District Airflow Measurements

About PPS's Airflow Testing Reports

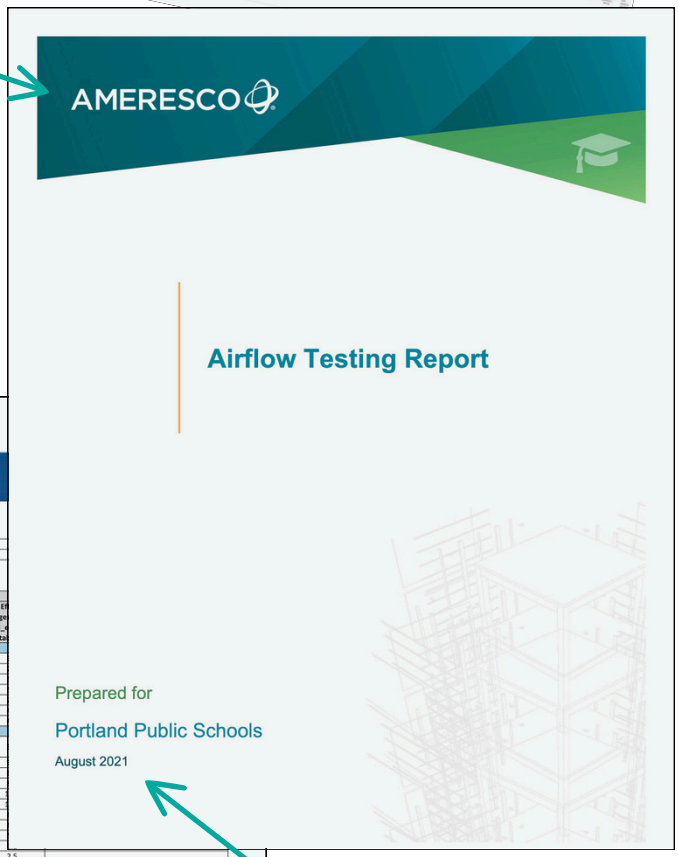
Each report has a complete map of the school.

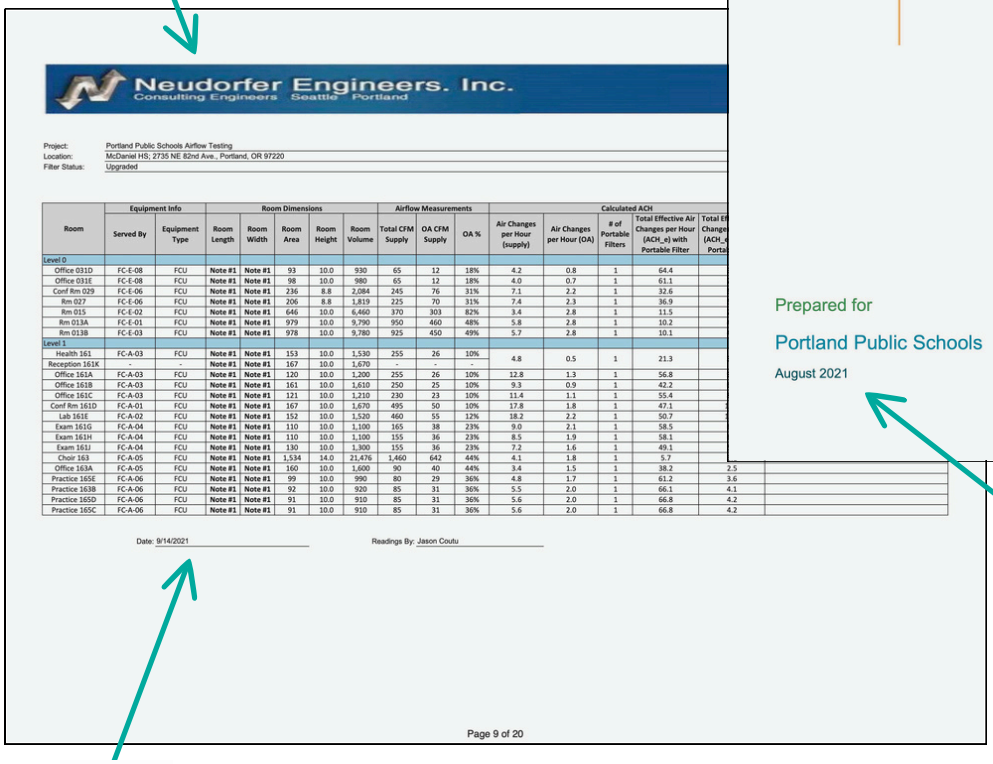
For example, this is the first floor map in McDaniel's report.

PPS contracted with Ameresco for these reports.

Ameresco, in turn, contracted with Neudorfer Engineers.

Neudorfer did the actual measurements and calculations.





Measurements were generally done in summer 2021, before the return to in-person learning.

Neudorfer's test engineer signed off on McDaniel's final table of data in September 2021.

HVAC-only airflows were measured using certified standard procedures

Ameresco contracted with Neudorfer Engineers, another professional engineering firm that conducts HVAC airflow measurements using Test-Adjust-Balance methods.

Neudorfer is certified by the National Environmental Balancing Bureau (NEBB) to perform accurate HVAC airflow measurements. The firm used calibrated equipment, current testing standards and procedures from NEBB's Procedural Standards for Testing, Adjusting, and Balancing of Environmental Systems, and a standardized report stamped with their certifications.

Calibrated equipment:
AirData Meter with flow hood and velocity grid
(Model: Shortridge ADM 870)

Submitted and certified by:
Neudorfer Engineers, Inc.
(Certification No: 3414)

Signed and sealed by:
Mike Vawter, P.E. and Eric Stotts
Certification seal:
Air and Hydronic Testing

Room	Equipment Info		Room Dimensions					Airflow Measurements				
	Served By	Equipment Type	Room Length	Room Width	Room Area	Room Height	Room Volume	Total CFM Supply	OA CFM Supply	OA %	Air Changes per Hour (supply)	Air Changes per Hour (OA)
Level 0												
Office 031D	FC-E-08	FCU	Note #1	Note #1	93	10.0	930	65	12	18%	4.2	0.8
Office 031E	FC-E-08	FCU	Note #1	Note #1	98	10.0	980	65	12	18%	4.0	0.7
Conf Rm 029	FC-E-06	FCU	Note #1	Note #1	236	8.8	2,084	245	76	31%	7.1	2.2
Rm 027	FC-E-06	FCU	Note #1	Note #1	206	8.8	1,819	225	70	31%	7.4	2.3
Rm 015	FC-E-02	FCU	Note #1	Note #1	646	10.0	6,460	370	303	82%	3.4	2.8
Rm 013A	FC-E-01	FCU	Note #1	Note #1	979	10.0	9,790	950	460	48%	5.8	2.8
Rm 013B	FC-E-03	FCU	Note #1	Note #1	978	10.0	9,780	925	450	49%	5.7	2.8

Airflow was measured in nearly every room

Airflows were measured in classrooms and other learning spaces across the district. Most rooms that staff and students spend time in were measured. However, many schools had no measurements in key spaces, and unoccupied rooms, such as storage closets, were often mischaracterized, leading to errors in district analyses.

Some key spaces were missed. For Example, at McDaniel, the commons, the locker rooms, the breastfeeding room, the black box theater, the kiln and glaze rooms, and several science prep rooms were not measured. In addition, no ventilation rates were obtained for any restrooms or hallways at any schools.

Types of rooms included:

- Classrooms
- Main offices
- Principal & assistant principal offices
- Nurse's offices
- Counseling & speech pathologist offices
- Libraries & media centers
- Gyms & auditoriums
- Cafeterias & kitchens
- Band, theater & performance rooms

Testing was done but adjusting and balancing were not

Neudorfer only conducted the testing portion of a Test-Adjust-Balance or TAB report. That means we know where things stand, but the airflows were not fixed to ensure a balance between different rooms. For example, if Mr. Smith's language arts class was getting 113% of the outdoor air required for the room, and Ms. Jones' math class was only getting 89% of the outdoor air required, nothing was done to correct issues in the HVAC ducts to deliver more fresh air to Ms. Jones and her students.

The airflow reports have gaps but the underlying data is good

Although PPS's airflow reports contain mistakes that need correction and include gaps, such as rooms that were missed, the errors in the reports can be fixed, and the reports provide invaluable data for each room that was measured. The data tables provide accurate information on:

✓ **The type of HVAC equipment serving the room, its identifier, and notes about the system**

Details about HVAC equipment provide context, such as the range of equipment used within each school and across the district, the role of equipment in driving poor ventilation rates, and in many buildings, these details help identify rooms that lack mechanical ventilation entirely. At McDaniel, for example, all rooms included are served by fan coil units and air handling units.

✓ **Room dimensions**

Room volume is used to calculate clean airflow from both the HVAC system and from air purifiers. The reports also provide room lengths, widths, heights, and areas. In other schools, these details have helped us correct cases where incorrect room dimensions caused serious errors in a room's airflow calculation.

✓ **Total amount of air supplied to the room by the HVAC system + how much of the total is from outside air**

The total air supply from the HVAC system was measured and reported in cubic feet of air flowing into the room each minute. Cubic feet per minute of outdoor air flowing to the room from the HVAC system was likewise included in the table, as was the percent of the total supply that comes from outside. This data also allows us to calculate how much of the airflow is recirculated air.

A problem in some schools in PPS is that the HVAC system is turned off in warm weather, meaning those schools do not actually get the measured ventilation rates during the fall and spring. .

Example: 179 rooms were detailed in McDaniel's ~$10,000 report. Most of the building's occupied rooms, including the Flexible Learning Room FX 105 (left) and Weight Room G122 (right) had HVAC equipment identified, room dimensions provided, and total and outdoor airflow measured. Another ~5,500 rooms across 85 active PPS buildings have these detailed and valuable data as well.

How air to each room was measured: flow hoods & velocity grids

With the ventilation system on, the engineers used a special device called a flow hood to measure the volume of air entering the room through the room's supply vents. The flow hood captures the air coming out of the vents, in order to determine the number of cubic feet of air flowing into the room each minute. This measurement is reported as "Total CFM supply" where CFM is cubic feet per minute.

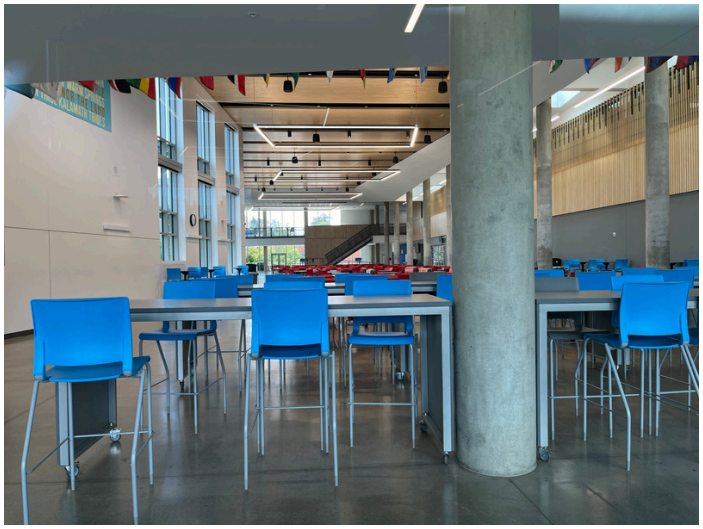
The amount of outside air coming in to the system was also measured with a flow hood at the louvres (slats on the outside of the building for intake of air from outdoors), where possible, but were recorded with a velocity grid if necessary. Cubic feet of outdoor air entering the room was then calculated by accounting for shape and size of the ducts, using measures of the open unobstructed area that air actually flows through. These areas were from AK factors (areas provided by the manufacturer) or were determined using the free area method (total area minus area of obstructions). Outdoor air is reported as "OA CFM Supply." The difference between total cubic feet per minute and cubic feet per minute of outdoor air then provides recirculated airflow.

Conducting such detailed measurements in each school could give the district a truly comprehensive view of ventilation problems and opportunities, if the data were analyzed and used correctly. The airflow data is incredibly valuable for identifying which rooms are falling short and by how much, providing an opportunity to add what the room needs to meet healthy airflow targets.

Room	Served By	Equipment Type	Room Length	Room Width	Room Area	Room Height	Room Volume	Total CFM Supply	OA CFM Supply	OA %	Air Changes per Hour (supply)	Air Changes per Hour (OA)	# of Portable Filters	Total Effective Air Changes per Hour (ACH_e) with Portable Filter	Total Effective Air Changes per Hour (ACH_e) without Portable Filter	Notes
.evel 0																

Original airflow reports available at: safeairoregon.org/original-airflow-reports

Important gap: some spaces were overlooked for measurements



Some rooms that should have been included in airflow measurements were not. At McDaniel High School, for example, rooms that got overlooked included the commons (pictured left), as well as the locker rooms, the breastfeeding room, the black box theater, the kiln and glaze rooms, and several science prep rooms. Most airflow reports did not have key rooms missed, but a number of other schools had issues with missed rooms similar to McDaniel. Across all airflow reports, bathrooms and hallways (including this McDaniel hallway, pictured right) were intentionally not measured.

The reports have serious errors but most can be corrected easily

Errors and issues in the airflow data tables include:

⚠ Calculation of air changes per hour provided by the HVAC system

In rooms that have mechanical ventilation, the best measure of clean air coming to the room from the vents is the sum of outdoor air and the 75 to 90% of recirculated air that gets cleaned when that air passes through a MERV 13 furnace filter, the type the district installed in all schools. This total is then multiplied by a correction factor to account for how well vs poorly HVAC systems distribute the air throughout a room. The airflow reports use a generous and questionable estimate of how much of the recirculated air is cleaned by the MERV 13 filter (90%).

At some schools that were not yet upgraded to MERV 13 filters, calculations used the percentage of cleaning that the old MERV 8 filters accomplish (57%). Those schools' air changes per hour from the HVAC are not correct in rooms with recirculation, and need to be recalculated to reflect the higher efficiency provided by the MERV 13 filters the district installed.

A grossly incorrect calculation of total air changes per hour in high schools

Total air changes per hour provided by the HVAC system and the original air purifier purchased by PPS for the room are wrong in every single high school room. The district's high school reports mix cubic feet with cubic meters in these calculations. This across-the-board error is easily fixed by doing calculations correctly at a fan speed setting that is realistic for the room. We have done this fix in our calculations for all high schools that still have valid airflow reports.

Another problem with the high school reports is that many rooms in PPS high schools received Intellipure air purifiers, which provide far less clean airflow than do the Medify air purifiers the district bought for most high school rooms. However, the reports fail to identify which high school rooms got Intellipures instead of Medifys. In some high schools, we have been able to identify the type of air purifier in most rooms, in order to calculate correct airflow values.

A misleading, sometimes incorrect calculation of total air changes per hour in other schools

Total air changes per hour (provided by the HVAC system and the original air purifier PPS bought for the room) are misleading because they are calculated at noisy fan speeds that only cafeterias can handle. Air changes per hour that classrooms can realistically achieve are easily calculated by using the air purifier's clean air delivery rate at fan speeds teachers can actually use. In addition, total air changes per hour are incorrect in schools where HVAC-only measurements were done with MERV 8 filters instead of MERV 13, but as described above, these values can be recalculated easily.

PPS needs help fixing errors in airflow reports

The district has made decisions about staff and students' air quality based on false data and faulty analyses. These errors need correction. Indoor air quality is a science that needs to be based on accurate calculations. SIAFOS and partners have analyses done and can assist with capacity challenges the district faces for air purifier inventories, getting corrected estimates, and using appropriate approaches with airflow data.

Examples from McDaniel of the error in every high school room

Air changes per hour with the portable filter is supposed to report the room's clean airflow if the air purifier is running at full speed, but is calculated incorrectly

Total Effective Air Changes per Hour (ACH_e) with Portable Filter	Total Effective Air Changes per Hour (ACH_e) without Portable Filter
64.4	3.1
61.1	2.9
32.6	5.3
36.9	5.5
11.5	2.7
10.2	4.4
10.1	4.3

Air changes per hour without portable filter = HVAC-only airflow

Calculated ACH			
Air Changes per Hour (OA)	# of Portable Filters	Total Effective Air Changes per Hour (ACH_e) with Portable Filter	Total Effective Air Changes per Hour (ACH_e) without Portable Filter
0.8	1	64.4	3.1
0.7	1	61.1	2.9
2.2	1	32.6	5.3
2.2	1	36.9	5.5
2.2	1	11.5	2.7
2.2	1	10.2	4.4
2.2	1	10.1	4.3

FALSE

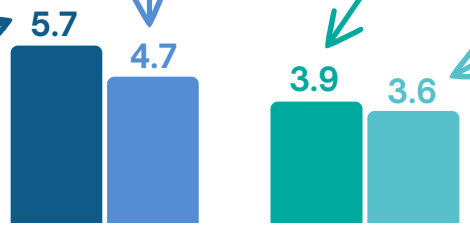
Air changes per hour with the air purifier running is wrong in every single room in the high school reports. This error makes air changes per hour look far higher in high schools than they actually are.

1 District report calculated air changes per hour with the air purifier at full speed incorrectly.

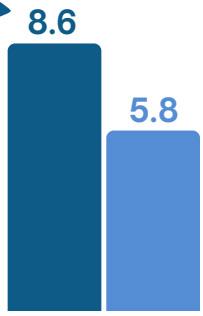
2 Actual air changes per hour at full speed are not as high as what PPS reported.

3 Air changes are even lower at the fan speed with a noise level that works for classrooms

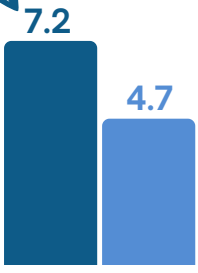
4 If the room has an Intellipure air purifier instead of a Medify, airflow is even lower.

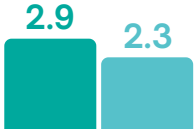


Choir Room 163



Classroom 247





Career Center 227

Error Correct

Full Speed
Medify MA-112

Speed 2
Medify MA-112

Half Speed*
Intellipure

What was the error?
Mixed units! Cubic meters and cubic feet are mixed in the calculations.

**Clean airflow rates with Intellipures at half speed may be lower than this estimate; see p. 41*

Error Breakdown

	Incorrect	*Correct**
Airflow from HVAC system	Total Effective Air Changes per Hour (ACH_e) without Portable Filter	Total Effective Air Changes per Hour (ACH_e) without Portable Filter
	+	+
	Airflow from the Medify MA-112 air purifier at full speed	
Clean air delivery rate at full speed	**950 cubic meters/hour**	**559 cubic feet/minute**
	x	x
Minutes in an hour	60	60
	÷	÷
Size of room	**room volume in cubic feet**	**room volume in cubic feet**
	≠	=
Total airflow	Total Effective Air Changes per Hour (ACH_e) with Portable Filter	Total Effective Air Changes per Hour (ACH_e) with Portable Filter

*Correct but impossible

Using the full speed setting of the original Medify MA-112 air purifier that was assigned to most (but not all) high school rooms is not feasible. A regular Medify MA-112 would add 57 decibels of noise to each room, if teachers and other school staff used the full speed setting that would deliver the 559 cubic feet of clean air per minute this unit provides at its highest setting. This is an impossible noise level to run these units at daily, especially given the Center for Green Schools' guidance to limit air purifier noise to 35 to 45 / 50 decibels and wide recommendations based on EPA guidance that classrooms need air purifiers at 45 decibels or lower.

Classroom-Appropriate Calculations

If Medify was placed

Total Effective Air Changes per Hour (ACH_e) without Portable Filter

+

Airflow from a Medify MA-112 at speed 2

281 cubic feet/minute

x

60

÷

room volume in cubic feet

=

Realistic Total Effective Air Changes per Hour (ACH_e) with Portable Filter

If Intellipure was placed

Total Effective Air Changes per Hour (ACH_e) without Portable Filter

+

*Airflow from Intellipure at half speed**

182 cubic feet/minute

x

60

÷

room volume in cubic feet

=

True & realistic Total Effective Air Changes per Hour (ACH_e) with Portable Filter

Recalculating for reality: getting it right and not too noisy

At speed 2, a regular Medify MA-112 is only 41 decibels. But speed 2 provides just 281 cubic feet of clean air per minute. This 281 value is the realistic amount of clean air that can be added to classrooms and is the clean air delivery rate that should be used for regular MA-112's. PPS's airflow reports also assume placement of MA-112's in all high school rooms, but many high school rooms got Intellipure units for their first air purifier instead of Medifys. Intellipures deliver less clean air than Medify MA-112's do and have a similar noise issue, where the unit must be run at a lower setting. The speed setting on the Intellipure that works best for classrooms is half speed, which is only ~39 decibels and delivers only 182 cubic feet of clean air per minute, according to information provided by the manufacturer to SIAFOS members.

**Clean airflow rates with Intellipures at half speed may be lower than this estimate; see p. 41 for details*

Airflow reports can be used to determine for every room ...

Air changes added by each fan speed of
- * the currently assigned air purifier(s)
- * air purifiers in district storage
- * any alternative model of air purifier

Impact of MERV 13 furnace filters
- * whether they improved airflow at all
- * how much they improved airflow

Time to clear out aerosols/pollutants

Expected carbon dioxide levels
- * screen for rooms where high levels are expected

Compliance with outdoor air standards

Airflows compared to targets for airflow
- * target air changes per hour
- * target per-person airflow rates

PPS is not using this comprehensive data set fully or correctly

After $940,000 in spending to conduct such valuable measurements in each school, this detailed airflow data could give the district a truly comprehensive view of ventilation problems and opportunities across the 85 buildings in the district where the airflow reports remain relevant and actionable.

With appropriate QA of the data, and analyzing and using the data correctly, or by working collaboratively with our organization and partners to make use of the corrected analyses we have already conducted and continue to refine, this resource could make a significant difference by improving indoor air quality for students and staff, and the health and learning outcomes air quality affects. The airflow data has incredible value for identifying which rooms are falling short and by how much, providing an opportunity to add what the room needs to meet healthy airflow targets. The airflow data can also be used to calculate expected carbon dioxide levels, and indicate which rooms have carbon dioxide levels that are too high. This use of the data could facilitate the facilities team getting a comprehensive view of which rooms in which schools are likely above their informal goal for an upper carbon dioxide limit, and promote improvements to achieve even lower CO_2 targets recommended by clean air advocates, education organizations, and health agencies. Additionally, the data can help evaluate how much MERV 13 filters are improving airflow within the room.

A tremendous amount of time, effort, and money went into collecting these data which have the power to guide simple, effective policies and actions to appropriately clean indoor air at PPS schools.

safeairoregon.org/mcdaniel-air-quality-report

Our full McDaniel High School Air Quality Report uses the airflow reports to look at:

Air changes per hour added by the currently assigned air purifiers

Air changes per hour added by the air purifiers in district storage

Impact of MERV 13 furnace filters

Time to clear out aerosols/pollutants

Airflows compared to target air changes per hour

PPS needs help using realistic and quiet air purifier settings to calculate clean airflows

In addition to fixing the units error that led to incorrect airflow values for every high school room, the district must also rely on calculations that use realistic airflow numbers. SIAFOS and partners have calculations of airflow with the air purifier(s) running using clean air delivery rates at fan speeds that meet appropriate classroom noise limits. Airflows need to use speed settings that staff will actually use, because noise levels at full speed compromise students' learning.

Likewise, the calculation of total air changes with the portable filter needs to use the model of air purifier actually in the room. Calculations for the high schools need accurate inventories of which room has which model.

Example errors from a K-8 school: Vernon K-8 School

Classroom 106A: A particularly egregious and obvious error in district-calculated air changes that inflated the classroom average

For Room 106A in Vernon K-8 School, the district airflow report gives a room area of 23 square feet and a room volume of 278 cubic feet. These dimensions are grossly incorrect and do not match the measured room length (28.4 feet) multiplied by width (21.9 feet), which calculates out to 622 square feet in area, not 28 square feet.

Air changes per hour are calculated by multiplying cubic feet per minute of air supplied to a room multiplied by 60 (to convert from minutes to hours), and then dividing by room volume. This gives the number of times per hour a volume of clean air equivalent to the room's volume "pours" into the room. As a result, the large error in room volume led to a large overestimate of air changes per hour.

Classroom	District report air changes with one air purifier has one classroom grossly incorrect	Corrected air changes per hour at full speed (Rm 106A + MERV 13 effects fixed)	Realistic air changes at the fan speed with a reasonable noise level
First floor			
Rm 116	1.8	2.0	1.7
Rm 117	2.4	2.6	1.9
Rm 115	2.7	2.9	2.3
Rm 114	2.0	2.3	1.8
Rm 113	3.0	3.3	2.5
Rm 112	2.7	2.9	2.2
Rm 107	3.0	3.3	2.6
Rm 106A	72.2	3.4	2.6
Rm 106	3.2	3.5	2.7
Rm 109	3.4	3.9	3.1
Rm 108	3.2	3.6	2.9
Rm 103	3.5	3.9	3.3
Rm 102	2.1	2.4	1.9
Rm 101	2.0	2.3	1.7
Rm 301	7.2	9.4	8.7
Rm 302	6.7	8.8	8.1
Rm 303	1.4	1.4	0.9
Rm 304	1.4	1.4	0.9
Second floor			
Rm 215	3.9	4.5	3.9
Rm 213	2.7	3.0	2.3
Rm 214	2.3	2.5	1.9
Rm 212	2.6	2.8	2.1
Rm 209	2.8	3.1	2.4
Rm 207	3.1	3.5	2.8
Rm 206	2.7	3.0	2.4
Rm 208	2.9	3.2	2.6
Rm 203	2.4	2.6	2.0
Rm 202	2.7	3.2	2.6
Rm 201	4.1	3.2	4.7
Average	**5.4**	**3.4**	**2.8**

The error in Room 106A contributes to, but does not fully explain, the district's false claim that average classroom airflow at Vernon exceeds 6 air changes per hour

Airflow reports included storage rooms and other small spaces misidentified as having a purifier and that students also do not go in. Based on patterns seen across 49 schools, it appears that the district averaged all airflows in the report, not just classrooms, so the district's average included these other types of inaccurate numbers.

Correct but unrealistic average classroom airflow with one air purifier at full speed is *not* >6

Correct full-speed airflow estimates for Vernon fix the error in Room 106A and account for the upgrade to MERV 13 furnace filters.

Correct and realistic average classroom airflow at Vernon is even lower

Vernon's true average is only 2.8, but the district claimed it was >6 and thus did not deliver its air purifiers until SIAFOS assisted Vernon parents.

Example errors from a PK-8 school: Faubion PK-8 School

These full speed numbers are unrealistic and impossible to sustain in real classrooms

IMPOSSIBLE

Faubion is another school where the district claim that average classroom airflow is >6 is false. It's also another example of how errors in room dimensions can inflate airflows and averages. At Faubion, four non-classroom spaces have errors, such as the staggering 120 air changes per hour claimed for Room 183R, due to the report's erroneous room width of 2 feet. Note that non-classroom 183R is not shown here in our list of classrooms only.

Similar to Vernon, the true average with one air purifier at Faubion indicates the district averaged all airflow values in the reports, not just classrooms. The reports include small rooms that students do not spend time in and that do not actually have the air purifiers the reports claim they do.

Faubion School was also completely re-built in 2016 — with poor ventilation!

31 out of 48 classrooms at Faubion do not even get 3 air changes per hour from the HVAC. The same firm that designed Faubion with such poor airflows is managing the designs of the next round of modernizations as well — making a commitment to 6 air changes per hour for new buildings' HVAC systems all the more urgent.

Watch a full video about the Faubion report errors and next steps for better air quality at Faubion at: safeairoregon.org/faubion-video

*District and SIAFOS full-speed calculations are in good agreement at Faubion. However, to SIAFOS's knowledge, Intellipure has not done gold-standard tests of clean air delivery rate (ANSI/AHAM AC-1), nor have they done any tests at half speed. Our estimates for half speed are based on Intellipure's guidance, but actual CADRs, at half speed, are likely lower.

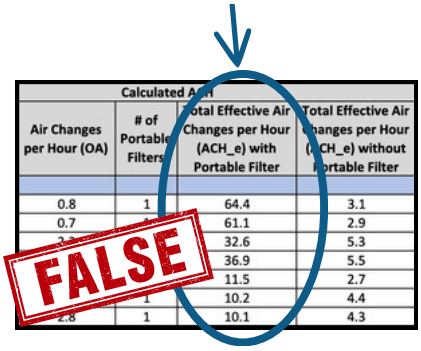
Classroom	District report air changes at full speed*	Realistic air changes at a reasonable noise level
Rm 188	5.7	4.9
Rm 186	5.3	4.6
Rm 184	5.5	4.7
Rm 181	6.6	6.0
Rm 149	4.7	4.2
Rm 147	4.7	4.0
Rm 145	5.2	4.6
Rm 143	3.7	3.1
Rm 141	2.9	2.3
Rm 115	2.6	2.3
Rm 117	3.1	2.6
Rm 119	2.7	2.2
Rm 122	4.7	4.6
Rm 201	4.2	3.8
Rm 203	3.7	3.4
Rm 205	2.2	1.9
Rm 209	3.3	2.8
Rm 211	3.9	3.4
Rm 213	4.6	4.1
Rm 215	4.5	4.0
Rm 217	4.7	4.2
Rm 219	4.0	3.5
Rm 221	3.5	3.0
Rm 222	3.9	3.3
Rm 223	3.7	3.2
Rm 225	3.7	3.2
Rm 227	3.3	2.8
Rm 229	3.9	3.4
Rm 231	3.6	3.0
Rm 301	3.9	3.7
Rm 303	0.8	0.7
Rm 309	4.5	4.0
Rm 311	5.3	4.8
Rm 313	3.3	2.8
Rm 315	4.2	3.8
Rm 317	2.7	2.3
Rm 319	4.0	3.5
Rm 321	3.4	3.0
Rm 323	3.3	2.8
Rm 325	3.5	3.0
Rm 327	3.8	3.3
Rm 329	3.7	3.3
Rm 331	2.8	2.4
Average	**3.9**	**3.4**

IMPOSSIBLE

The district did not calculate a correct classroom average even at the unrealistic full speed fan setting. The corrected (but still unachievable) full-speed average for Faubion classrooms is only 3.9. Faubion's classrooms do not average >6 as the district claimed in its memo.

Example of errors in classroom averages from McDaniel

The district report calculated air changes per hour with one air purifier at full speed incorrectly



An accurate and realistic average with only one air purifier for rooms that are labelled as classrooms on the McDaniel airflow map is only 5 air changes, not above 6 as claimed in the air purifier distribution memo. Using a more liberal definition of classrooms increases the average slightly but it is still under 6.

This listing of labeled classrooms also illustrates that relying on an average obscures rooms that fall below the minimum benchmark. In addition, an averaging approach fails to recognize the benefits of going above 6 air changes. At 6 air changes, it still takes 23 minutes to clear out 90% of airborne particles from sneezes and coughs. At 12 air changes, they clear out much faster — it's only 12 minutes to clear 90%.

*If the room has a less effective Intellipure air purifier instead of a Medify MA-112, its air changes are even lower than given here.

To SIAFOS's knowledge, there is no inventory of air purifiers at McDaniel to identify which rooms have which models.

Classroom	District report air changes with the air purifier are calculated incorrectly	Actual air changes per hour at full speed are lower than PPS reported	Realistic air changes at the fan speed with a reasonable noise level, if the room has a Medify*
Level 0			
Rm 047	11.2	8.6	6.7
Rm 043	10.3	7.5	5.6
Rm 041	10.4	7.6	5.6
Rm 039	10.4	7.7	5.7
Rm 037	10.8	7.9	5.9
Rm 015	11.5	7.9	5.3
Rm 013A	10.2	7.8	6.1
Rm 013B	10.1	7.7	6
Level 1			
Rm 181	10.1	7.5	5.5
Rm 183	10.3	7.5	5.6
Rm 185	10.3	7.6	5.7
Rm 187	10.3	7.6	5.7
Rm 189	10.3	7.6	5.6
Rm 122	9.4	6.8	5.1
Rm 120	10.0	7.4	5.5
Rm 117	9.9	7.5	5.8
Rm 115	10.2	7.8	6.0
Rm 113	8.5	6.5	5.0
Level 2			
Rm 281	9.6	6.7	4.6
Rm 283	9.9	6.9	4.7
Rm 284	8.4	5.8	4.0
Rm 285	9.9	6.9	4.8
Rm 286	8.9	6.2	4.3
Rm 287	9.8	6.8	4.7
Rm 289	10.0	7.0	4.8
Rm 290	9.2	6.4	4.4
Rm 292	9.3	6.4	4.7
Rm 247	8.6	5.8	3.9
Rm 242	8.3	5.7	3.9
Rm 243	9.6	6.7	4.7
Rm 240	8.4	5.8	4.0
Rm 241	9.6	6.7	4.7
Rm 238	8.4	5.9	4.0
Rm 239	9.6	6.7	4.7
Rm 236	9.3	6.6	4.7
Rm 234	9.6	6.7	4.6
Rm 231	9.7	6.7	4.6
Rm 220	8.6	6.0	4.2
Rm 218	8.7	6.0	4.1
Rm 217	8.7	6.2	4.4
Rm 2	8.5	5.9	4.1
Average	**9.6**	**6.9**	**5.0**

FALSE

IMPOSSIBLE

FALSE

UNREALISTIC

Check some of our numbers yourself!

- Download district reports from the PPS website at tinyurl.com/airflowreports
- Match the numbers in our first column colored in **navy blue** against the numbers in the district report under the column "Total Effective Air Changes per Hour (ACH_e) without Portable Filter"
- Check which rooms are classrooms vs. non-classrooms, using the maps at the end of each report
- Look for errors we identified such as Room 106A at Vernon falsely claiming 72.2 air changes per hour
- Calculate air changes using equations from pages 18, 19 and 22 (also see page 3 of the district reports)

Correcting errors and filling gaps in PPS airflow data

The original airflow data provided by the district contained significant miscalculations, incorrect assumptions, and missing information that obscured the true ventilation conditions at PPS schools. We correct these errors to provide an accurate picture of baseline ventilation rates from the HVAC and the clean airflows that are achievable using air purifiers.

Key issues that were identified and fixed:

✓ **Fixed** ⟶ **Incorrect unit conversions**
The district's airflow reports included an error in units of measurement, leading to incorrect calculations of air changes per hour with one regular Medify air purifier in high school rooms. As a result, airflow with the air purifier running was significantly overstated in every high school room. We use correct units in all calculations.

✓ **Fixed** ⟶ **Failure to account for realistic conditions**
The district's estimates did not account for the fan speed that staff can actually use on their regular Medify and Intellipure air purifiers. Given noise guidelines for healthy learning environments and feedback from many teachers, airflow calculations must use speeds that the particular room can handle. We address this by calculating air changes per hour using the quiet, realistic fan speed setting on the Medify units (speed 2) and an estimate of clean air delivery rate at half speed for Intellipure units.

✓ **Fixed** ⟶ **Lack of airflow projections with additional air purifiers**
The district's analysis did not include calculations of the impact of second air purifiers. We present clear data showing how much airflow improvement is achievable with two of the air purifier models owned by the district.

✓ **Fixed** ⟶ **No assessment of aerosol clearance times**
We add critical context by calculating how long it takes to clear most aerosol particles from a room under the room's different achievable clean airflow conditions. These clearance times give staff a practical understanding of air quality risks and opportunities in each room analyzed.

Addressing these gaps and errors provides a more accurate and actionable understanding of school indoor air quality in PPS. Accurate airflow information can also empower staff and decision-makers to take informed steps towards improving air quality across all PPS schools.

Air changes per hour
=
How many times in one hour an airflow source delivers a volume of air equal to the size of the room*

Airflow 101

Add up the clean air!

Outdoor airflow + 90% of recirculated airflow

x

Multiply by 0.8 to account for weaknesses in the HVAC system's ability to distribute clean air throughout the room

=

Air changes per hour from the HVAC system

Air changes per hour from the HVAC system

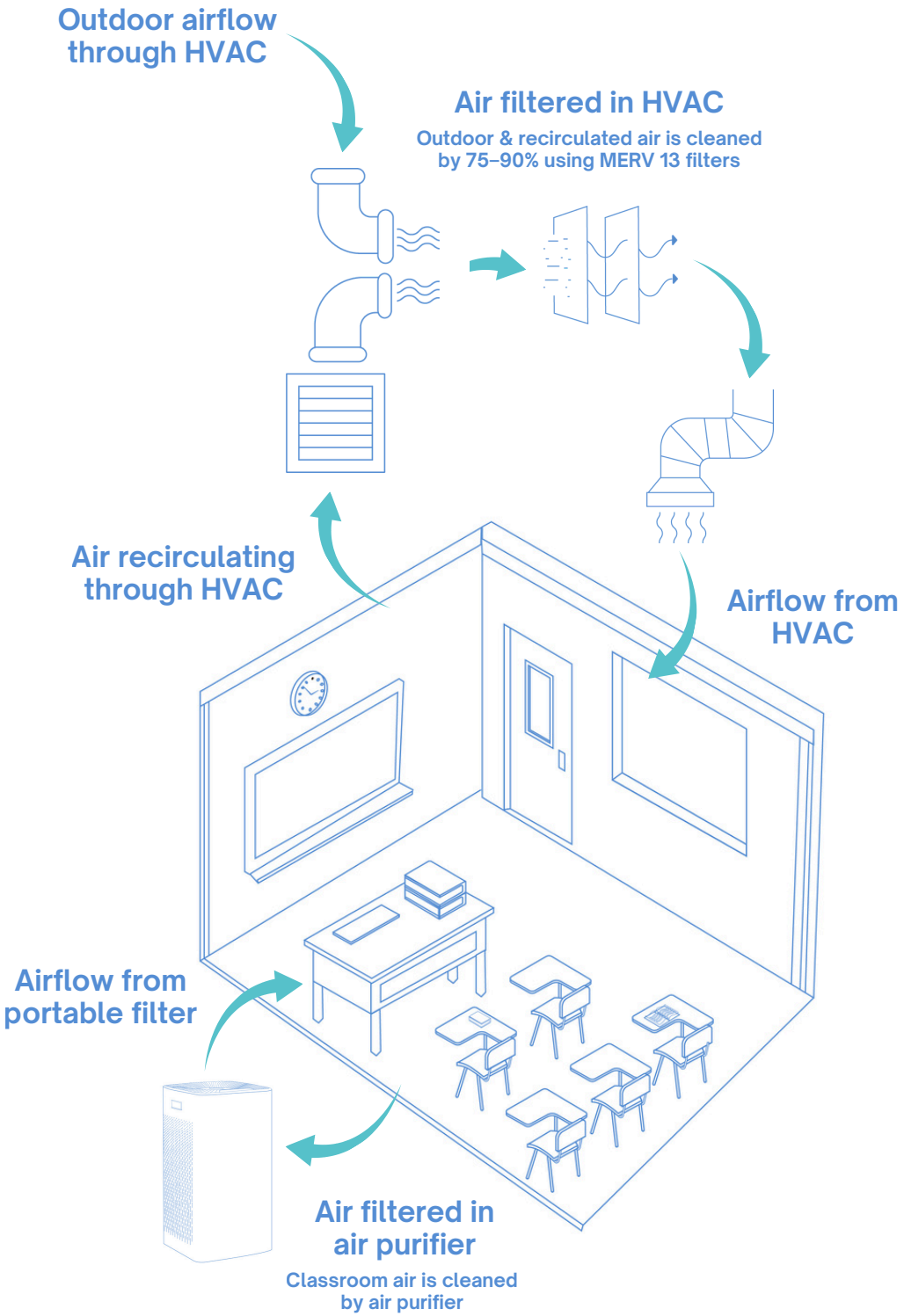
+

Air changes per hour from any air purifiers

=

Total air changes per hour

*Note: We use air changes/hour for effective air changes/hour; see p. 24.



Air changes per hour are not actual full changes of air — an analogy

A good analogy for airflow expressed in air changes per hour is to imagine one bucket of clean water being poured into a bucket of dirty water, in order to clean out the dirty water. In this analogy, one "change" has occurred once a full bucket's worth of clean water has been poured into the bucket full of dirty water. The new clean water will displace a lot of the old dirty water, but not all of it.

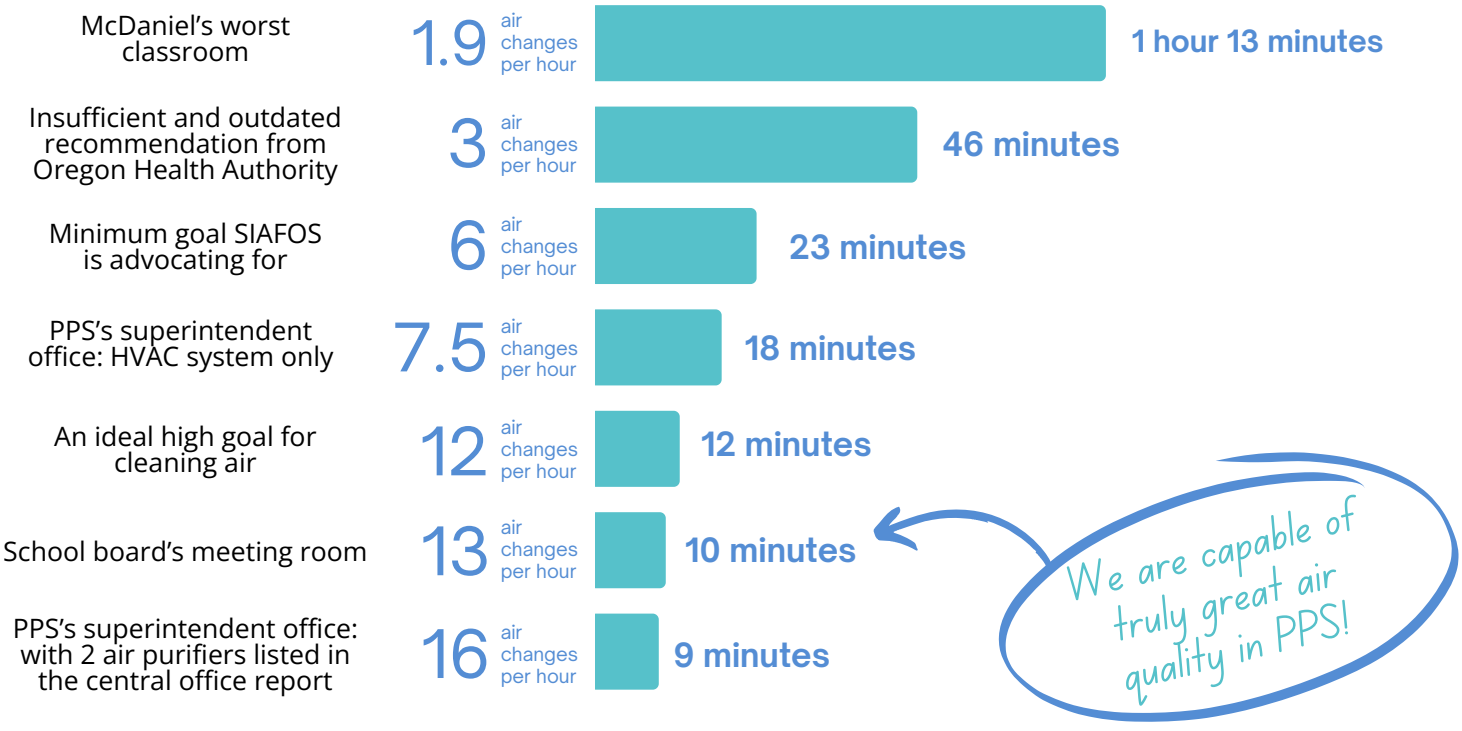
Similarly, when a room's worth of clean air pours into a room from the HVAC vents, air purifiers, and other sources of clean air, that new air will displace much, but not all, of the stale, dirty air already in the room. Each air change clears some pollution, but complete replacement requires multiple changes.

Translating air changes to how long sneezes and coughs float around the classroom

Because an air change is not an actual full exchange of air in the room, we need more changes than you might expect to sufficiently clean the room's air and clear indoor air pollutants and aerosols out.

In McDaniel's worst-performing room, the HVAC system provides only 1.9 air changes per hour. At that rate, each cough, sneeze, plume of smoke that penetrated the building, and cloud of dust kicked up by students moving about takes well over an hour to clear out. The Oregon Health Authority's early pandemic guidance of 3 to 6 air changes per hour also leaves classrooms with sneezes and coughs lingering in the air for far too long – 3 air changes per hour takes 46 minutes to clear out 90% of any given sneeze or cough's bioaerosols. At 6 air changes per hour, it only takes 23 minutes to clear out 90% of aerosols and pollutants, and at 12 air changes, that comes down to 12 minutes. PPS is capable of providing this kind of excellent airflow. The superintendent's office and the school board's meeting room each get high air changes per hour from the HVAC system alone — 7.5 air changes in the superintendent office; 13.4 in the school board meeting room. And in the central office airflow report, each of these rooms is designated with 2 air purifiers on top of that already-excellent HVAC airflow.

How long it takes to clear out 90% of respiratory aerosols and other indoor air pollutants



Targets for air changes

The SIAFOS Clean Air Score is based on a room's air changes per hour, and the SIAFOS Clean Air Schoolwide Score is based on a composite of room scores and school factors.

12 air changes per hour is an ideal high goal to limit spread of pathogens and infectious aerosols and provide students and staff with exceptionally clean air

Air changes vs. effective air changes

A strict definition of air changes per hour is airflow from outdoor air only, while effective air changes per hour refers to airflow from filtration or a mix of outdoor air and filtration.

For simplicity, we use air changes per hour in this report regardless of whether the airflow source is outdoor air, filtered air, or a mix of both.

Air changes per hour	Grade
3 or less	F
3 to 3.5	D⁻
3.5 to 4	D
4 to 4.5	D⁺
4.5 to 5	C⁻
5 to 5.5	C
5.5 to 6	B⁻
6 to 6.5	B
6.5 to 7	B⁺
7 to 8	A
8 to 10	A⁺
10 and above	A⁺⁺

More from our Airflow 101 guide is available at:

*** safeairoregon.org/mcdaniel-air-quality-report (our full McDaniel Air Quality Report)**

*** safeairoregon.org/airflow-101**

Multiple air purifiers
=
Additional air changes per hour
to achieve airflow targets

Clean More Air

The power of two!

Air changes per hour from the HVAC system

+

Air changes per hour from one air purifier

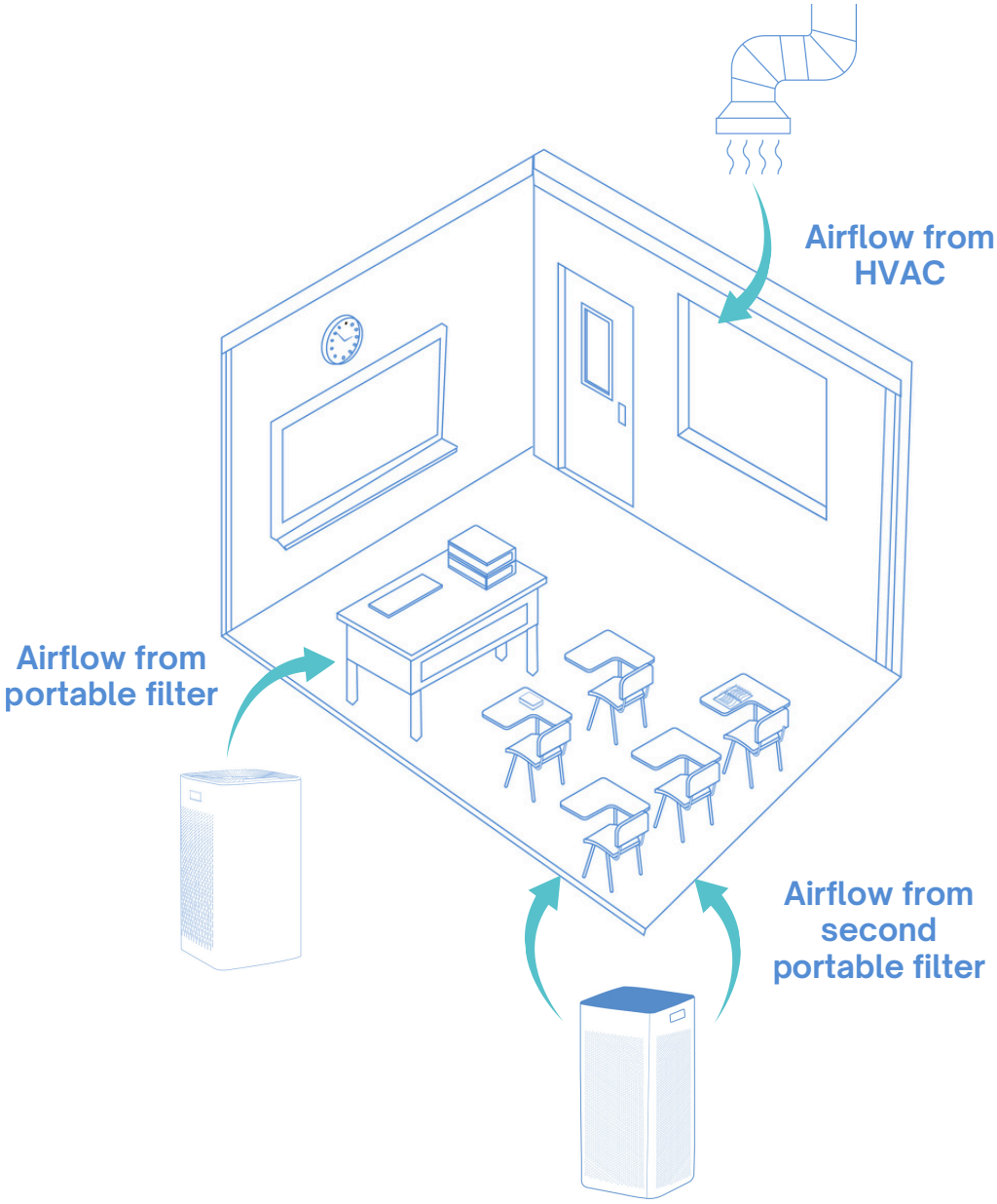
+

Air changes per hour from a second air purifier

=

More total air changes per hour

Large rooms in PPS, like band, choir, dance, and weight rooms, were originally assigned two air purifiers, but generally still need more. Larger spaces need a third unit to get above or closer to clean air targets.



One air purifier set at its highest fan speed is too noisy for classrooms

Two air purifiers set at medium speeds deliver a lot of clean air while being quiet

Studies and experts agree: multiple air purifiers are key to quiet clean air

Two or more air purifiers in one room can dramatically improve air quality and reduce harmful exposures, without causing the disruptive noise levels that one unit running at full speed does. Experts consistently recommend using more than one unit in order to achieve effective air cleaning at quiet operation. Studies and online indoor air quality tools also show that multiple air purifiers can get a room to clean airflow targets and do so while running at quiet settings.

A CDC study found that two HEPA air cleaners positioned strategically in a room were able to reduce aerosol exposure by up to 65%. CDC findings also underscored that multiple air purifiers helps clean the air near people who may be coughing, sneezing, or talking in different parts of the room. Similarly, the Healthy Buildings program at Harvard's T.H. Chan School of Public Health emphasizes that multiple units allow classrooms to meet air change rate goals, while also ensuring more uniform distribution of clean air. Using multiple units helps to distribute filtered air more evenly throughout a room, addressing areas with poor circulation and improving overall filtration efficiency.

The California Department of Public Health, as well as experts from the Corsi-Rosenthal Foundation, Patient Knowhow, Clean Air Stars, and Indoor Air Care Advocates also all recommend using multiple air purifiers in classrooms and other spaces to effectively clean the air while avoiding the noise generated by running a single purifier at full capacity. Multiple units per classroom or other learning space help schools to meet airflow and clean air delivery rate targets without sacrificing quiet — the combination of more airflow and low noise is especially valuable when quieter settings are important.

One vs. two district air purifiers in high school classrooms assigned Medify units

One Medify MA-112 air purifier

Top speed (speed 4)

559 cubic feet of clean air per minute

57 decibels

✓ *Great air cleaning*
✗ *Too noisy*

Mid speed (speed 2)

281 cubic feet of clean air per minute

41 decibels

✗ *Insufficient air cleaning*
✓ *Quiet*

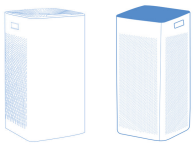
Two Medify MA-112's*

Mid speed (speed 2)

668 cubic feet of clean air per minute

44 decibels

✓ *Great air cleaning*
✓ *Quiet*



*One regular MA-112 and one MA-112 Pro

Meets EPA & Center for Green Schools noise recommendations

At the top speed that provides a good level of air cleaning, the original air purifier most high school spaces have from the district is too loud (57 dB) and far above recommendations for decibel levels in classrooms (EPA: 45 dB, Center for Green Schools: 35 to 45 / 50 dB). At mid speed 2, the one air purifier is quiet but provides insufficient clean air for most spaces. Two district air purifiers per room can give PPS classrooms and other spaces quiet clean air. Similar dynamics apply to Intellipure air purifiers assigned to elementary schools, middle schools, and K-8 schools in PPS.