UNSW SYDNEY

Clean Air Schools Program: Final Report

Written for:
School Infrastructure, NSW Department of Education

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Executive Summary

This final report presents the background, methods, analysis and recommendations from the Clean Air Schools Program, a collaborative initiative between School Infrastructure and UNSW Sydney. Operating between 2023 and 2025, the program successfully collected one year of air quality data from representative classrooms in 59 schools across urban and rural NSW. We measured levels of particulate matter 2.5 microns or less in diameter ($PM_{2.5}$ indoor and outdoor), nitrogen dioxide (NO_2 outdoor, for urban schools), and carbon dioxide (CO_2 indoor).

Given the generally low levels of NO_2 across NSW, we strategically focused our outdoor NO_2 monitoring on urban schools and those near known industrial areas. Nearly half of monitored schools exceeded the NSW government *annual* threshold for NO_2 during the data collection period. However, very few schools exceeded the *hourly* threshold, and for almost all these schools, these exceedances occurred only a handful of times over the monitoring period. Among the 29 schools monitored for outdoor NO_2, only one site exhibited consistently elevated levels. We recommend further consideration of this site to identify and potentially mitigate the source of this pollution.

Our analysis of $PM_{2.5}$ revealed that both indoor and outdoor measurements largely remained below current NSW government thresholds for *annual* and *daily* exposure. Indoor $PM_{2.5}$ levels in classrooms typically remained lower than outdoor levels, indicating that school buildings generally provided a protective effect. We observed threshold breaches in some classrooms for indoor $PM_{2.5}$ compared with outdoor levels, likely due to indoor sources of air pollution being present for short periods. It should be noted that during the monitoring period NSW experienced relatively good air quality, with few bushfires and limited hazard reduction burn activity. Consequently, we were unable to identify whether this indoor/outdoor pollution gradient would become more pronounced on poor air quality days.

Our monitoring of CO_2 levels showed that the majority of the 59 monitored classrooms exceeded 850 ppm at some point over the school day. However, these exceedances were typically short-lived: for most classrooms, CO_2 levels remained below the 850 ppm CO_2 threshold for the majority of core school hours between 8:30am and 3pm, meaning the eight hourly average threshold was not consistently exceeded. Three classrooms consistently recorded levels above 1000 ppm throughout much of the school day. We recommend comprehensive ventilation assessments for these schools to determine whether this issue extends beyond the sampled classrooms.

Classrooms with natural cross-ventilation and/or participating in the Cooler Classrooms Program had lower CO_2 levels compared to classrooms without these features. However, many of these classrooms still regularly experienced CO_2 levels above the 850 ppm threshold.

These findings indicate that some teachers in naturally ventilated classrooms may be teaching with closed windows. While this may help reduce infiltration of outdoor $PM_{2.5}$ pollution into the classroom, it reduces fresh air ingress, which is needed to dilute indoor CO_2 levels. The reasons why teachers keep windows closed are likely not directly related to air quality concerns. Further research is needed to identify their motivations; however, anecdotal reasons include reducing external noise, minimising distractions or discomfort caused by drafts, and preventing rain from entering through open windows. Additionally, depending on the season, temperature control may be another factor influencing teachers' decisions to keep windows closed.

More detailed findings are presented in subsequent sections of this report. We provide program background, data overview, analysis and limitations, and recommendations based on our analysis. We have included simplified best practices for improving air quality in the form of an infographic and an education campaign targeted at school children and teachers.

Background

About Clean Air Schools

The Clean Air Schools Program was provided with a list of 100 schools prepared by School Infrastructure. Due to constraints around access and installation caused by the COVID-19 response, a subset of 59 of these schools were successfully included in the program. The majority of these were primary schools, but 15 high schools and one all-ages school also participated. We identified that these schools included 12 Cooler Classroom Program schools and three sealed schools. Participating schools are listed in Appendix A.

Locations of participating schools

Distributed across six asset management units (AMU), 49 of the participating schools were within the Sydney Greater Metropolitan Region (GMR), eight in and around Newcastle, and two in Wollongong, as detailed in Figure 1. Several schools had a start date prior to June 2024, however, the program collected data from all schools by this date until April 2025.

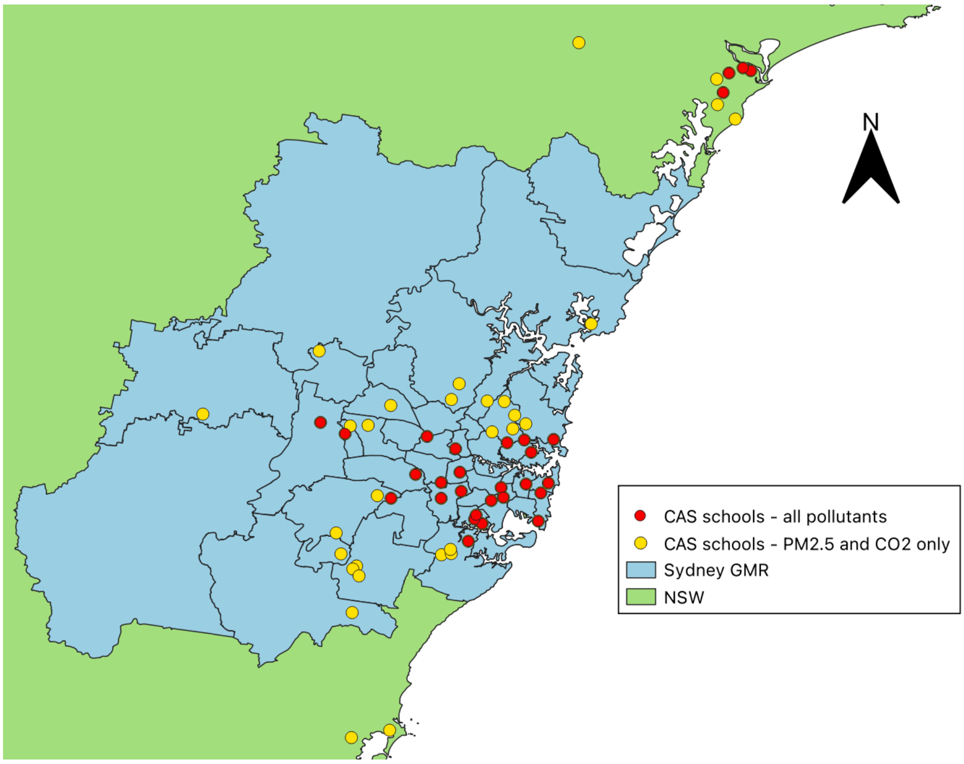


Figure 1: Location of participating schools in the Sydney Greater Metropolitan Region and beyond.

Methods

Significant logistical hardware installation and data communication issues needed to be resolved before data collection could begin, as some AMUs were unable to install hardware in schools directly as initially planned.

Hardware and data collection

Each participating school had two weather stations and two air quality sensors installed – one of each inside and outside the school buildings. We installed Clarity Node sensors and Efento weather stations.

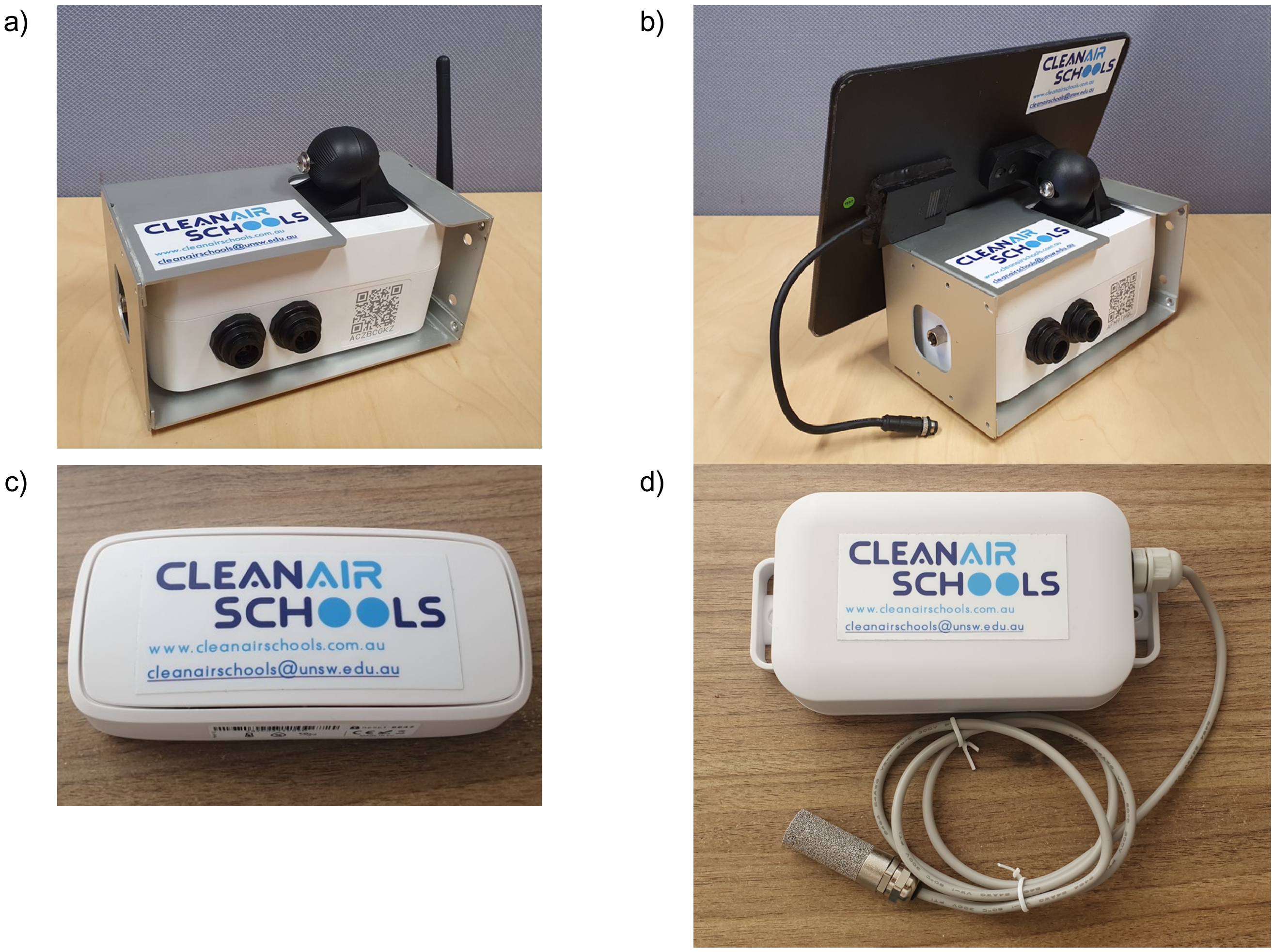


Figure 2: Air quality sensors and weather stations: a) indoor air quality sensor; b) outdoor air quality sensor; c) indoor weather sensor; and d) outdoor weather sensor.

Room selection and outdoor placement of hardware

A representative classroom was chosen for each school by the installing contractor or visiting asset services officer (ASO), based on criteria provided for them. Chemistry labs, workshops or other non-standard rooms were not permitted as install locations. Within each selected classroom, sensors were placed to avoid obvious sources of air pollution such as printers, air conditioning units, chalkboards or electric pencil sharpeners. Each indoor sensor was installed following a set criteria aimed at being representative of the room's air quality while reducing the chance of interference by students. These criteria included ensuring each indoor sensor was wall-mounted at least 1.5m from the floor, with the indoor weather station installed next to the wall-mounted indoor air quality sensor. Initially, in nine schools, the decision was made by the visiting ASO or contractor to install the indoor sensors in the school library or common room rather than a classroom. For reasons covered in more detail later in this report, these sensors were subsequently relocated to representative classrooms as detailed above.

Outdoor sensor locations were chosen to be representative of air quality in locations accessed by children for recess or other outdoor activities, such as sports fields. They were installed on fences or poles about two metres above the ground, away from external vents, roads, or excessive shading that could hinder proper solar panel function.

The air quality sensors were set to measure particulate matter 2.5 microns or less in diameter ($PM_{2.5}$) and nitrogen dioxide (NO_2), in selected schools every 15 minutes. Carbon dioxide (CO_2), temperature, relative humidity and air pressure were measured every 30 minutes. An interface was built to download and securely store these data.

In-situ school surveys were conducted during pupil-free times in the summer holidays of 2024–25 to gather secondary data (see Appendix B). This survey included identifying room ventilation type, room volume and proximity to nearby roads or other possible external pollution sources.

At the end of the data collection phase, all AMUs were contacted to inform them of the need to remove and safely dispose of the sensors, which had reached the end of their life.

Air quality results and analysis

Nitrogen dioxide levels

In all 29 schools where outdoor NO_2 levels were monitored, the average NO_2 level in each school was compared to the hourly and yearly health thresholds set by NSW: currently 15 parts per billion (ppb) per year and 80 ppb per hour. Of the 29 schools, two schools were excluded from the final analysis due to concerns about data quality (Callaghan College Jesmond Senior Campus and Garden Suburb Public School - see next sub-section). For the remaining 27 schools where outdoor NO_2 was analysed, 12 had an average NO_2 level above the yearly NSW threshold of 15 ppb. Only three had an average NO_2 level above 20 ppb, and only one had an average level above 30 ppb (see Figure 3a).

While a significant number of schools exceeded the average yearly threshold, concern from NO_2 exposure typically comes from short-term exposure to high levels. Out of 27 schools, five had hourly NO_2 concentrations that breached the NSW hourly threshold of 80 ppb (see Figure 3b). Of these five schools, two breached the threshold once over the entire 10-month monitoring period, and two breached the threshold fewer than five times (see Figure 4). The school with the highest number of hourly threshold exceedances experienced 14 hourly threshold breaches. These figures suggest that for the most part, monitored schools rarely experienced outdoor NO_2 concentrations that posed an elevated health threat to students or staff.

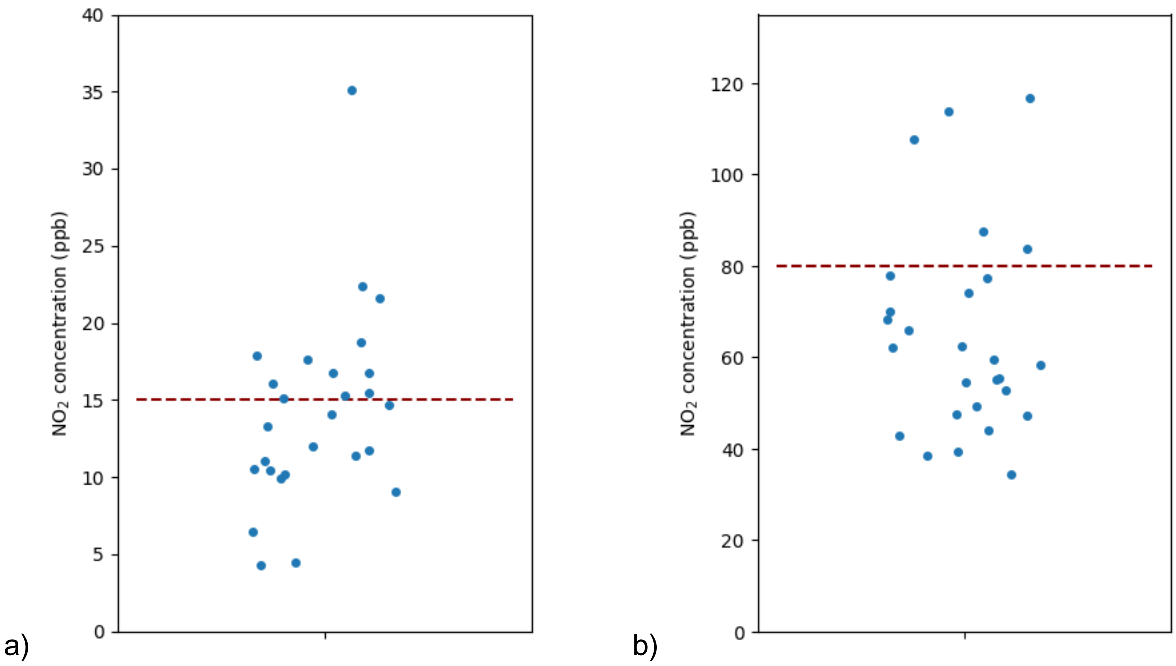


Figure 3: NO_2 levels measured for each school against NSW thresholds: a) annual; and b) hourly, represented by a dashed dark red line.

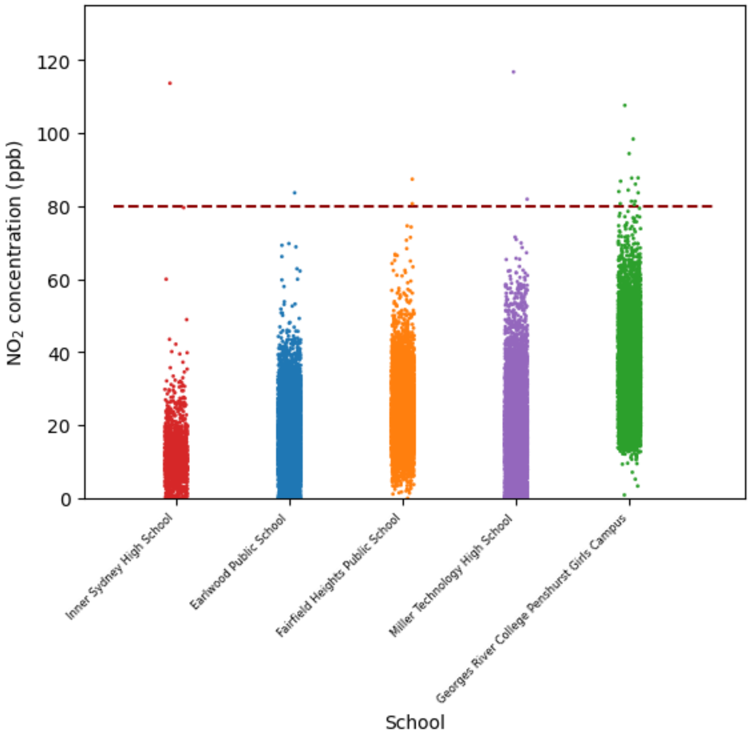


Figure 4: Hourly NO_2 concentrations measured in each school compared to the NSW hourly NO_2 threshold, represented by a dashed dark red line.

When comparing the spatial distribution of schools and their overall average NO_2 readings, we found no strong spatial correlation between schools with elevated levels of NO_2 (Figure 5). This likely illustrates that sources of NO_2 near schools – such as traffic and industry – are highly localised.

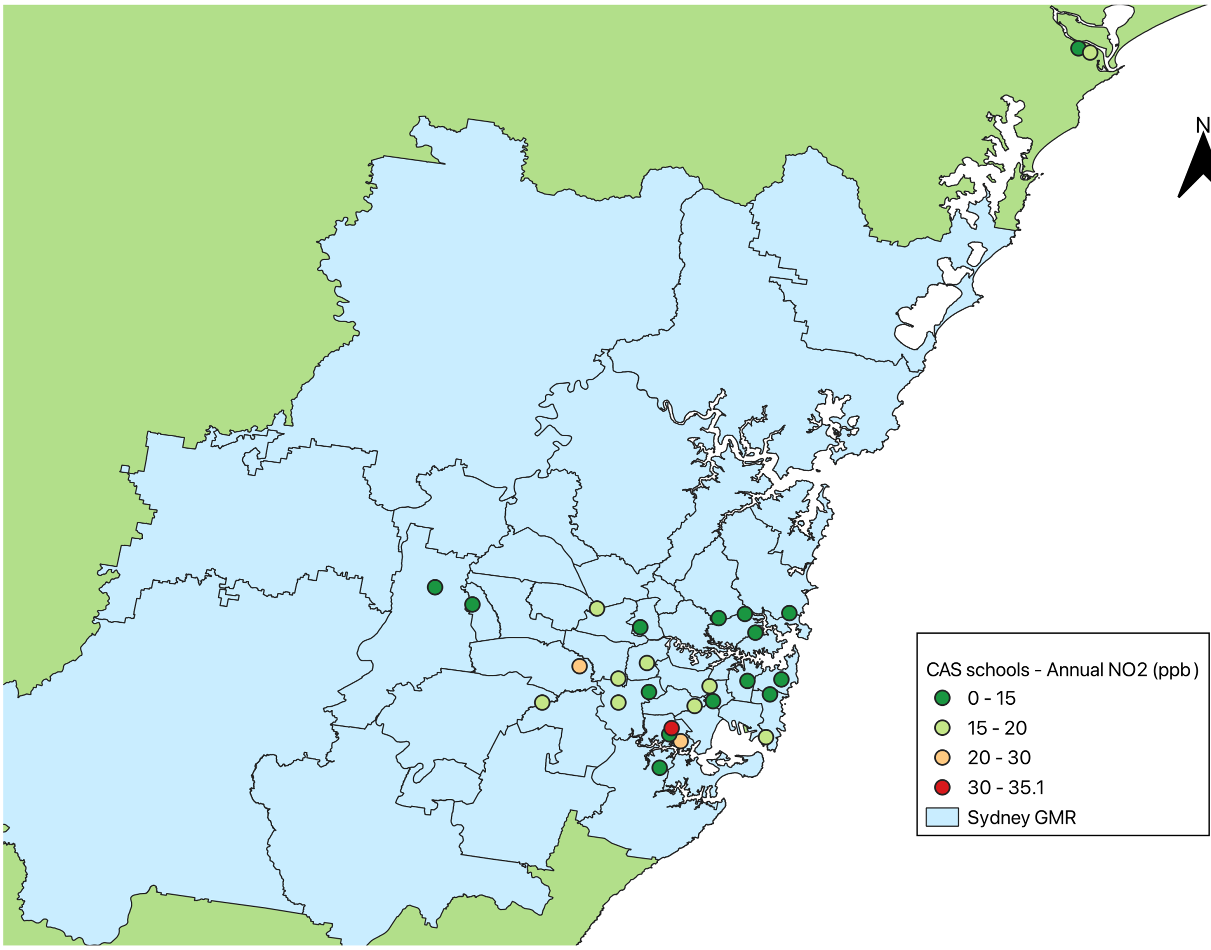


Figure 5: Map of schools and their overall average NO_2 levels.

Data quality verification

Based on the initial readings from the sensors of 29 schools prior to the full analysis, the program team expressed concerns about the sensors from three schools that experienced hourly outdoor NO_2 threshold exceedances. To verify the data, we communicated extensively with the monitor manufacturer, assessed the effects of temperature and humidity on reading accuracy, and tested alternative calibration models to compare and assess their representativeness.

One school, Callaghan College Jesmond Senior Campus, was assessed to be overestimating NO_2 concentrations - likely due to a hardware malfunction. This malfunction occurred in early August after almost two months of monitoring. Prior to the likely malfunction, the NO_2 concentration outside the school had never exceeded 40 ppb.

Garden Suburb Public School was also assessed to be overestimating NO_2 concentrations due to an unsuitable calibration model. Prior to deployment, all NO_2 sensors had their measurements calibrated against a NSW reference monitor for at least four weeks. These calibration models adjust for various meteorological conditions but may not be representative enough of the actual conditions in which the sensor is deployed. Based on the sensor measuring substantially higher NO_2 levels in summer compared to winter, despite no evidence of higher emissions near the school, it was concluded that the elevated sensor readings were due to a calibration model that was not representative of the meteorological conditions outside the school.

Only one school of the three, Georges River College Penshurst Girls Campus, was concluded to have accurately represented the NO_2 levels experienced at the school. This was significant, as the overall average outdoor NO_2 level was well above the yearly threshold (35.68 ppb) and the hourly level was frequently near the hourly threshold. The high overall level and consistency of NO_2 at this school could possibly be explained by nearby roads/train movements, nearby construction and industrial pollution, local idling of internal combustion engine cars during pick-up/drop-off times, or a combination of any of these factors. Further investigation might be warranted at this school to identify and, if possible, reduce pollution sources.

The results of our monitoring of outdoor NO_2 illustrate that, in general, areas around tested schools in NSW have low levels of NO_2. These levels may be slightly above long-term thresholds in some schools; however, the risk from exceedances from more acute short-term NO_2 peaks – which may pose a more serious risk to children – was rarely seen in our data. These results are supported by existing monitoring, which has found that NSW generally low levels of outdoor NO_2.

Fine particulate matter

Out of the 59 schools monitored for $PM_{2.5}$, indoor levels were monitored in all schools and outdoor levels were monitored in all but one school (its exclusion was due to the monitor being stolen shortly after installation). The measured $PM_{2.5}$ levels from these schools were compared to the current NSW thresholds for annual and daily levels of $PM_{2.5}$, which are 8 and 25 micrograms per cubic metre (µg/m³), respectively.

Outdoor fine particulate matter

The average overall levels of outdoor $PM_{2.5}$ in all schools were below the NSW annual threshold of 8 µg/m³ (Figure 6a). Unsurprisingly, outdoor $PM_{2.5}$ levels of schools near each other tended to trend closely.

The daily average levels of outdoor $PM_{2.5}$ exceeded the NSW daily threshold of 25 µg/m³ once in one school (see Figure 6b). Four other schools almost exceeded the NSW daily threshold, but these peaks were rare, and in three cases, their daily average outdoor $PM_{2.5}$ exceeded 15 µg/m³ only once or twice. The generally low levels of outdoor $PM_{2.5}$ reflect the absence of major bushfire and dust storm events in NSW during the monitoring period.

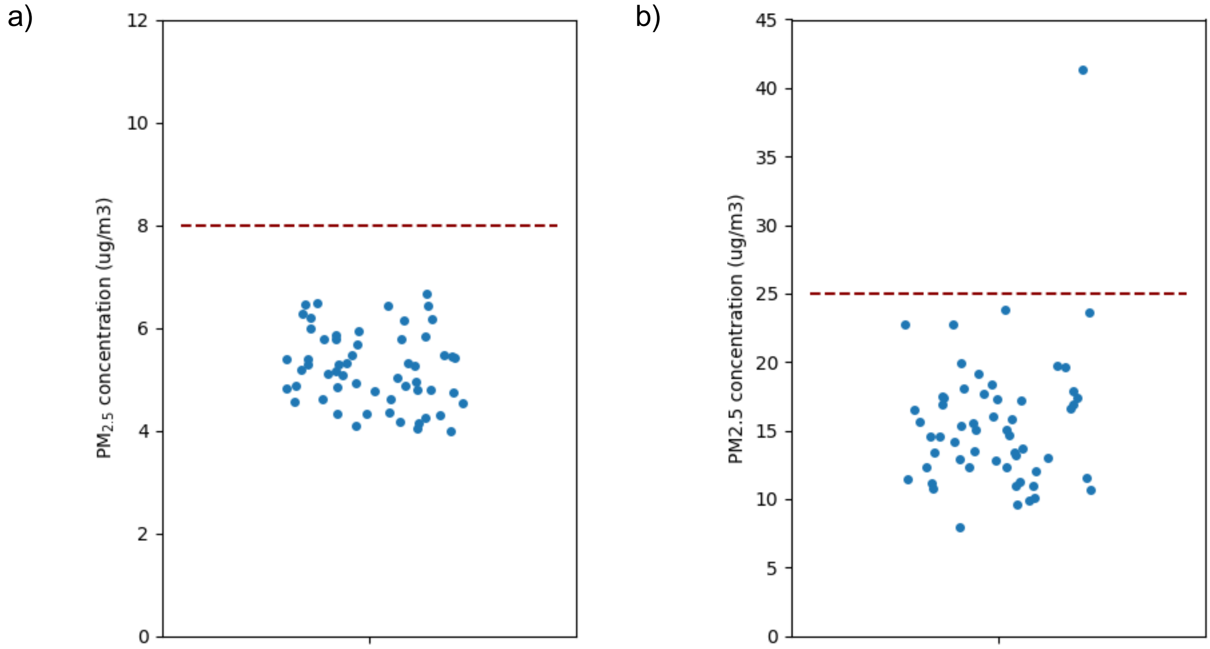


Figure 6: Outdoor $PM_{2.5}$ levels measured by schools over program duration against NSW thresholds: a) annual; and b) daily, represented by a dashed dark red line.

Indoor fine particulate matter

Average annual indoor $PM_{2.5}$ levels in all schools were below the NSW yearly threshold of 8 µg/m³ (Figure 7a). This aligns with previous research that has found that the primary source of indoor $PM_{2.5}$ comes from outdoors, and that indoor spaces generally provide some level of protection from outdoor sources.

The daily average levels of indoor $PM_{2.5}$ exceeded the NSW daily threshold of 25 µg/m³ in six classrooms (Figure 7b). Of these six locations, four exceeded the daily threshold only once, and the maximum exceedances experienced by any school was three (see Figure 8).

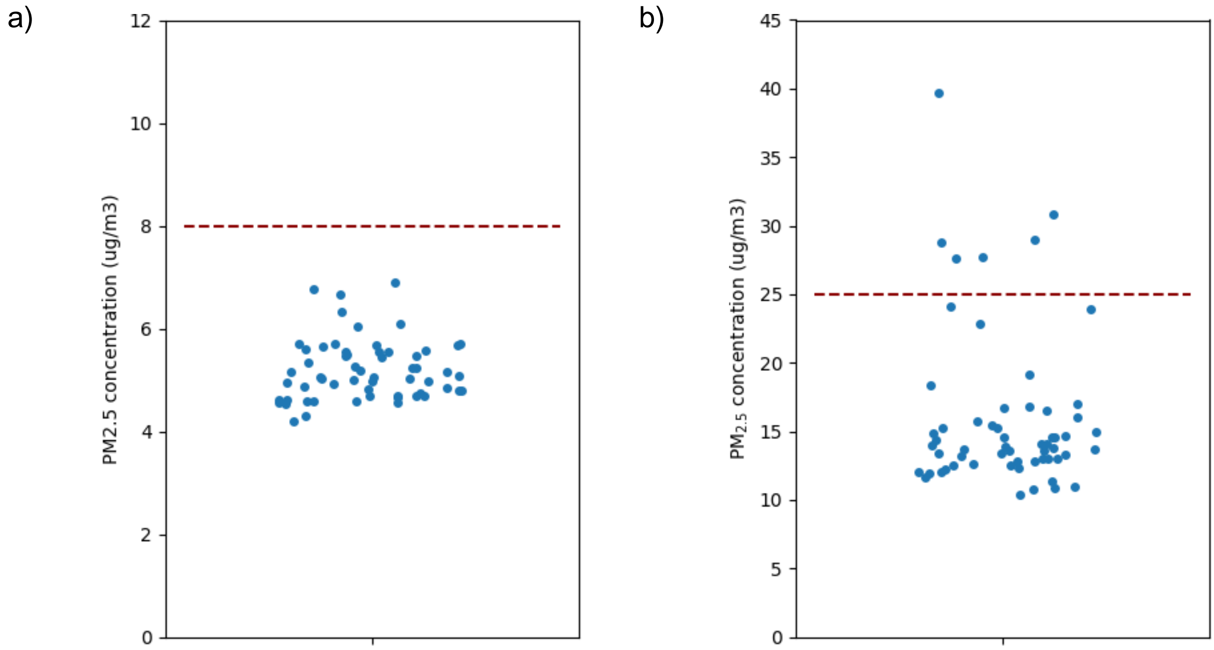


Figure 7: Indoor $PM_{2.5}$ levels measured by schools over program duration against NSW thresholds: a) annual; and b) daily, represented by a dashed dark red line.

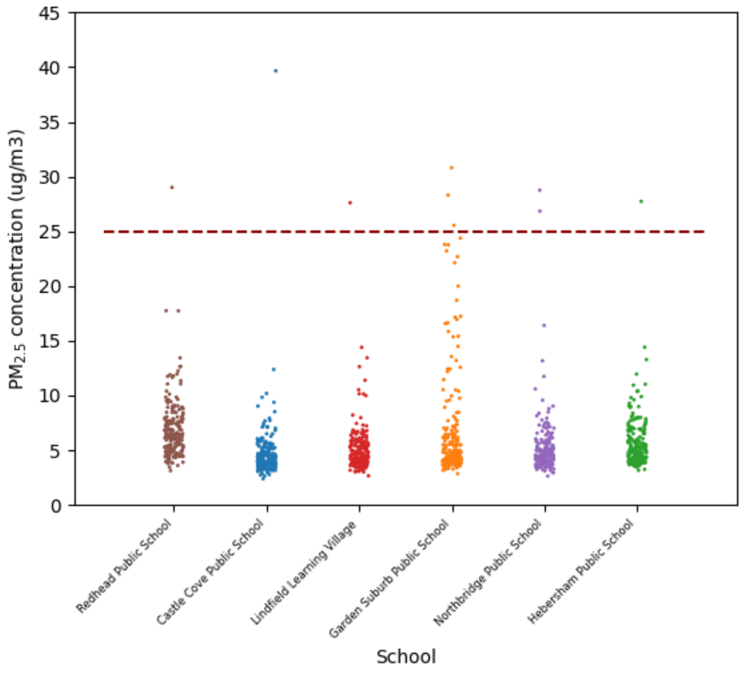


Figure 8: Daily $PM_{2.5}$ concentrations measured in each school that exceeded the NSW daily thresholds compared to the NSW daily $PM_{2.5}$ threshold, represented by a dashed dark red line.

The higher number of daily exceedances of indoor $PM_{2.5}$ levels compared to outdoor levels is supported by previous research. That research shows that while outdoor sources are the primary source of indoor air pollution most of the time, indoor sources can cause acute peaks, causing indoor air pollution levels to spike above outdoor levels for short periods. Indoor sources contributing to $PM_{2.5}$ levels depend on the specific classroom and activities involved. Examples of possible sources include students running around on carpet and recirculating dust, burning candles, and using kitchen or cooking equipment.

The results of $PM_{2.5}$ monitoring show that, apart from major outdoor events such as bushfires and dust storms (which did not occur during the monitoring period), the classrooms tested in NSW schools experienced low levels of $PM_{2.5}$ air pollution. Further monitoring of a smaller number of classrooms is recommended to capture and understand the impact of major events such as bushfires or prescribed burns on outdoor and indoor $PM_{2.5}$ levels in schools. This will be essential to more accurately assess the protective nature of school buildings during peak pollution episodes, to inform policy and the actions that should be taken during these times.

Carbon dioxide levels

Between June 2024 and December 2024, CO_2 sensors were mostly located in classrooms, with nine put in libraries or common rooms. Median CO_2 values from these sensors are reported because the distribution of CO_2 values is heavily skewed towards the ambient level and therefore the mean tends to be heavily influenced by a few very high values. Over this period, the average of all median CO_2 levels in monitored libraries and common rooms was 542.7 ppm, substantially lower than the average of all median values for classrooms which was 659.6 ppm. No libraries or common rooms had median CO_2 values that breached the recommended 850 ppm threshold set by NCC, likely due to being occupied less frequently by fewer people and having larger room volumes (see Figure 9). For this reason, after the initial six program months, these sensors were relocated to classrooms.

The three classrooms that consistently recorded levels above 1000 ppm throughout much of the school day were at Mayfield East Public School, Condell Park High School and Hebersham Public School.

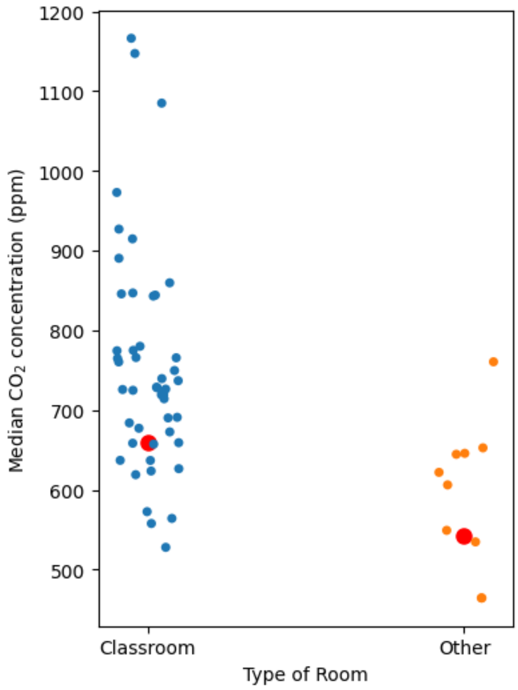


Figure 9: Median CO_2 concentrations between classrooms compared to non-regularly used rooms (i.e., libraries and common rooms) for 2024 data. Classrooms missing > 25% of data were excluded. Large red dots represent the average of all median CO_2 levels by room type.

For the remainder of the program period, with all non-classroom sensors relocated to classrooms, we found 39 of the 59 participating schools had median levels of CO_2 during school hours that were below the 850 ppm threshold (see Figure 10). However, if the full program period (with all participating schools) was considered, 46 out of 59 schools had median levels of CO_2 under the 850 ppm threshold.

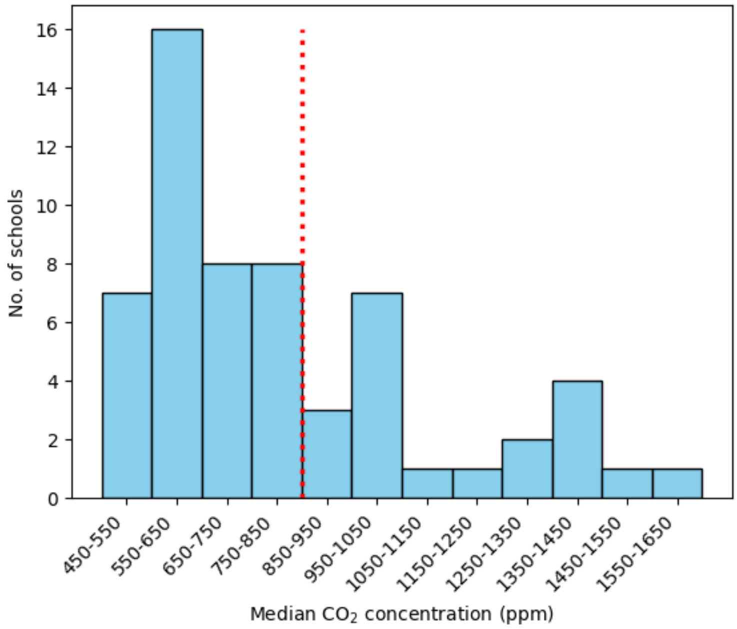


Figure 10: Histogram of median CO_2 concentrations for schools during 2025. The red dashed line represents the recommended threshold of 850 ppm.

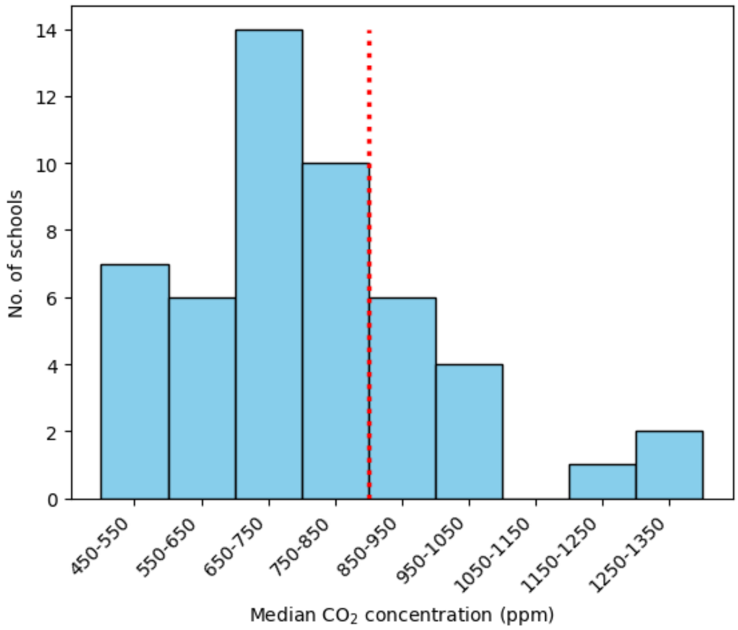


Figure 11: Histogram of median CO_2 concentrations for schools with libraries and common rooms excluded. The red dashed line represents the recommended threshold of 850 ppm.

When measuring seasonal or term-based differences in CO_2 levels within classrooms, median CO_2 concentrations were relatively consistent between each term (see Figure 12). Term 4 of 2024 had a somewhat lower average of median CO_2 levels (740.7 ppm) compared to others (Term 2, 2024: 817.6 ppm; Term 3, 2024: 789.3 ppm; Term 1, 2025: 814.9 ppm), but not substantially so. Further, the number of classrooms with very high median CO_2 levels was notably highest in Term 1 of 2025 with seven classrooms experiencing median CO_2 levels above 1200 ppm, more than any other semester. This may be explained by a change in teacher behaviour and student numbers with the new school year.

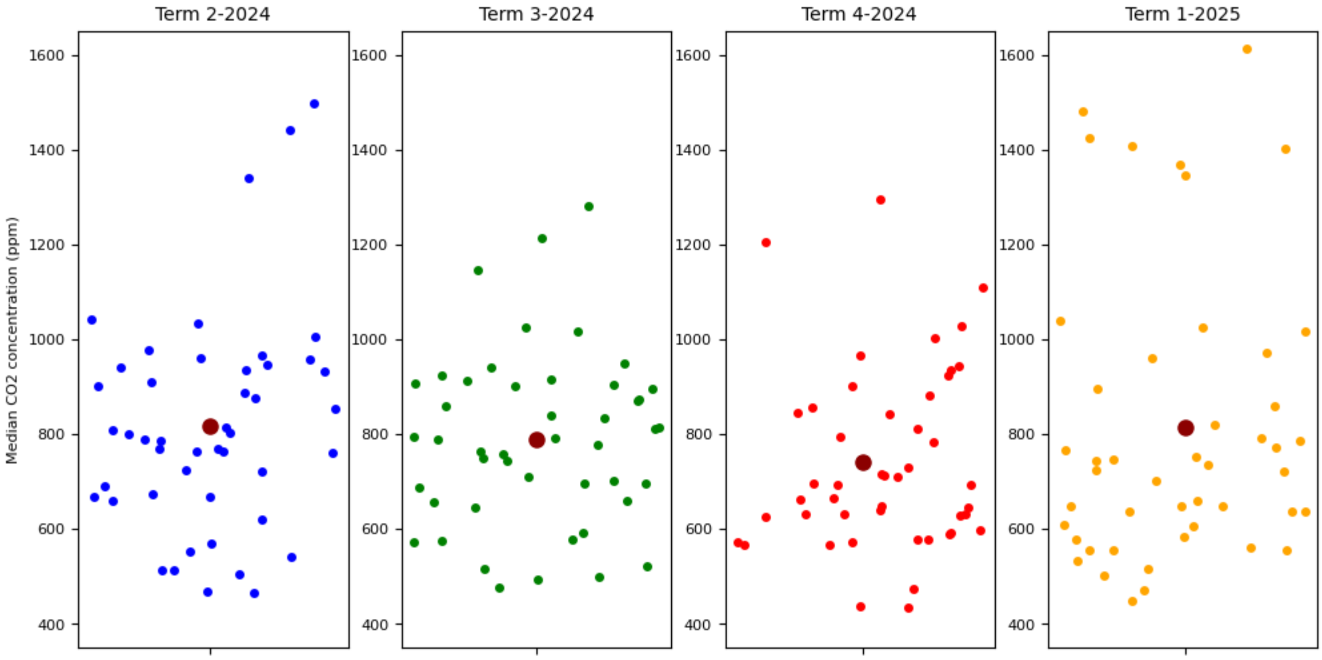


Figure 12: Median CO_2 concentrations for schools across each term. Schools with sensors installed in libraries and common rooms at any time, had low student numbers or missing >25% data across any term were excluded. Large dark red dots represent the average of all median CO_2 levels by school term.

We also compared CO_2 levels in primary school classrooms to those in high school classrooms. When accounting for the entire monitoring period, we did not find a substantial difference in classroom CO_2 levels between primary and high schools (762.1 versus 807.5 ppm respectively; Figure 13).

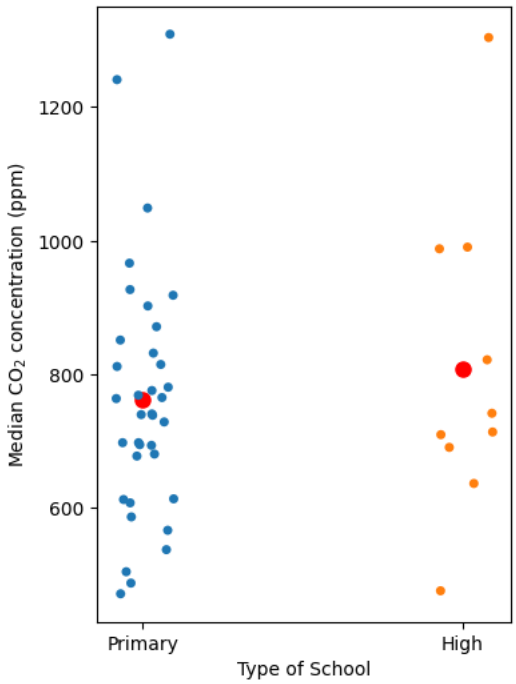


Figure 13: Median CO_2 concentrations comparing classrooms of primary and high schools for the entire monitoring period (all data). Libraries and common rooms, and classrooms missing > 25% of data were excluded. Average of each school type is shown as a large red dot.

However, there was a more substantial difference in CO_2 levels when only 2025 data was assessed, with high schools having a considerably higher average of median CO_2 levels of 895.9 ppm compared to 789.1 ppm for primary schools (Figure 14).

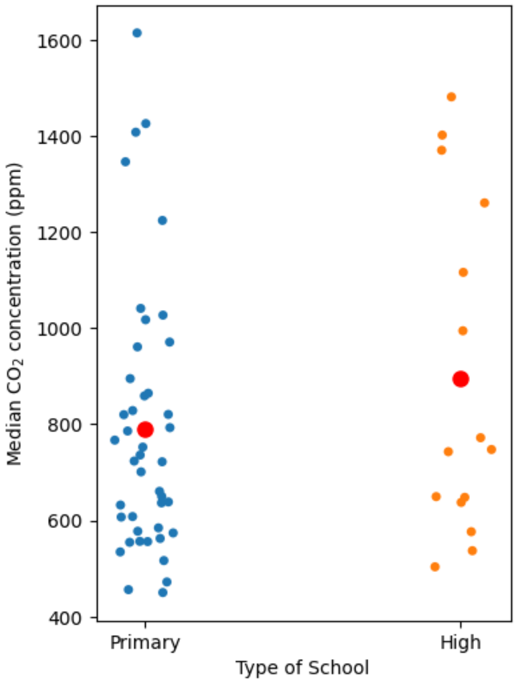


Figure 14: Median CO_2 concentrations comparing classrooms of primary and high schools for 2025 data only. Average of each school type is shown as a large red dot.

Effects of classroom characteristics on carbon dioxide levels

To understand the impact of classroom characteristics on CO_2 levels, the relationship between the arithmetic mean average of median CO_2 levels was compared for several different classroom characteristics. These characteristics were: room volume, type of mechanical ventilation present, and presence (or absence) of cross-ventilation.

There was some evidence of decreased levels in CO_2 as the size of the room increased. The classrooms with the highest median CO_2 concentrations above the 850 ppm threshold were most likely to have room volumes near, or less than, the 195m^3 volume recommended by School Infrastructure. However, several classrooms with greater volume sizes still had median CO_2 concentrations that exceeded the 850 ppm threshold (Figures 15 and 16).

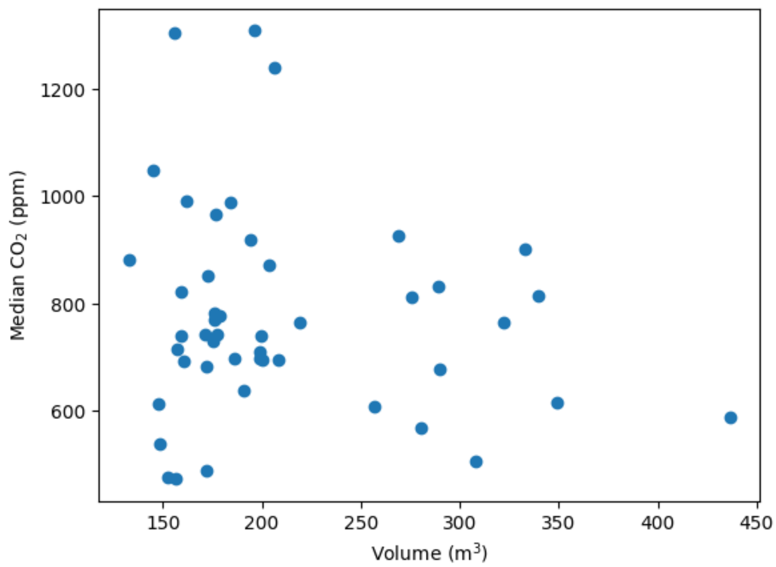


Figure 15: Median CO_2 levels by room volume for the entire monitoring period (all data). Libraries, common rooms and classrooms missing > 25% of data were excluded.

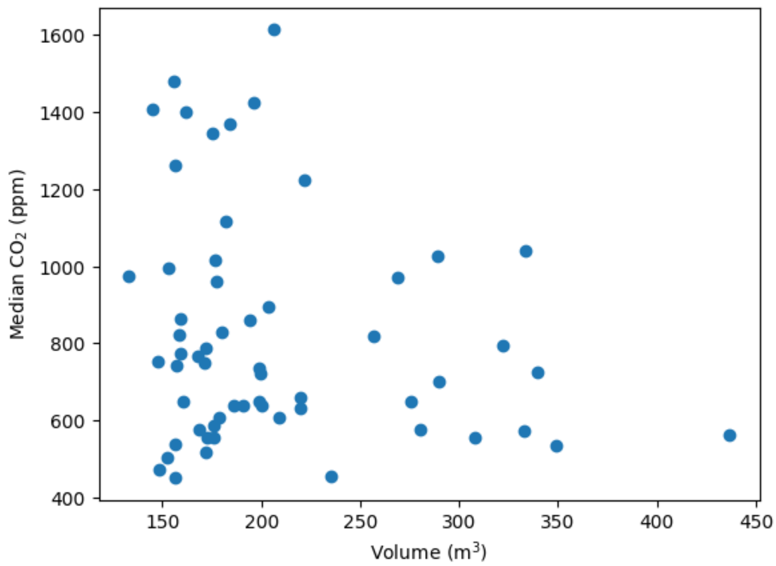


Figure 16: Median CO_2 levels by room volume for 2025 data.

Across classrooms, the average median CO_2 concentrations were lower in schools participating in the Cooler Classrooms Program, compared to non-participating schools with split air conditioning (A/C) systems (750.7 versus 820.4 ppm, respectively). The difference was slightly larger when the readings for 2025 were examined separately (777.6 versus 869.5 ppm, respectively) due to replacing several larger volume rooms with smaller ones for this data collection period (Figures 17 and 18).

The classrooms with split A/C systems were significantly more likely to have median CO_2 concentrations that exceeded the 850 ppm threshold for the year 2025. For classrooms in schools participating in the Cooler Classrooms Program, four out of the 12 (33.3%) had median CO_2 levels above 850 ppm, compared to 15 out of 36 classrooms (41.7%) in schools that use split A/C. This difference increased when the complete dataset was examined and libraries and common rooms were excluded, as one out of eight schools (12.5%) of classrooms in the Cooler Classrooms Program had median levels above 850 ppm compared to 11 out of 29 classrooms (37.9%) with split A/C systems.

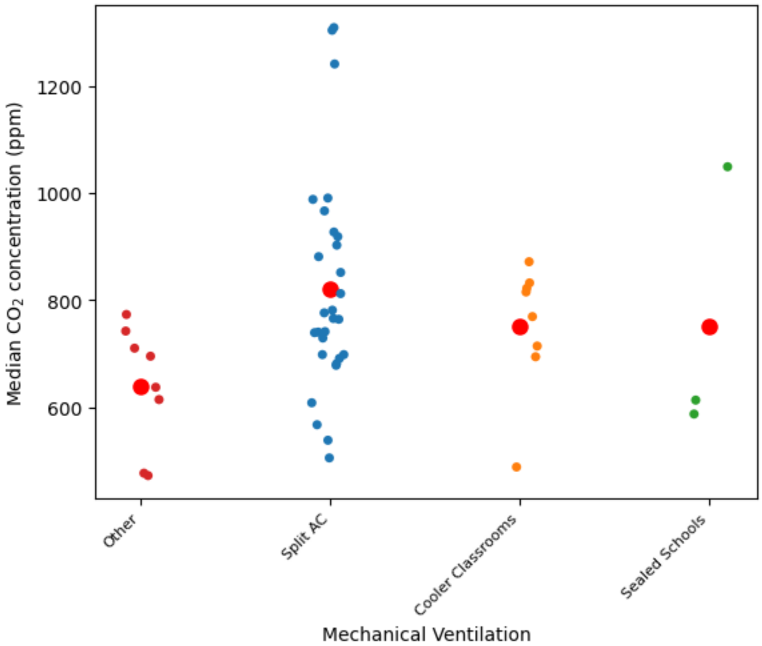


Figure 17: Median CO_2 concentrations for schools disaggregated by mechanical ventilation type for entire monitoring campaign (all data). Libraries, common rooms and classrooms missing > 25% values were excluded. Average of each category is shown as a large red dot.

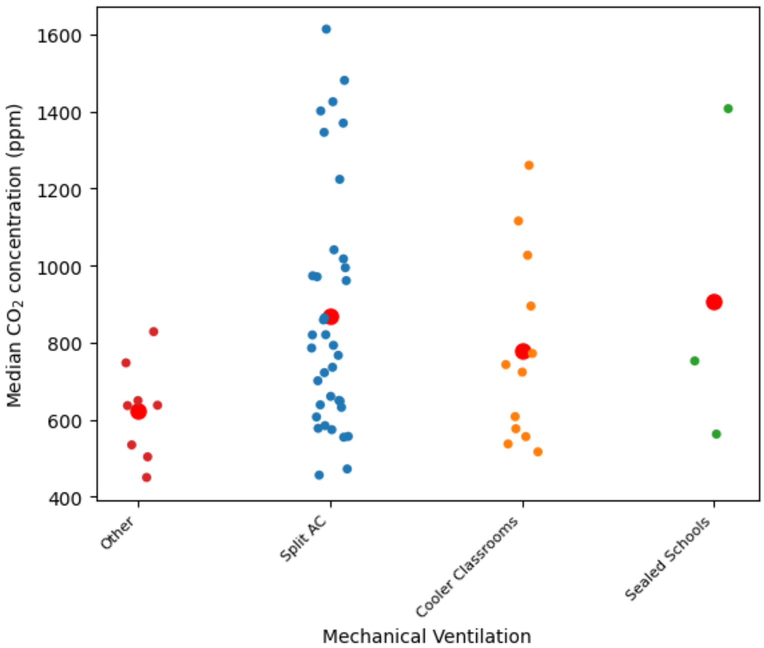


Figure 18: Median CO_2 concentrations for schools disaggregated by ventilation type for 2025 data only. Average of each category is shown as a large red dot.

The effect of cross-ventilation on CO_2 levels was assessed, with sealed schools removed from this analysis to provide a more representative comparison. Classrooms with cross-ventilation were defined as rooms with two or more sides with openable windows (the definition excludes classrooms with windows on one side, and windows/a door onto an internal corridor on the other).

Cross-ventilated classrooms had lower median CO_2 concentrations compared to classrooms without cross-ventilation (718.8 ppm versus 823.6 ppm, respectively). Among classrooms without cross-ventilation, a higher proportion had median CO_2 levels that exceeded the 850 ppm threshold (33.3% and 41.4% for the entire monitoring period and for 2025 only, respectively), compared to those with cross-ventilation (20.0% and 25.9%, respectively; Figures 19 and 20).

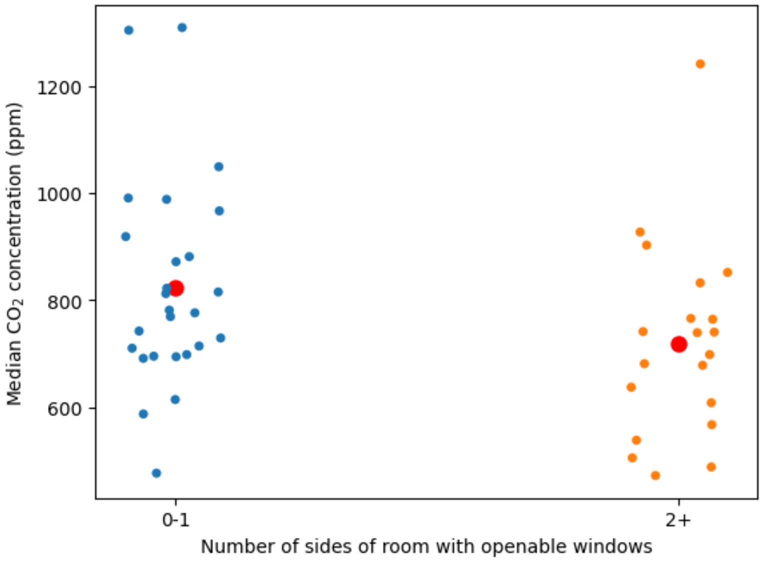


Figure 19: Median CO_2 concentrations for schools by cross ventilation for entire monitoring campaign (all data). Libraries, common rooms, sealed schools and classrooms > 25% of values were excluded. Average of each category is shown as a large red dot.

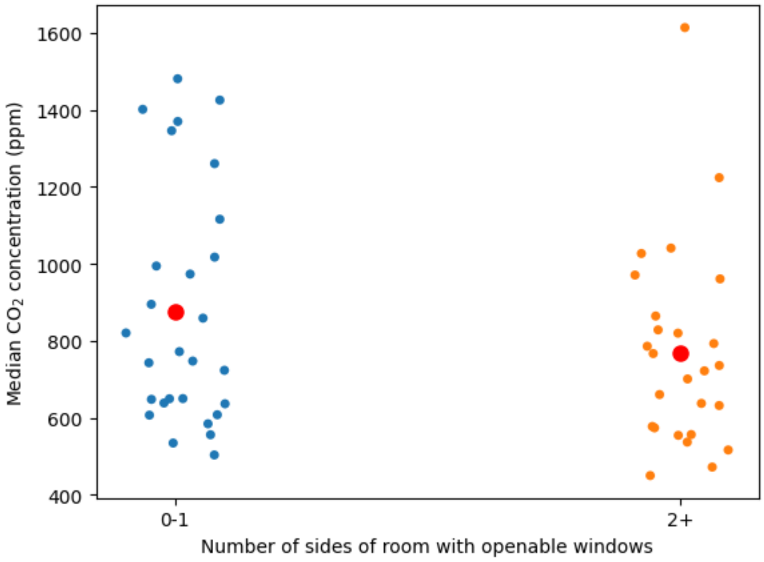


Figure 20: Median CO_2 concentrations for schools by cross ventilation for 2025. Sealed schools were excluded. Average of each category is shown as a large red dot.

Based on observed differences in CO_2 levels according to cross-ventilation and participation in the Cooler Classrooms Program, we assessed whether there were differences in median CO_2 concentration based on the interaction between cross-ventilation and Cooler Classrooms schools.

As could be expected, we found the highest average CO_2 median concentration for schools that had no cross-ventilation and were not participating in the Cooler Classrooms Program (all data: 837.9 ppm; 2025 data only: 894.4 ppm). Classrooms with cross-ventilation but which were not Cooler Classrooms school participants had, on average, lower median CO_2 levels (all data: 725.3 ppm; 2025 data only: 766.6 ppm), compared to Cooler Classrooms schools without cross-ventilation (all data: 780.9 ppm; 2025 data only: 805.6 ppm).

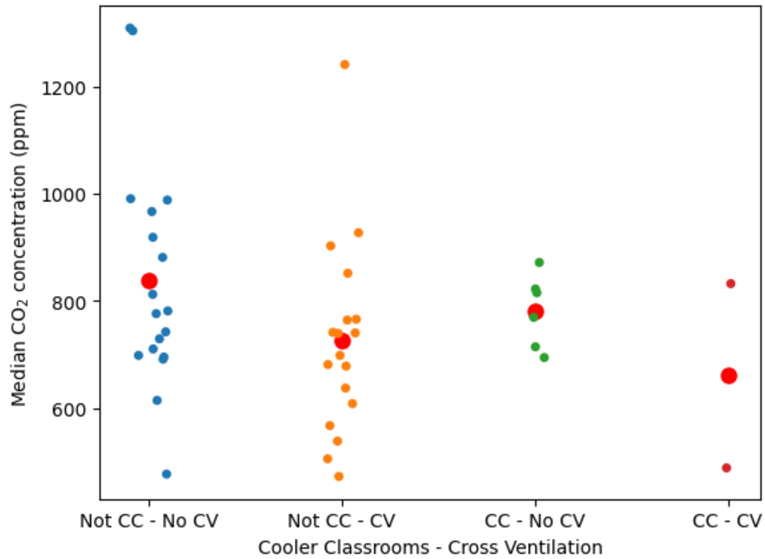


Figure 21: Median CO_2 concentrations for schools disaggregated to look at interactions between cross-ventilation and Cooler Classrooms for entire monitoring campaign (all data). Libraries, common rooms, sealed schools and classrooms missing > 25% of values excluded. Average of each category is shown as a large red dot.

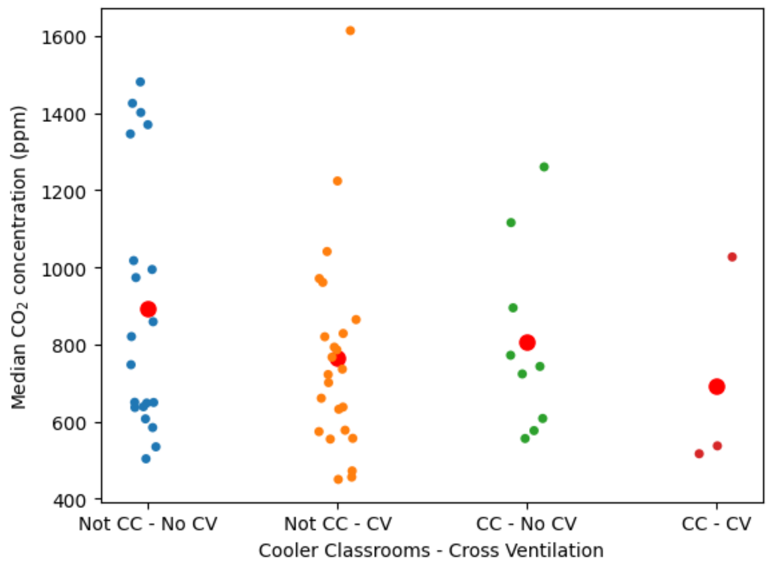


Figure 22: Median CO_2 concentrations for schools disaggregated to look at interactions between cross-ventilation and Cooler Classrooms for 2025 data. Sealed schools were excluded. Average of each category is shown as a large red dot.

In summary, there is some evidence that indoor CO_2 levels in NSW classrooms we tested are exceeding levels optimal for students' learning and health. There is some evidence that the Cooler Classrooms Program has somewhat mitigated this issue, however, our analysis shows that there are still cases of Cooler Classrooms levels above the recommended 850 ppm threshold. This would be expected given that the ventilation in the Cooler Classroom Program only switches on when CO_2 levels exceed 1500 ppm for 10 minutes. Further analysis across a larger range of classrooms and schools would be useful for better quantifying the impact of various classrooms characteristics.

Limitations

This project has collected one of the largest calibrated data sets for indoor / outdoor air pollution in school buildings in Australia. Having this data is useful to identify, and, if need be, mitigate any potential air quality concerns. However, there are a few limitations to the project that should be considered. These include: the initial installation locations rarely fulfilled all optimal criteria set out by the research team. Sensors were installed with the intention of finding the best compromise between security, safety and accuracy, particularly for the installation of indoor sensors. For this reason, sensors may not always have been representative of the air quality in classrooms or the outdoor areas of schools. There were some issues with students and staff intentionally or accidentally interfering with indoor sensors, such as the power being turned off or sensors being moved.

As only one classroom was monitored per school, the extent to which air quality readings were representative of other classrooms within the school is uncertain. A wider range of monitored classrooms within each school would have allowed for a more detailed and accurate analysis. The initial installation of sensors in libraries and common rooms in a few schools was helpful in that it illustrated these room types experienced significantly lower CO_2 levels compared to regular classrooms, however, it limited the number of classrooms monitored across the whole monitoring period.

Finally, the monitoring campaign took place during a year with especially good ambient air quality, where there were either very limited numbers or no bushfires, prescribed burns or dust storms in or around the Sydney Greater Metropolitan Region. As a result, this analysis does not measure the protective capacity of school classrooms from severely elevated levels of $PM_{2.5}$ typical of such events.

Discussion

Previous ventilation advice provided for School Infrastructure by the Steensen Varming report (2021) stated that:

> *The results of the high level assessment undertaken shows the typical classroom satisfies and exceeds the WHO roadmap first strategy approach of providing the nominated fresh air ventilation rate of 10 l/s per person. Additionally, the results also show satisfactory CO_2 levels in the typical classroom.*

During the period the above report by Steensen Varming was produced, there was a great emphasis on keeping windows open and ventilating classrooms to reduce transmission of infectious diseases. After that period, however, our data suggests that for many classrooms, adequate ventilation is not occurring.

We found evidence that classrooms with retrofitted mechanical ventilation through the Cooler Classrooms Program, on average, experienced lower levels of CO_2 than those that did not. Until retrofitted ventilation with filtration can be installed in all classrooms, there is evidence that better awareness of the need to flush fresh air through classrooms is required within the school community.

Until such a time, employing a parallel strategy for teachers, professional staff and students could be used to assist with raising the awareness of the need to regularly and constantly ventilate classrooms. Such programs could be deployed to allow students to get involved and make air quality awareness part of the learning experience, rather than purely another task for teachers or staff to maintain. Such resources should also encourage awareness about when to close (and then re-open) windows when outdoor air quality deteriorates due to fires, dust or traffic.

Alongside regular reminders in teachers' newsletters, an infographic about air quality, like those used for UV and heat, could be sent to schools to be displayed in a prominent location, such as at the school reception (see Appendix C). To engage primary school children, we have suggested a sticker campaign to raise awareness and engage them directly (see Appendix D).

Air quality information and decision-making

Improving student and staff awareness of air quality would also involve teaching staff how to get access to reliable outdoor air quality data that is representative of the school. While outdoor air quality data can be accessed from the NSW Department of Climate Change, Energy, the Environment and Water website, it is likely that the 'closest' ambient reference station is not necessarily the one most representative of what the school is exposed to. For this reason, and due to the ubiquity of smartphone use, we have included the suggestion of a Google Maps air quality layer to quickly see the geolocated air quality in the infographic included in the appendix.

It is important to consider whether identifying specific guidelines—for example, threshold levels of $PM_{2.5}$—should be created to inform decisions about school closure. These guidelines could address whether a school should close pre-emptively for the day, whether it should close if air quality conditions worsen during school hours, or whether it is feasible to relocate sensitive individuals within the school community (such as those with asthma action plans) to a room with better-controlled air quality or to send them off school grounds.

There would need to be differentiation for sealed schools with filtration, where school closure may not be necessary under these conditions.

Recommendations

Based on the findings of this air quality assessment, the following recommendations are proposed to improve the learning environment in non-sealed NSW schools. Please see some suggested options for an infographic for schools (Appendix C) and a possible primary school awareness campaign (Appendix D). Appendix E should be read in association with the excel sheets to allow for individual feedback for each CAS school if requested.

Immediate actions

1. **Enhance natural ventilation practices**
    - Implement regular reminders in teachers' bulletins explaining why and how to maintain adequate ventilation
    - Develop protocols to ensure windows are opened consistently to keep CO_2 levels down
2. **Improve air quality information systems**
    - Establish protocols for principals /FM to access locally relevant air quality forecasts
    - Develop guidance on appropriate responses when poor $PM_{2.5}$ levels are forecast.

Medium-term actions

3. **Accelerate mechanical filtered ventilation installation**
    - Prioritise the installation of mechanical filtered ventilation systems in schools with a focus on schools identified as having consistently poor natural ventilation
4. **Develop comprehensive thresholds**
    - Create official guidance infographic documents for air quality management that is tailored to sealed, mechanically ventilated and naturally ventilated schools
    - Establish uniform protocols for decision-making during air pollution events.

Long-term actions

5. **Retrofit naturally ventilated and hybrid schools**
    - Include filtration in any Cooler Classroom Program like expansion along with a revised CO_2 threshold
6. **Educational integration**
    - Integrate air quality awareness into curriculum as both a learning opportunity and practical health measure
7. **Monitoring and assessment**
    - Continue air quality monitoring programs to track improvements.

These recommendations aim to create healthier learning environments while building capacity within school communities to respond appropriately to varying air quality conditions.

Appendix A: Clean Air Schools list

Schools list

Empire Bay Public School
Galungara Public School
Northern Beaches Mackellar Girls Campus
St Ives Park Public School
Ambarvale Public School
Appin Public School
Banksia Road Public School
Barramurra Public School
Chester Hill Public School
Condell Park High School
Fairfield Heights Public School
Miller Technology High School
Mount Annan High School
Thomas Acres Public School
Earlwood Public School
Engadine West Public School
Ferncourt Public School
La Perouse Public School
Marton Public School
Randwick Public School
Sutherland North Public School
Colo High School
Hebersham Public School
Lawson Public School
Winston Heights Public School
Redhead Public School
Davidson High School
Middleton Grange Public School
St Helens Park Public School
Carinya School
Kingswood Park Public School
St Marys Public School
Callaghan College Jesmond Senior Campus
Asquith Girls High School
Castle Cove Public School
Dural Public School
Galston Public School
Ku-ring-gai High School
Lindfield Learning Village
Northbridge Public School
West Pymble Public School
Killara High School
Lidcombe Public School
Bellevue Hill Public School
Georges River College Penshurst Girls Campus
Inner Sydney High School
Connells Point Public School
Dundas Public School
Elermore Vale Public School
Garden Suburb Public School
Mayfield East Public School
Mount Hutton Public school
Mayfield West Public School
Mount View High School
Dapto High School
Warrawong Public School
Lewisham Public School
Yarrawarrah Public School
Chifley College Dunheved Campus

Appendix B: School survey

Variable	Details	How it was measured
Type of room	Whether room is a classroom, library or other type of room	In-room visit and photos
Grade	Grade of students (Primary schools only)	In-room visit and photos
Level	Floor of building (ground, level 1 etc.)	In-room visit and photos
A/C	Any A/C and what type (Split or Ducted? Cooler Classrooms?)	In-room visit and photos
Fans	Number of ceiling fans	In-room visit and photos
Heaters	Presence of heaters and what type (electric vs gas)	In-room visit and photos
Air purifiers	Number of air purifiers and whether they are HEPA purifiers	In-room visit and photos
Blackboard	Presence of blackboard in room	In-room visit and photos
Carpet	Presence of carpet on floor	In-room visit and photos
Nearby sources	Any sources of indoor air pollution near sensors (for e.g. pencil sharpeners)	In-room visit and photos
Windows	Number of openable windows, their openable size and how many sides of room have openable windows.	In-room visit and photos, plus measuring windows with tape measure
Building Materials	Brick, Timber, Plaster etc.	In-room visit and photos
Door outdoors	Is the main door to the room directly outdoors?	In-room visit and photos
Roller to classroom	Does the room connect to another classroom via a large roller?	In-room visit and photos
Trees near windows	Whether trees or other greenspace take up space in front of windows to the room.	In-room visit and photos
Sensor height	How high the sensors are	In-room visit and photos plus measuring sensor height with tape measure
Damage	If any record of damage to the room (inc. broken windows, water damage etc)	In-room visit and photos
Room size	The area, volume and height of the room.	Use of LIDAR app to accurately measure room dimensions
No. students	The likely number of students in the room.	In-room visit and photos of number of chairs and tables
School times	Times that schools start, end, recess and lunch.	Website searches and contact with admin staff
Building orientation	Where the front of the room faces, and proximity to traffic, industry and the edge of the room.	In-room visit and photos
Near construction	Is there any nearby construction or renovation that has taken place?	In-room visit and photos

Appendix C: Infographic for Schools

Air Quality Action Guide

Take these simple steps for healthier classrooms and better learning

1 Identify your school's ventilation system

Look for the Cooler Classrooms panel. Do your classrooms have a control panel that looks like the photo on the right? If yes, your school uses the Cooler Classrooms system.

If no Cooler Classrooms panel is present. Your school likely uses natural ventilation and may be equipped with split system air conditioning units.

Type	What this means
Cooler Classrooms	Retrofitted, ducted air conditioning system with fresh-air intake from outside fed into each classroom.
Naturally ventilated, possibly with split AC	Ventilated by operable windows. These rooms may also have split air conditioning systems that recirculate heated or cooled indoor air. These systems do not bring in outdoor air.

2 Check today's outdoor air quality

Here are two ways to check air quality in your area:

- Use Google Map's Air Quality Layer to find out about the air quality outside your school.
- Use the Air Quality NSW website: airquality.nsw.gov.au. You can use this website to sign up for daily alerts.

3 Take action

	Air quality category				
Classroom type	**Good**	**Fair**	**Poor**	**Very poor**	**Extremely poor**
Cooler Classrooms Run A/C systems as instructed by lights on panel	Open windows and doors	• Close windows • Run HEPAs on high, if available			
Naturally ventilated/ split A/C Run split A/C system as normal	Open windows and doors	• Close windows • Open windows when room is empty, such as during breaks, to refresh air • Run HEPAs on high, if available		• Close windows • Run HEPAs on high, if available	

More opening = more air. Even a few centimetres' gap at each opening can make a big difference to ventilation.

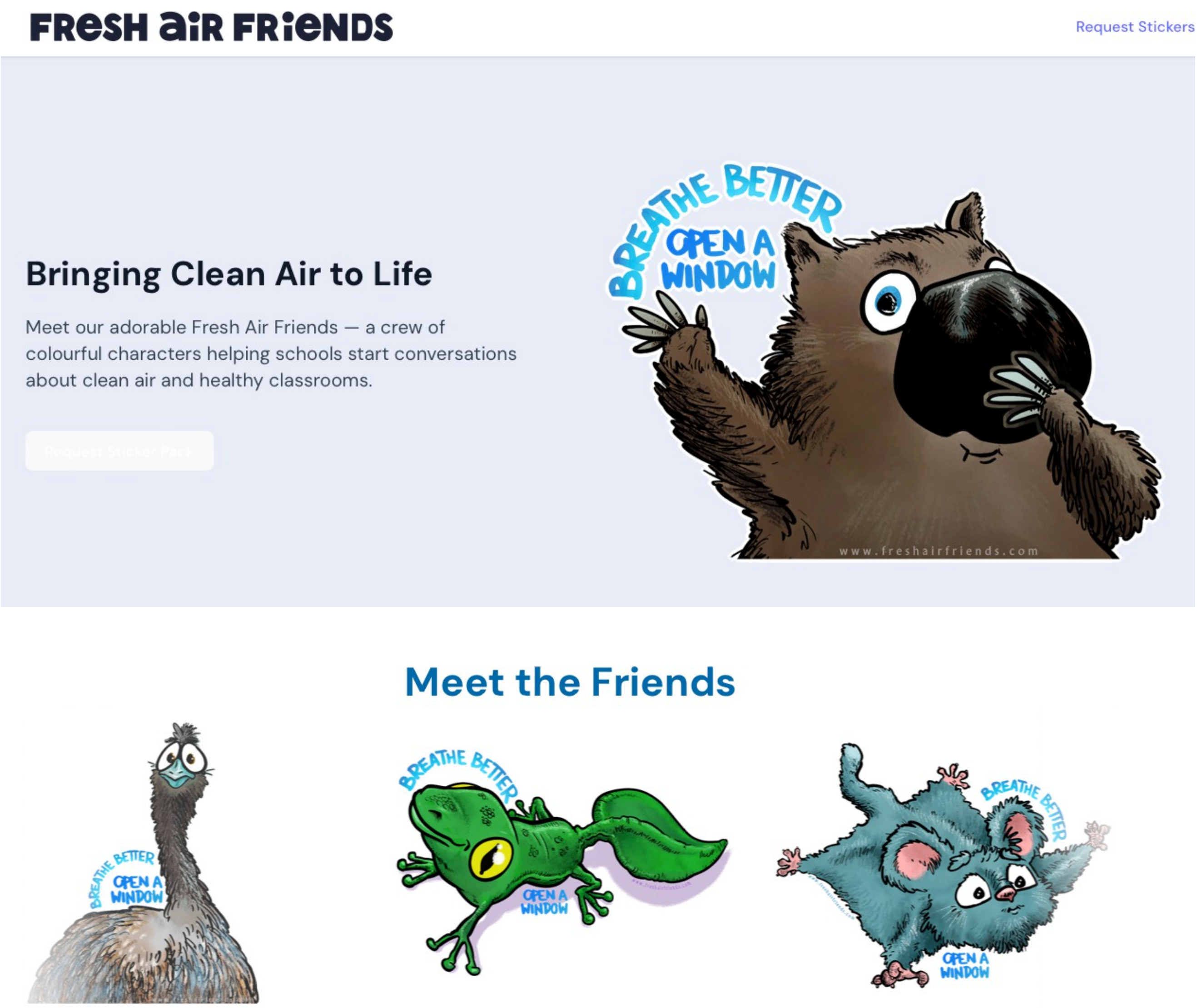
HEPA filters are appliances that remove pollution from the air. If you have HEPAs in your classrooms, always run them when people are present for cleaner, healthier air. Try to place them away from operable windows. More about HEPA: cleanairschools.com.au/what-is-hepa/

All fonts, colour palette, spacing and iconography follow the Digital NSW Design System to meet NSW Government brand, readability and WCAG 2.1 AA accessibility requirements. A high resolution A4 print-ready file can be sent on request.

Appendix D: Suggested Primary School Campaign

An engaging and informative campaign could be used such as Fresh Air Friends. The animals remind the viewer that keeping the windows open improves air quality.
Larger static cling window stickers with the phrase 'Breathe better, open a window' are placed on the lower sections of classroom windows to remind people to open them, and smaller stickers of the animals can be handed out to children as collectables.

See: freshairfriends.com



Appendix E: Individual feedback to each clean air school template letter (and associated results)

Feedback to individual schools can be given via the template .doc below read in concert with the excel sheet of individual readings for each school. Please let us know if you would like any further guidance about these sheets.

To **[Principal of SCHOOL]**

The Clean Air Schools project, a research collaboration between Schools Infrastructure NSW and UNSW, has been monitoring air quality at **your school**. As the Clean Air Schools project has completed the monitoring phase of the project, we would like to give you a summary of our findings.

What is the Clean Air Schools Project?

Clean Air Schools was a non-invasive air quality program, analysing indoor and outdoor air quality from selected schools across NSW to develop air quality protocols, aiming to improve the overall learning environment for schools.

As part of this project, one classroom and one outdoor area of the school were nominated for monitoring. Some air quality pollutants were measured in those spaces. They included:

INCLUDED ONLY FOR SCHOOLS WHERE ACCURATE NO_2 MEASUREMENTS WERE COLLECTED:

Nitrogen dioxide (NO_2)

Nitrogen dioxide is a pollutant primarily emitted by vehicle exhaust, industry or from other sources of burning fossil fuels. At elevated levels, it is known to affect children's health, particularly for those with asthma or other respiratory conditions.

We measured NO_2 in the outdoor area of the school to understand the levels that children are exposed to outdoors at the school.

Fine particulate matter ($PM_{2.5}$)

Fine particular matter is a widespread air pollutant that is representative of the general outdoor air quality experienced by each school. It is released from a range of outdoor sources including bushfires, prescribed burns, dust storms, industry and traffic. It can also come from various indoor sources including dust, candles or from vacuuming carpets. At elevated levels, it is known to affect children's health, particularly children with asthma or other respiratory conditions.

We measured $PM_{2.5}$ in the outdoor area and indoors in the nominated classroom of the school to understand what levels of $PM_{2.5}$ children are exposed to in class and while out in the playground. **However, due to the outdoor monitor being misplaced early in the monitoring campaign, we only were able to monitor $PM_{2.5}$ levels in the nominated classroom.**

Carbon dioxide (CO_2)

Carbon dioxide is an air pollutant that causes tiredness, a loss of focus and, at high levels, nausea and headaches. We measured CO_2 in the one nominated classroom to understand what levels of CO_2 students are exposed to during class times.

What is the air quality at your school?

A summary of the air quality at your school is shown in the table below along with the NSW health and other relevant domestic thresholds. A description of each result and its meaning is provided below:

Pollutant	*NSW threshold (year)*	*NSW threshold (daily/hourly)*	*Overall average*	*No. of exceedances (daily/hourly) threshold*
NO_2	15 ppb	80 ppb (hourly)	...	...
$PM_{2.5}$ (outdoors)	8 µg/m^3	25 µg/m^3 (daily)	...	...
$PM_{2.5}$ (indoors)	8 µg/m^3	25 µg/m^3 (daily)	...	...
CO_2	850 ppm	-	... (median)	_

INCLUDED ONLY FOR SCHOOLS WHERE ACCURATE NO_2 MEASUREMENTS WERE COLLECTED

Nitrogen dioxide (NO_2)

Option 1 – If NO_2 annual and hourly values were below NSW thresholds (14 schools)

The data shows your school's average NO_2 levels did not exceed the annual and hourly NSW thresholds for outside air.

Option 2 - If NO_2 annual threshold was exceeded but hourly threshold was not exceeded (8 schools)

The data shows your school's average NO_2 levels exceeded the annual NSW threshold. Nonetheless, the short-term hourly levels did not exceed the hourly NSW threshold, which is the primary indicator for whether students at your school are exposed to elevated levels of NO_2.

Option 3 – If NO_2 was below the annual threshold but exceed the hourly threshold less than 5 times (1 school)

The data shows your school's average NO_2 levels did not exceed the annual NSW threshold for outside air. The short-term hourly levels exceeded the hourly NSW threshold **[n] times/less than 5 times**, which is the primary indicator for whether students at your school are exposed to elevated levels of NO_2.

Option 4 - If NO_2 annual threshold was exceeded and hourly threshold exceeded less than 5 times (3 schools)

The data shows your school's average NO_2 levels exceeded the annual NSW threshold. The short-term hourly levels exceeded the hourly NSW threshold **[n] times/less than 5 times**, which is the primary indicator for whether students at your school are exposed to elevated levels of NO_2.

Option 5 - If NO_2 annual threshold was exceeded and hourly threshold exceeded more than 10 times (1 school)

The data shows your school's average NO_2 levels exceeded the annual NSW threshold, and exceeded the hourly NSW thresholds more than 10 times across the monitoring period.

Fine particulate matter ($PM_{2.5}$)

Option 1 - If indoor and outdoor $PM_{2.5}$ did not exceed annual and daily thresholds (52 schools)

The data shows average $PM_{2.5}$ levels did not exceed the annual and daily NSW thresholds for air quality in the assessed outdoor and indoor spaces.

This result indicates that the overall air quality at your school was not significantly impacted by major outdoor or indoor sources of air pollution. It should be noted that there were no major bushfire and dust storm events during the monitoring period. Such events are likely to have severe and negative impacts on air quality inside and outside the school.

Option 2- If outdoor and indoor $PM_{2.5}$ did not exceed the annual thresholds but exceeded the daily threshold (1 school)

The data shows average $PM_{2.5}$ levels did not exceed the annual NSW thresholds for air quality in the assessed outdoor and indoor spaces. In addition, the daily $PM_{2.5}$ indoor levels only exceed the daily NSW threshold **n times**, and the outdoor levels only exceeded the daily NSW threshold once.

This result indicates that the overall air quality at your school was not significantly impacted by major outdoor or indoor sources of air pollution. It should be noted that there were no major bushfire and dust storm events during the monitoring period. Such events are likely to have severe impacts on air quality at the school.

Option 3 – If outdoor $PM_{2.5}$ did not exceed any thresholds but the daily indoor threshold was exceeded (5 schools)

The data shows average $PM_{2.5}$ levels did not exceed the annual NSW thresholds for air quality in the assessed outdoor and indoor spaces. In addition, the daily $PM_{2.5}$ outdoor levels did not exceed the daily NSW threshold and the indoor levels only exceeded the daily NSW threshold **[n] times/less than 5 times**.

This result indicates that the overall air quality at your school was not significantly impacted by major outdoor or indoor sources of air pollution. It should be noted that there were no major bushfire and dust storm events during the monitoring period. Such events are likely to have severe impacts on air quality at the school.

Option 4 – if outdoor $PM_{2.5}$ was not measured and indoor $PM_{2.5}$ did not exceed annual and daily thresholds (1 school)

The data shows average $PM_{2.5}$ levels did not exceed the annual and daily NSW thresholds for air quality in the assessed indoor spaces.

This result indicates that the overall air quality at your school was not significantly impacted by major outdoor or indoor sources of air pollution. It should be noted that there were no major bushfire and dust storm events during the monitoring period. Such events are likely to have severe and negative impacts on air quality inside and outside the school.

Carbon dioxide (CO_2)

Option 1 – If median CO_2 was below 850 ppm threshold (42 schools)

The data shows the nominated classroom's median CO_2 level was below the recommended threshold of 850 ppm, and was considered optimal for students' learning most of the time.

It should be noted that these results may not be representative of other classrooms.

Option 2 - If median CO_2 was above 850 ppm threshold (17 schools)

The data shows the nominated classroom's median CO_2 level was above the recommended threshold of 850 ppm, and was not considered optimal for students' learning most of the time.

It should be noted that these results may not be representative of other classrooms.

What can you do to improve your students' learning environment?

The Department of Education has been provided with information sheets that can be used to guide best practice to promote good indoor air quality. Please get in touch with them to get access to this information.