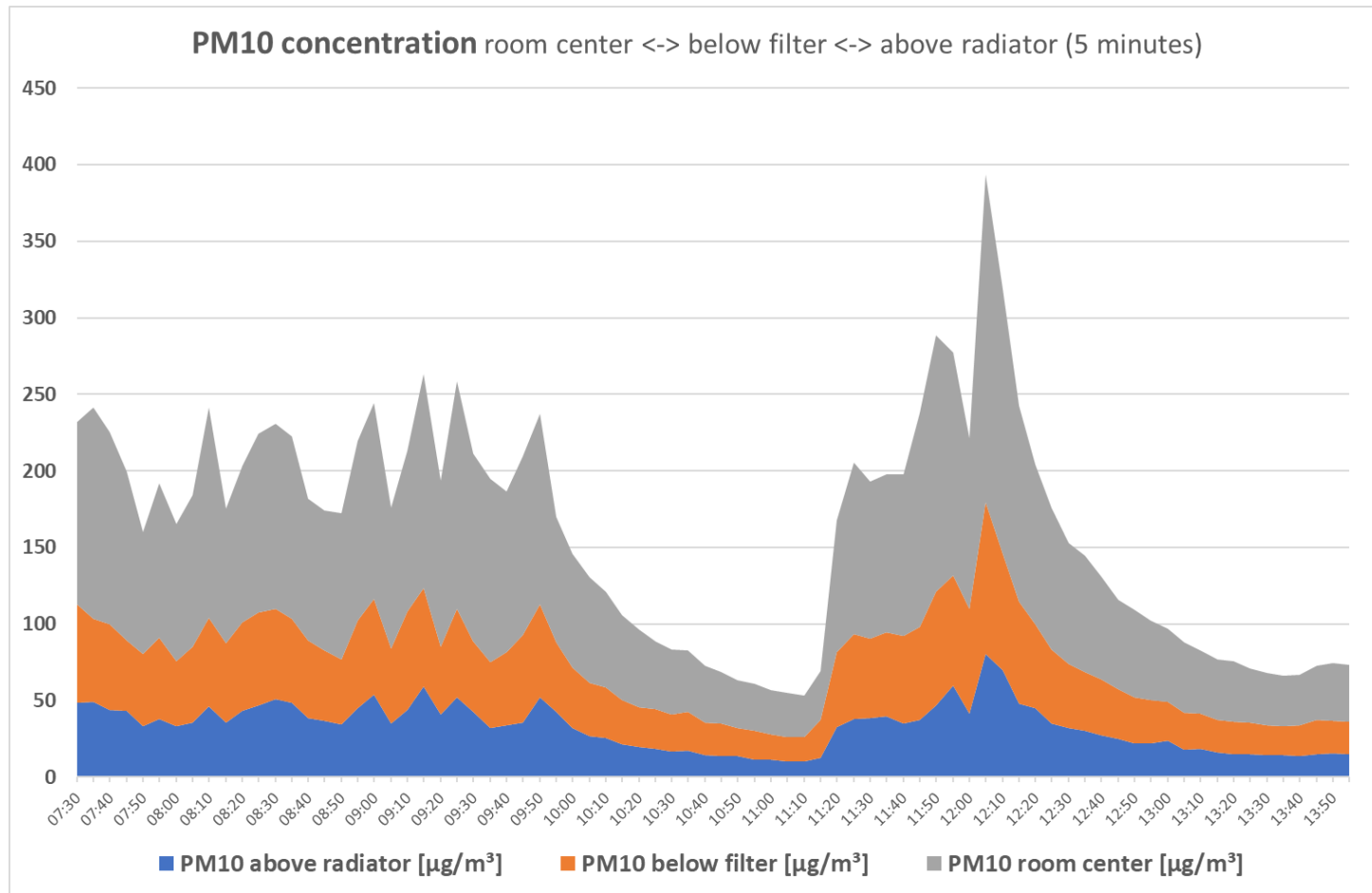
# Detailed analysis of February 24<sup>th</sup>

Due to Sahara-High and high ambient temperatures operation of active fan support



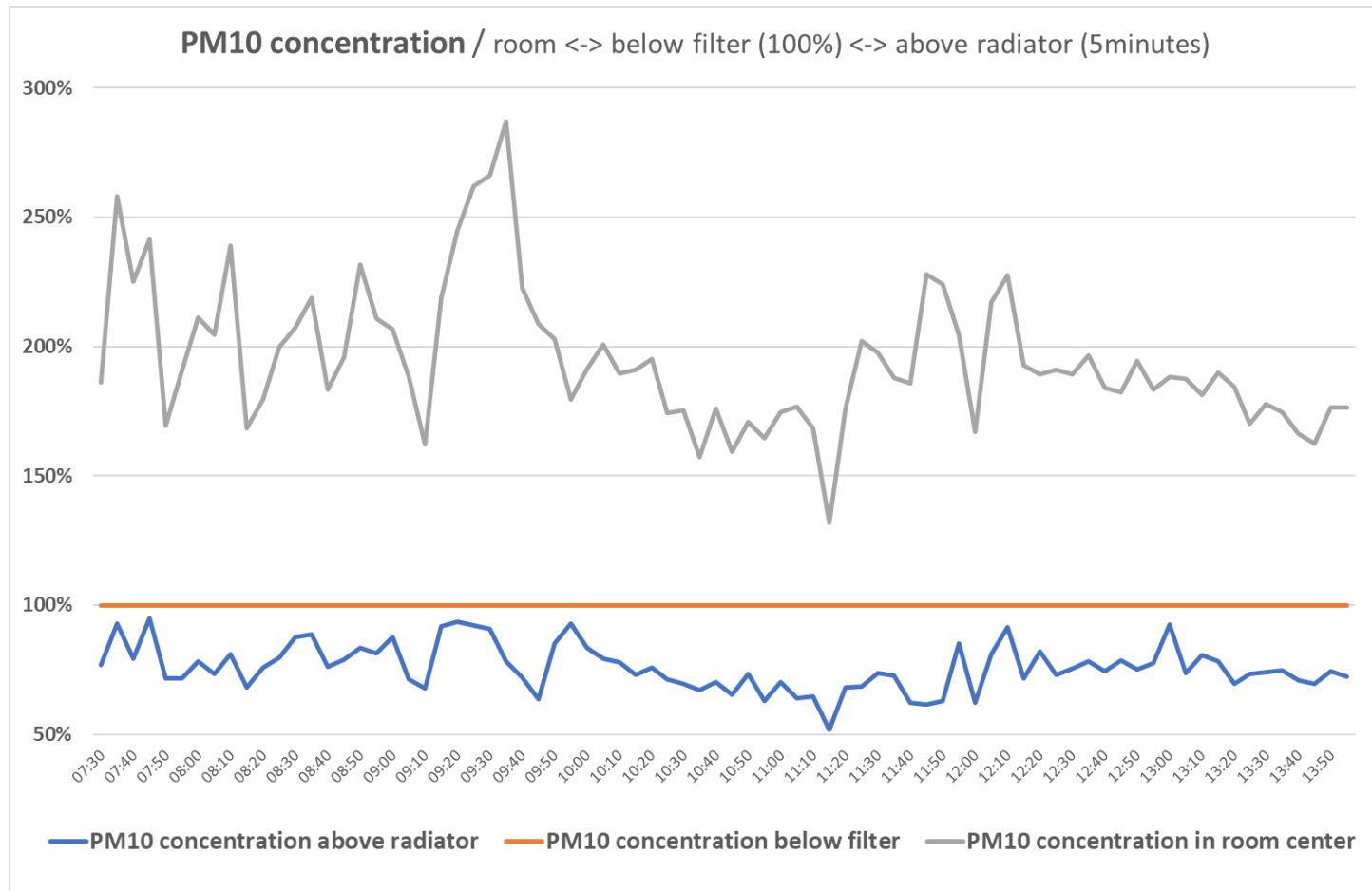
# PM10-Analysis February 24<sup>th</sup>

## PM10-finedust concentration in classroom 1A



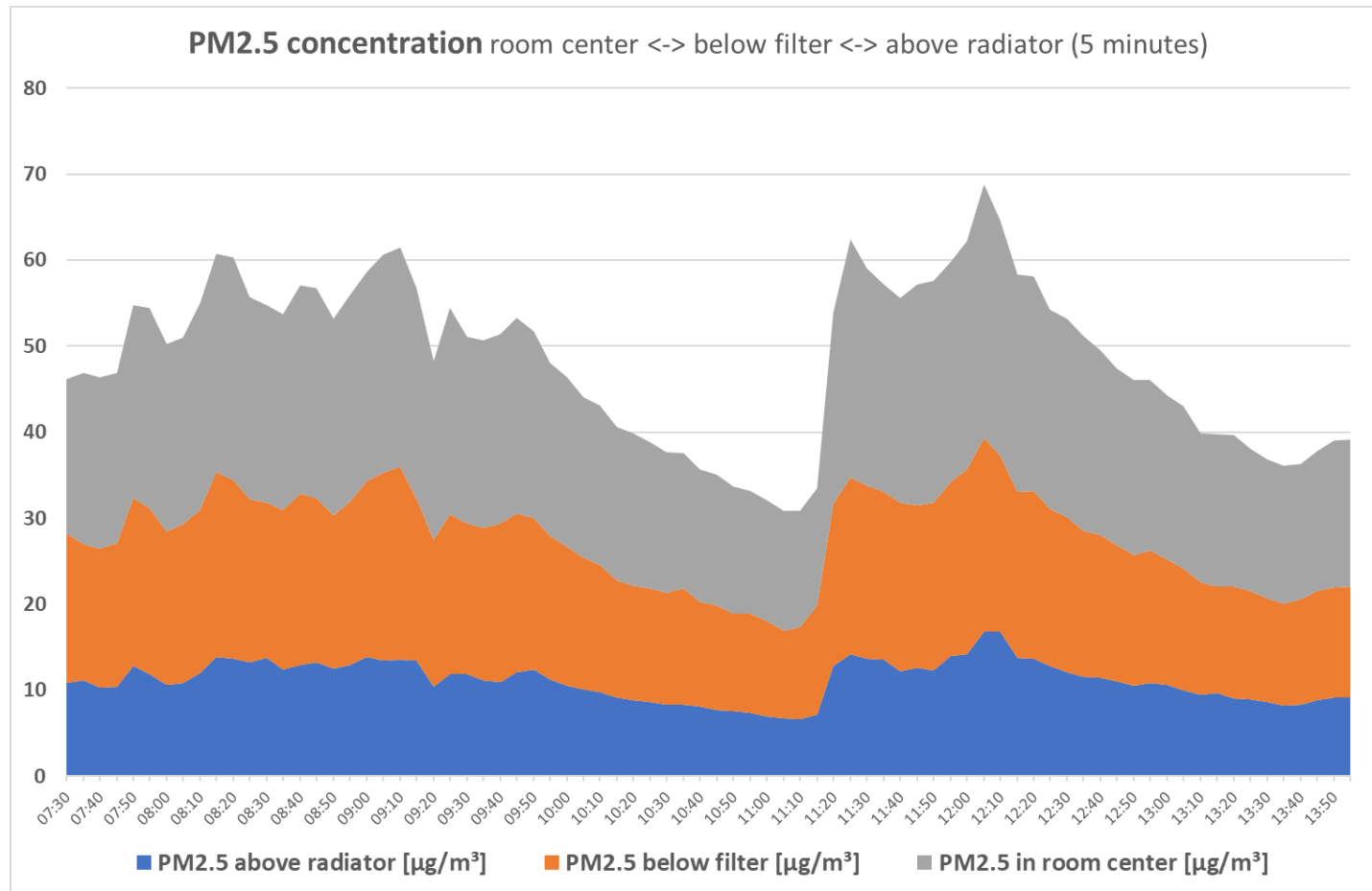
# PM10-Analysis February 24<sup>th</sup>

## PM10-finedust concentration in classroom 1A



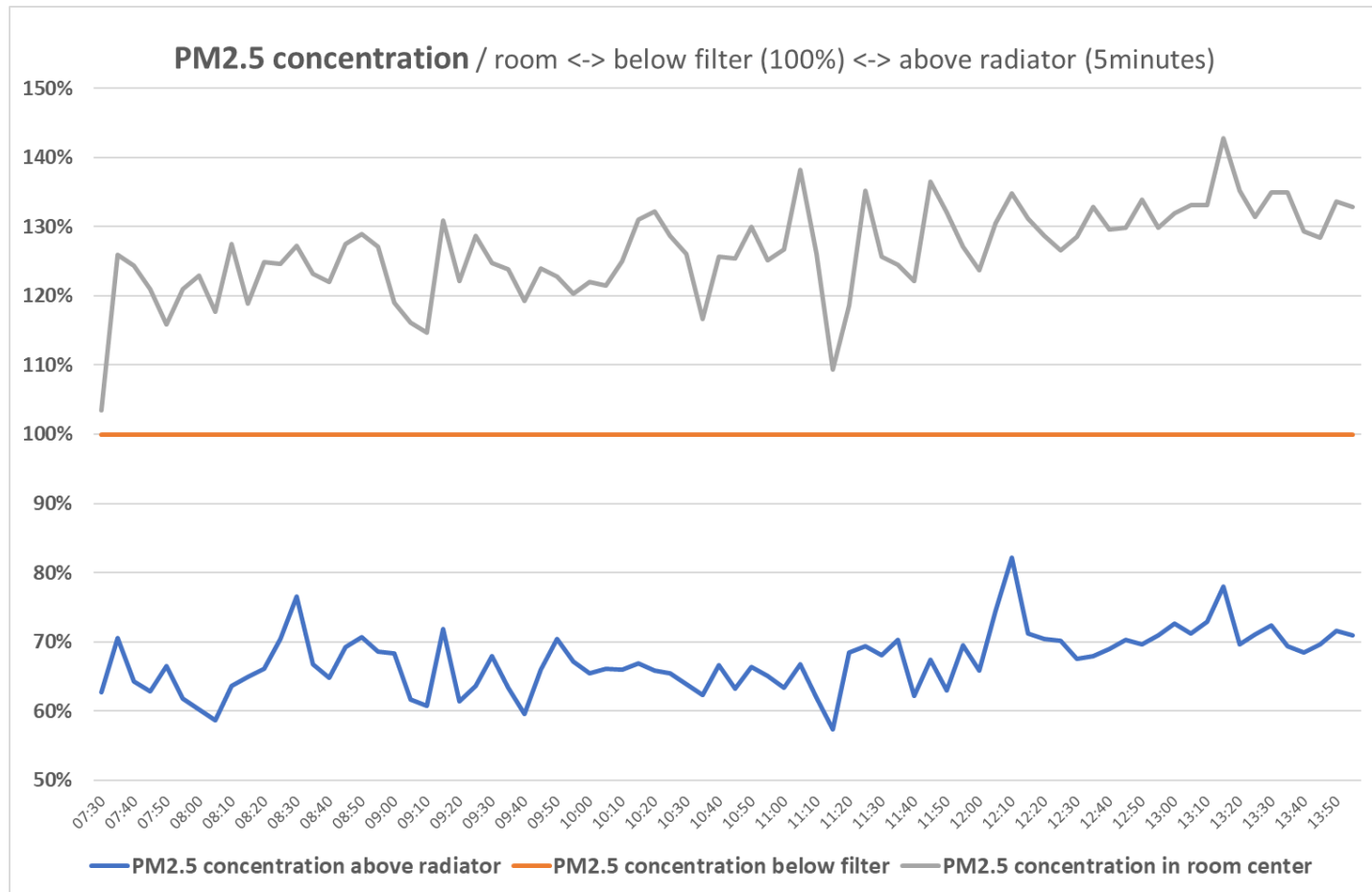
# PM2.5-Analysis February 24<sup>th</sup>

## PM2.5-finedust concentration in classroom 1A



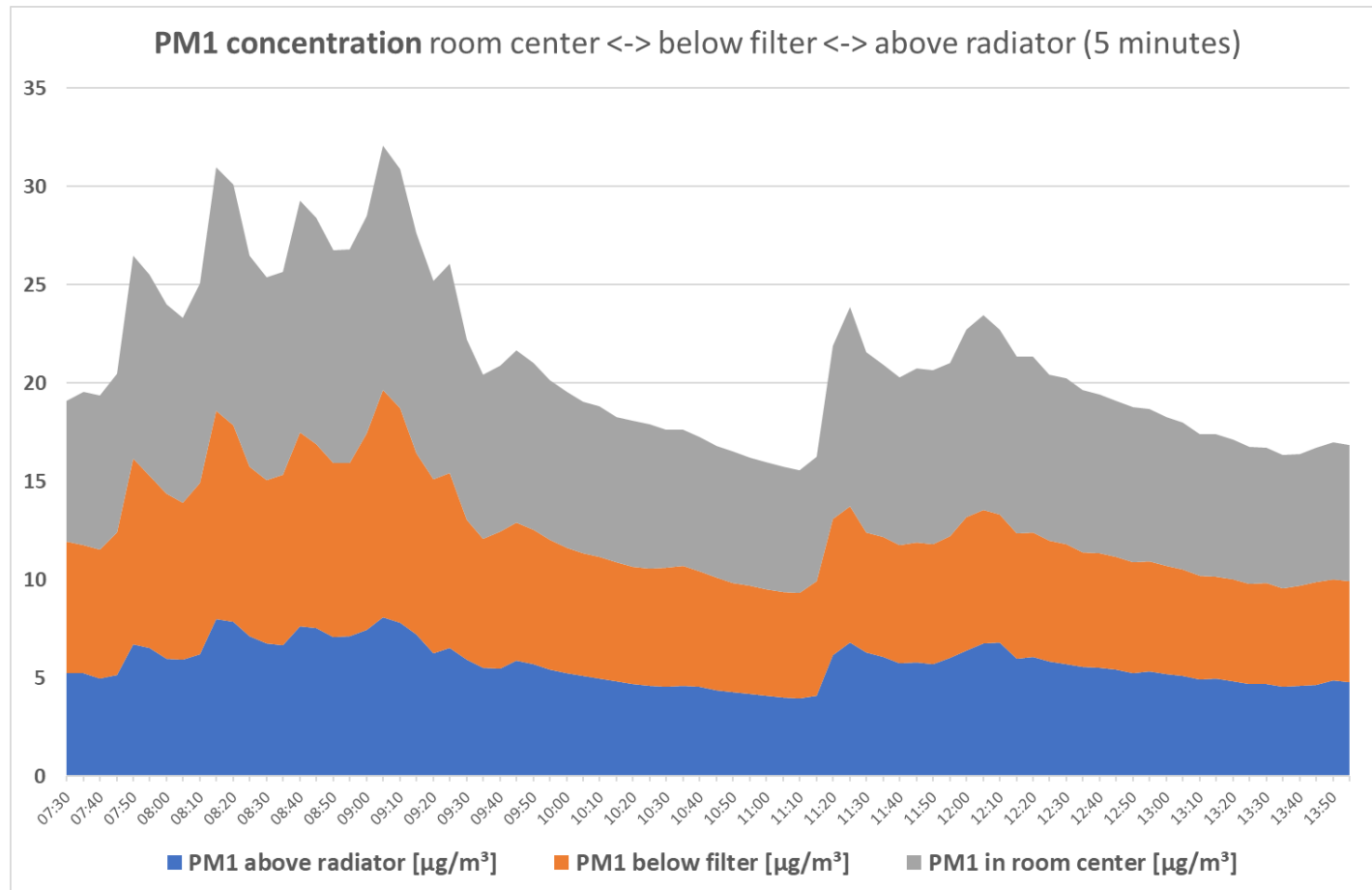
# PM2.5-Analysis February 24<sup>th</sup>

## PM2.5-finedust concentration in classroom 1A



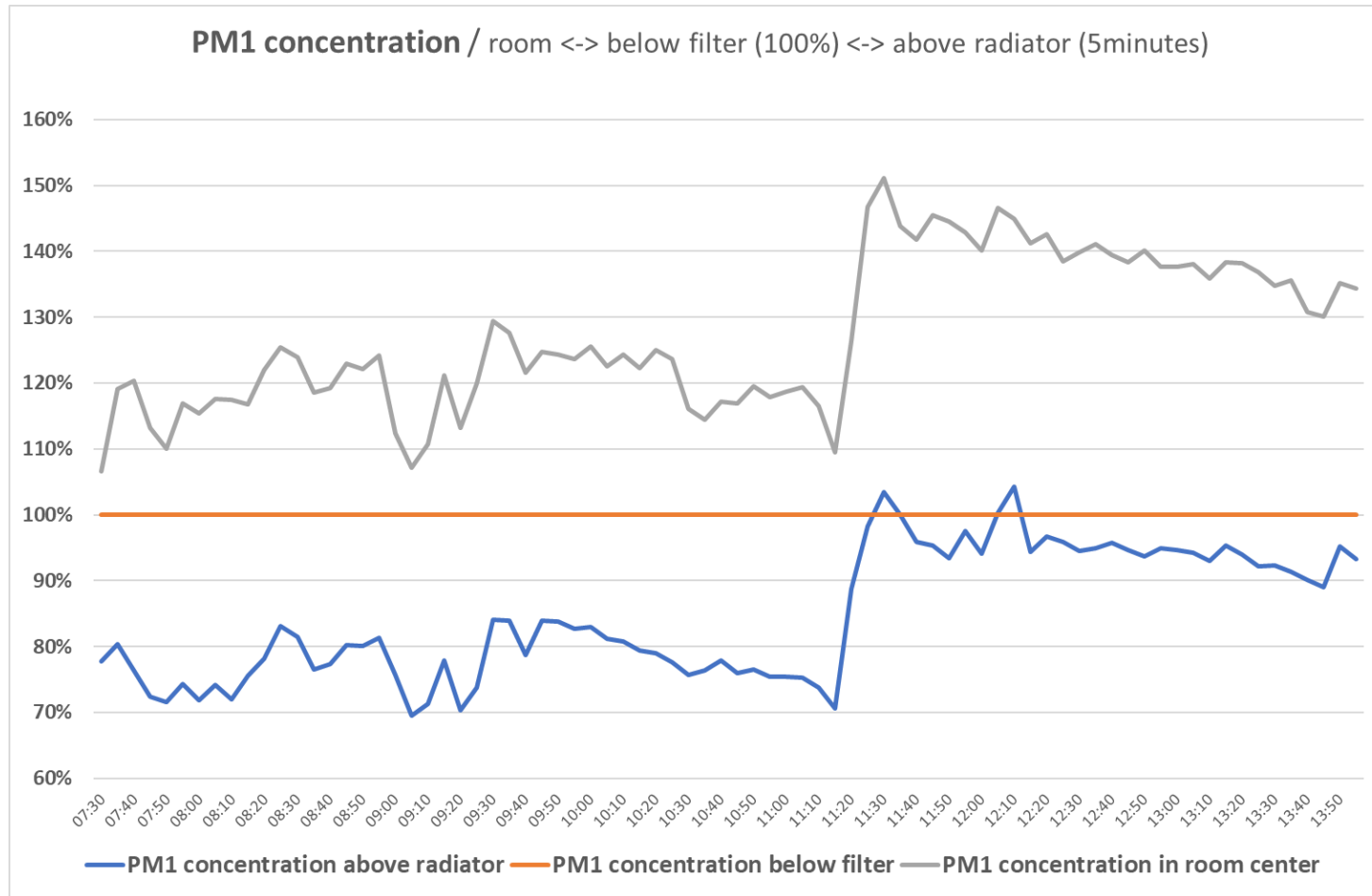
# PM1-Analysis February 24<sup>th</sup>

nanometer-size / ultrafine-dust-concentration in classroom 1A



# PM1-Analysis February 24<sup>th</sup>

nanometer-size / ultrafine-dust-concentration in classroom 1A



# Conclusion: Filter Effectiveness

## Degree of separation in the course of the day (sample day February 24):

The room air of the elementary school class (256 m<sup>3</sup>) is circulated 1.6 times per hour. This means that the room air is passing the filters and cleaned repeatedly a total of 38 times a day times 2 radiators.

1 Air throughput per radiator (= air circulation) was measured with an average filter effectiveness of:

<b>PM10:</b>	<b>24%</b>	<b>(3 hours 99% purification)</b>
<b>PM2.5:</b>	<b>33%</b>	<b>(1.5 hours 99% purification)</b>
<b>PM1:</b>	<b>17%</b>	<b>(5 hours 99% purification)</b>

After just a few runs, a **99% filter effectiveness** can be expected in all fine dust particle sizes.



# Overall filter assessment

- >> Proven filter effect in all fine dust sizes.
- >> Sustainable, environmentally friendly filter solution .

Dexwet filters show a satisfactorily high separation efficiency in all particle ranges and especially PM10 and PM 2.5

The filter solution is completely silent and does not require any energy. The PV-operated fan support even ensures an improved energy transfer from the radiators into the room.

Through the use of photovoltaic panels, **preventive, permanent room air purification is possible all year round** (use of solar energy to improve the air quality indoors).

In principle, a high level of particle imission by the students, but also extreme imission of environmental fine dust could be measured (Sahara-high with fine sand particles in the second week of the test).



# Overall assessment air quality

- >> High indoor air quality all year round.
- >> High health prevention.

The **high degree of separation** in all fine dust classes and the PV-operated fan solution guarantee excellent indoor air quality all year round.

A **dilution effect** in the CO<sub>2</sub> values can be demonstrated, but the CO<sub>2</sub> concentration remains consistently well below the limit values.

**Potential negative effects from airing every 20 minutes:**

Children and teachers report high distraction effects and impaired ability to concentrate and learn in weeks 2 and 3.

The **noise pollution** from the gravimetric measuring device in the corridor was also rated negatively (corresponds to the noise distraction generated by air purifier devices).



# Air purification in comparison

DPA – passive air purification	active air purifier devices
No electricity costs / photovoltaics	Additional electricity costs (overcoming filter resistance)
Improvement of energy efficiency through fan support and keeping the radiators clean as well as using the radiators for cooling outside the heating season	No influence on the energy efficiency of the heating system tems
Annual filter cleaning and long-term use	Regular filter replacement required (months-term)
No noise creation	Permanent background noise exposure
No ionization and no electrostatic fields	Additional electrosmog exposure
Low initial investment and hardly any running costs	Higher initial investment and higher running costs due to replacement filters and electricity costs

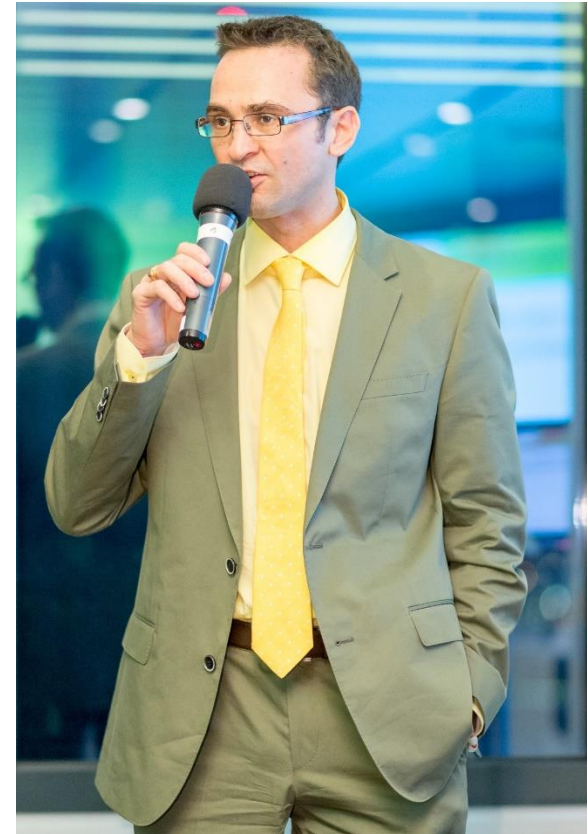
# Project team



Expert DI Peter Tappler



Jürgen Kettinger



Mag. Clemens Sparowitz