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WHITE PAPER

Proposed Ventilation and Energy Efficiency Verification/Repair Program for School Reopening

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This paper presents a proposal for a Ventilation and Energy Efficiency Verification/Repair Program that would prepare schools for reopening during the COVID-19 crisis. This program includes certifying school facilities as having functioning air ventilation and filtration systems that meet or exceed OSHA and California Energy Commission requirements, and, to the extent feasible, that meet ventilation and filtration recommendations for reopening schools set forth by the World Health Organization, the Centers for Disease Control and Prevention, and the American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE), as well as any applicable local and state agency school reopening guidance. The program would also ensure that systems are operating energy efficiently and will identify recommendations for future efficiency and safety upgrades.

This program would require recipients to (1) assess, maintain, adjust, and, if necessary, repair existing heating, ventilation and air conditioning (HVAC) systems to verify proper and efficient operation, as well as compliance with health and safety standards; (2) install carbon dioxide (CO_2) sensors in classrooms to verify that proper ventilation is maintained throughout the school year; and (3) prepare an HVAC Assessment Report documenting the work performed and identifying any additional system balancing, upgrades, replacements or other measures recommended to improve the health, safety, and/or efficiency of the HVAC system. School Facilities that comply with these requirements would be provided a COVID-19 Reopening Ventilation Verification Certificate for posting in the building.

Research has shown that underventilation of classrooms is common and negatively impacts student health and learning. A 2003 report to the Legislature by the California Air Resources Board and the State Department of Health Services found significant indoor air quality problems in California schools, including problems with ventilation, temperature and humidity, air pollutants, floor dust contaminants, moisture, mold, noise, and lighting. The report found that ventilation with outdoor air was inadequate during 40% of classroom hours and seriously deficient during 10% of classroom hours, in both portable classrooms and traditional classrooms.[1]

[1] Whitmore, et al., California Portable Classrooms Study, Phase II: Main Study, Final Report, Volume II., Report to the California Air Resources Board and California Department of Health Services (2003) at pp. xxii & xxiii (https://ww2.arb.ca.gov/sites/default/files/classic//research/apr/past/00-317_v2.pdf).

The California Building Energy Efficiency Standards has set minimum ventilation rates for classrooms.[2] The California Education Code requires school districts to maintain schools in good repair, including HVAC systems that are functional, supply adequate ventilation to classrooms, and maintain interior temperatures within acceptable ranges.[3] Despite these requirements, poor performing HVAC systems and underventilation of classrooms continues to be a persistent problem in California.

A 2020 report by the University of California-Davis Western Cooling Efficiency Center and the Indoor Environment Group of Lawrence Berkeley National Laboratory found over half of new HVAC systems in schools had significant problems within three years of installation, and that the vast majority of classrooms in California continue to fail to meet minimum ventilation rates.[4] Nearly 20% of classrooms had average daily maximum CO_2 concentrations above 2,000 ppm, where an adequately ventilated classroom should not exceed a concentration of 1,100 ppm. The researchers recommended periodic testing of HVAC systems and continuous real-time CO_2 monitoring to detect and correct these problems.

The persistence of underperforming HVAC systems and inadequate ventilation rates in the classroom is of particular concern as California looks to reopen schools during the COVID-19 pandemic. An April 2020 paper by ASHRAE found that viruses such as COVID-19 can spread through the air in two ways. Larger droplets travel between 6 and 7 feet before dropping to the ground, but smaller droplets can evaporate and become aerosolized, remaining airborne for extended periods.[5] Increasing filtration levels and ventilation rates removes and dilutes these aerosolized viruses, reducing the risk of infection for occupants. For that reason, the World Health Organization (WHO), the Centers for Disease Control and Prevention (CDC) and ASHRAE recommend ensuring ventilation systems operate properly, increasing ventilation rates, and installing MERV 13 or better filters where possible in order to reduce the spread of COVID-

[2] See Cal. Code Regs, tit. 24, Part 6, Section 120.1 and Table 120.1-A (Minimum Ventilation Rates).
[3] Cal. Education Code §§ 17070.75 & 17002.
[4] Chan, et al, Ventilation rates in California classrooms: Why many recent HVAC retrofits are not delivering sufficient ventilation, Building and Environment Journal 167 (2020) (https://www.sciencedirect.com/science/article/pii/S0360132319306365).
[5] ASHRAE, ASHRAE Position Document on Infectious Aerosols. ASHRAE (April 2020), (https://www.ashrae.org/file%20library/about/position%20documents/pd_infectiousaerosols_2020.pdf); see also Neeltje van Doremalen, et al, Aerosol and surface stability of HCoV-19 (SARS-CoV-2) compared to SARS-CoV-1, medRxiv preprint doi (March 13, 2020) (finding that viable COVID-19 viruses could be detected in aerosols up to 3 hours post aerosolization) (https://www.medrxiv.org/content/10.1101/2020.03.09.20033217v2).

19.[6] A May 2020 report by Dr. Jovan Pantelic at UC Berkeley further recommends continuous CO_2 monitoring and maintaining relative humidity in the range of 40%-60%.[7]

These steps can however increase energy consumption, particularly in systems that are not installed correctly. Studies have shown that the efficiency of an HVAC system is highly dependent on the quality of its installation. Poor quality installation of HVAC systems results in a 20% to 30% increase in energy use.[8] Moreover, poor quality installation is pervasive. A study by the California Energy Commission found that over 50% of new HVAC systems and 85% of replacement HVAC systems that they evaluated were not performing correctly due to poor quality installation.[8] Utility-funded studies have found the vast majority of HVAC installers don't have the technical training, knowledge, skills, or abilities to properly install systems, resulting in high failure rates for job performance on even routine tasks.[9]

The program would prepare schools to reopen with functional ventilation systems that are verified as having been tested, adjusted, and if necessary repaired or replaced, by qualified personnel in order to provide recommended ventilation rates as reliably and energy efficiently as possible. Ventilation rates will be documented in an HVAC assessment report submitted to the program administrator and available to the public upon request.

Improving the performance of school HVAC systems not only saves energy and provides a safer and healthier building environment, it also has a significant correlation to student performance. In a 2017 literature review, W. J. Fisk summarized that 8 studies reported statistically significant improvements in some measures of student performance associated with increased ventilation rates or lower CO_2 concentrations, with performance increases up to 15%.[10]

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[6] Centers For Disease Control and Prevention, Interim Guidance For Businesses and Employers Responding To Coronavirus Disease 2019 (COVID-19) (May 2020) (https://www.cdc.gov/coronavirus/2019-ncov/community/guidance-business-response.html); ASHRAE, ASHRAE Epidemic Task Force: Building Readiness (updated May 22, 2020) (https://www.ashrae.org/file%20library/technical%20resources/covid-19/ashrae-building-readiness.pdf) ASHRAE, ASHRAE Epidemic Task Force: Schools & Universities (updated May 5, 2020) (https://www.ashrae.org/file%20library/technical%20resources/covid-19/ashrae-reopening-schools.pdf); AHRAE, ASHRAE Position Document on Infectious Aerosols (April 14, 2020) (https://www.ashrae.org/file%20library/about/position%20documents/pd_infectiousaerosols_2020.pdf); World Health Organization, Considerations for school-related public health measures in the context of COVID-19 (May 10, 2020) (https://www.who.int/publications-detail/considerations-for-school-related-public-health-measures-in-the-context-of-covid-19); World Health Organization, Considerations for public health and social measures in the workplace in the context of COVID-19 (May 10, 2020) (https://www.who.int/publications-detail/considerations-for-public-health-and-social-measures-in-the-workplace-in-the-context-of-covid-19).

[7] Pantelic, Using IoT Environmental Sensing to Reopen Spaces, SenseWare (May 2020) (https://cdn2.hubspot.net/hubfs/5238584/White%20Paper%20Senseware%20Covid.pdf).

[8] California Energy Commission, *Strategic Plan to Reduce the Energy Impact of Air Conditioners* (June 2008), CEC-400-2008-010, at p. (v) (http://www.energy.ca.gov/2008publications/CEC-400-2008-010/CEC-400-2008-010.PDF); see also Zabin, et. al, *Workforce Issues and Energy Efficiency Programs: A Plan for California's Utilities*, Don Vial Center for Employment in the Green Economy (2014), at pp. 32-34 and Appendix 2B (http://laborcenter.berkeley.edu/workforce-issues-and-energy-efficiency-programs-a-plan-for-californias-utilities/).

[9] SCE Energy Efficiency Business Plan 2018-2025 at p. 63; SDG&E Energy Efficiency Business Plan 2018-2025 at p. 216; PG&E Energy Efficiency Business Plan (2018-2025), Residential Appendix at p. 30; see also C. Zabin, et. al, *Workforce Issues and Energy Efficiency Programs: A Plan for California's Utilities*, Don Vial Center for Employment in the Green Economy (2014), at p. 34 (http://laborcenter.berkeley.edu/workforce-issues-and-energy-efficiency-programs-a-plan-for-californias-utilities/).

[10] Fisk, W. J., The ventilation problem in schools: literature review, Indoor Air. 2017;27:1039–1051 (https://onlinelibrary.wiley.com/doi/epdf/10.1111/ina.12403)

A 2018 report in the Environment International Journal found that short-term CO_2 exposure beginning at 1000 ppm affects cognitive performance, including decision making and problem resolution.[11] The Wisconsin Department of Health states that CO_2 levels between 1000 and 2000 ppm are associated with drowsiness and attention issues. CO_2 levels above 2000 ppm affect concentration and can cause headaches, increased heart rate, and nausea.[12]

This program will thus also provide the additional benefit of addressing the numerous studies finding that the widespread underventilation of classrooms in California is negatively impacting student health and learning.

[11] Azuma, et al, Effects of low-level inhalation exposure to carbon dioxide in indoor environments: A short review on human health and psychomotor performance, Environment International 121 (2018) (https://www.sciencedirect.com/science/article/pii/S0160412018312807).
[12] Wisconsin Department of Health Services, Carbon Dioxide (Dec. 20, 2019) (https://www.dhs.wisconsin.gov/chemical/carbondioxide.htm).

PROPOSED REQUIREMENTS:

Section ____. School Ventilation and Efficiency Verification and Repair Program. The Office of Public School Construction shall create and administer a School Ventilation and Efficiency Verification and Repair Program that shall allocate grants to Local Educational Agencies (LEAs) to prepare schools to reopen with functional ventilation systems that are tested, adjusted, and if necessary repaired, by qualified personnel in order to provide recommended ventilation rates as reliably and energy efficiently as possible. Recipients shall: (1) assess, maintain, adjust, and, if necessary, repair existing HVAC systems to ensure ventilation rates meet or exceed the standards set forth in Table 120.1-A of the 2019 Title 24 California Building Energy Efficiency Standards; (2) provide MERV 13 filtration or better where feasible, or the maximum MERV filtration that the system design can handle; (3) install CO_2 sensors in classrooms to verify that proper ventilation is maintained throughout the school year; and (4) prepare an HVAC Assessment Report documenting the work performed and identifying any additional system balancing, upgrades, replacements or other measures recommended to improve the health, safety, and/or efficiency of the HVAC system. School Facilities that comply with these requirements shall be provided a COVID-19 Reopening Ventilation Verification Certificate for posting in the building.

An LEA that accepts a grant under this Program for verification of a school facility shall perform the following tasks for all air handling units, roof top units and unitary and single zone equipment in that facility's HVAC system or systems:

(a) Assessment, Maintenance, Adjustment and Repair of Existing Facility Ventilation System.

1. Filtration. Consistent with the recommendations of the ASHRAE Guidance for Reopening Schools, MERV 13 or better filtration shall be installed in the facility's HVAC system where feasible. Qualified personnel shall review system capacity and airflow to determine the highest Minimum Efficiency Reporting Value (MERV) filtration that can be installed without adversely impacting equipment, shall replace or upgrade filters where needed, and shall verify that such filters are installed correctly. Where a system uses Ultraviolet Germicidal Irradiation (UVGI) to disinfect the air, the UVGI lamp shall be checked for proper operation, replacing bulbs as needed and verifying that the ultraviolet light does not shine on filters. Recommendations for additional maintenance, replacement or upgrades to allow for more protective filtration shall be recorded in the HVAC Assessment Report.

2. Economizer. For systems with economizers, qualified personnel shall test system economizer dampers per Section B of NRCA-MCH-05-A – Air Economizer Controls and repair any economizer dampers and controls that are not properly functioning. Recommendations for additional maintenance, replacement or upgrades shall be recorded in the HVAC Assessment Report.

3. Ventilation and Exhaust.

A. Assessment. Following the assessment of the filtration and economizer, qualified personnel shall assess the ventilation rates in the facility classrooms, auditoriums, gymnasiums,

nurses offices, restrooms and other occupied areas to determine whether they meet the minimum ventilation rate requirements set forth in Table 120.1-A of the 2019 Title 24 California Building Energy Efficiency Standards. Assessment shall include:

(i). Calculation of the required minimum outside air ventilation rates for each occupied area based on the anticipated occupancy and the minimum required ventilation rate per occupant set forth in Table 120.1-A of the 2019 Title 24 California Building Energy Efficiency Standards. Calculations shall be based on maximum anticipated classroom or other occupied area occupancy rates and determined by the performing technician. Natural Ventilation shall be designed in accordance with Section 402.2 of the 2019 California Mechanical Code and shall include mechanical ventilation systems designed in accordance with Section 403.0, Section 404.0, or both. Additionally, any room relying on Natural Ventilation shall have a continuously operational CO2 monitor as prescribed in section 7a of this document.[13]

(ii). Measurement of Outside Air per Section B of NRCA-MCH-02-A – Outdoor Air Acceptance and verification of whether the system provides the minimum outside air ventilation rates calculated in subsection (i).

(iii). Survey readings of inlets and outlets to verify all ventilation is reaching the served zone and that there is adequate distribution. Verify if inlets and outlets are balanced within tolerance of the system design. Document read values and deficiencies. If the original system design values are not available, document available information and note unavailability of system design values in the HVAC Assessment Report.

(iv). Verification of building pressure relative to the outdoors to ensure positive pressure differential and to ensure building is not over pressurized.

(v). Verification of coil velocities and coil and unit discharge air temperatures required to maintain desired indoor conditions and to avoid moisture carry over from cooling coils.

(vi). Verification that separation between outdoor air intakes and exhaust discharge outlets meet code requirements.

(vii). Confirmation that the air handling unit is bringing in outdoor air and removing exhaust air as intended by the system design.

(viii) Measurement of all exhaust air volume for exhaust fans, including restrooms. Document any discrepancies from system design. Per ASHRAE Guidance for Reopening and Operating Schools exhaust fans operate whenever HVAC systems are in operation.

(ix) Energy Recovery Ventilation (ERV) system operation and leakage concerns should be addressed according to the recommendations of the ASHRAE Building Readiness document.

[13] California Building Standards Commission. (2019). *California mechanical code*. Sacramento, CA.

B. Adjustment. If the system does not meet the minimum ventilation rate requirements set forth in Table 120.1-A of the 2019 Title 24 California Building Energy Efficiency Standards, qualified personnel shall review the system airflow and capacity to determine if additional ventilation can be provided without adversely impacting equipment performance and building Indoor Environmental Quality (IEQ). If additional ventilation can be provided, qualified personnel shall adjust ventilation rates to meet the minimum ventilation rate requirements set forth in the 2019 Title 24 California Building Energy Efficiency Standards to the extent feasible. After adjustment, steps (ii), (iv) and (v) of subsection A shall be repeated.

If minimum ventilation rate requirements set forth in Table 120.1-A of the 2019 Title 24 California Building Energy Efficiency Standards cannot be met, the system shall be repaired, upgraded or replaced as necessary to meet these requirements. Such repairs shall be considered a critical repair and shall be eligible for additional funding under this Program per subsection (7). Priority recommendations for additional HVAC system maintenance, replacement or upgrades to improve ventilation outcomes or ventilation efficiency shall be recorded in the HVAC Assessment Report.

4. Demand Control Ventilation. If installed, demand control ventilation shall be adjusted to a CO_2 set point of 800 ppm or less and tested by qualified personnel per Section B of NRCA-MCH-06-A – Demand Control Ventilation Systems Acceptance[14]. If the demand control ventilation system does not maintain average daily maximum CO_2 levels below 1,100 ppm, it shall be disabled until such time as the LEA determines that the COVID-19 crisis has passed, unless disabling the control would adversely affect operation of the overall system. When disabling a demand control ventilation system, the system must be configured to meet the minimum ventilation rate requirements and tested and adjusted in accordance with section 3. Recommendations for additional maintenance, replacement or upgrades shall be recorded in the HVAC Assessment Report.

5. General Maintenance. Qualified personnel shall verify coil condition, condensate drainage, cooling coil air temperature differential (entering and leaving dry bulb), heat exchanger operation, and drive assembly and perform critical repairs. Recommendations for additional maintenance, replacement or upgrades shall be recorded in the HVAC Assessment Report.

6. Operational Controls. Qualified personnel shall review control sequences to verify systems will maintain intended ventilation, temperature and humidity conditions during school operation. Previously unoccupied buildings shall perform the recommended practices of reopening a building as covered in the ASHRAE Building Readiness document. Verify a daily flush is scheduled for 2 hours before and after scheduled occupancy or demonstrate calculation of flush times per ASHRAE Guidance for Reopening and Operating Schools and Buildings or otherwise applicable local or state guidance. Verify that HVAC system operational times, exhaust fans operation times, setpoints, and enabled features meet ASHRAE Guidance for Reopening and Operating Schools and Buildings or otherwise applicable local or state guidance.

[14] The CO_2 set point of 800 ppm is recommended by the UC Davis Western Cooling Efficiency Center. The purpose of the 800 ppm set point for demand control ventilation systems is to prevent the automated control system from overshooting a maximum 1,100 ppm CO_2 concentration.

7. Repairs. If installed HVAC systems or system components are broken, fail to meet minimum ventilation requirements, pre and post occupancy purge recommendations, or are unable to operate to the original design and intent, corrective work must be completed by qualified personnel prior to resumption of school operation. The Office of Public School Construction shall set aside 10% of Program funds to provide supplemental grants for critical repairs. To the extent available, Program funds may also be used to repair, upgrade or replace system components to improve HVAC system efficiency.

(a) CO_2 Monitoring. To ensure proper ventilation is maintained throughout the school year, all classrooms shall be equipped with a CO_2 monitor that:

(1) Is hard-wired or plugged-in and mounted to the wall between 3 – 6 feet above the floor and at least 5 feet away from the door and operable windows.

(2) Displays the CO_2 readings to the teacher through a display on the device or other means such as a web-based application or cell-phone application.

(3) Notifies the teacher through visual indicator on the monitor (e.g. indicator light) or other alert such as e-mail, text, or cell phone application, when the CO2 levels in the classroom have exceeded 1,100 ppm.

(4) Maintains a record of previous data which includes at least the maximum CO2 concentration measured.

(5) Has a range of 1 - 2000 ppm or greater;

(6) Is certified by the manufacturer to be accurate within 75 ppm at 1,000 ppm CO2 concentration and is certified by the manufacturer to require calibration no more frequently than once every five years.

If a classroom CO_2 concentration exceeds 1,100 ppm more than once a week as observed by the teacher or the facilities staff, the classroom ventilation rates shall be adjusted by qualified personnel to ensure peak CO_2 concentrations in the classroom remain below the maximum allowable CO_2 PPM setpoint. Verification of the installation of CO_2 Monitors in all classrooms shall be included in the HVAC Assessment Report.

(b) HVAC Assessment Report. The LEA shall prepare an HVAC Assessment Report for each school facility that receives Program funds. The HVAC Assessment Report shall include the following information:

(1) Name and address of school facility and person/contractor preparing and certifying Report.

(2) Description of assessment, maintenance, adjustment and repair activities and outcomes.

(3) Document HVAC equipment model number, serial number, general condition of unit, and any additional information that could be used to asses replacement and repair options given potential for increased energy efficiency benefits.

(4) Verification that the LEA has complied with all requirements of this Section.

(5) Either verification that MERV 13 filters have been installed or verification that the maximum MERV-rated filter that the system is able to effectively handle has been installed and what that MERV-rating is.

(6) The verified ventilation rates for facility classrooms, auditoriums, gymnasiums, nurses' offices, restrooms, offices and other occupied areas and whether those rates meet the requirements set forth in the 2019 Title 24 California Building Energy Efficiency Standards. If ventilation rates do not meet applicable guidance, then an explanation for why the current system is unable to meet those rates should be provided.

(7) The verified exhaust for facility classrooms, auditoriums, gymnasiums, nurses' offices', restrooms and other occupied areas and whether those rates meet the requirements set forth in the design intent.

(8) Clearly define system deficiencies and provide recommendations for additional maintenance, replacement or upgrades, such as upgrading systems to allow for additional ventilation and filtration and/or to improve energy efficiency. Deficiencies to include:

i. Discrepancies between supply, return, exhaust, and outside air summations which signal duct leakage.
ii. Discrepancies between designed total airflow and actual airflow which signal leakage, excessive resistance, or faulty operation.
iii. Low cooling coil air temperature differential (entering and leaving dry bulb), in comparison to design, which signal improper refrigerant charge.

(9) Reports shall clearly document initial operating verifications, adjustments, and final operating verifications and document any adjustments or repairs performed.

(10) Verification of installation of CO_2 Monitors, including make and model of monitors.

The LEA shall maintain a copy of the HVAC Assessment Report and make it available to any member of the public upon request. The LEA shall provide a copy of the HVAC Assessment Report to the Office of Public School Construction. No later than January 1, 2021, the Office of Public School Construction shall prepare a report to the legislature summarizing the additional maintenance, replacement or upgrades needed in California's public schools to meet ASHRAE COVID-19 school safety and efficiency recommendations, along with an estimate of the cost of such work.

(c) COVID-19 Reopening Ventilation Verification Certificate. Upon receipt of a copy of the HVAC Assessment Report, the Office of Public School Construction shall provide the LEA a COVID-19 Reopening Ventilation Verification Certificate for posting in the verified school building that states that the school meets the minimum 2019 Title 24 California Energy Commission requirements for ventilation.

(d) Energy and Ventilation Upgrades. Upon completion of the HVAC Assessment Report, a Mechanical Engineer shall review and determine if upgrades can be made to the HVAC system to increase energy efficiency and ventilation. All repairs, beyond adjustment, shall be evaluated for equipment upgrades that would result in increased energy efficiency, ventilation, and filtration.

Factors to determine HVAC replacements and upgrades:

- Consider the general condition of the unit and the cost to repair the unit versus cost to replace. Consider equipment service life and maintenance costs with the ASHRAE Service Life and Maintenance Cost Database. [15] Replacement costs should consider potential energy savings.
- Consider energy usage over life of unit by a comparison of the unit's Seasonal Energy Efficiency Ratio (SEER) to that of potential replacement options.[16]
- Improper airflow and temperature differentials determined in the assessment should be diagnosed as they signal reduced energy efficiency.[17]
- Units containing R-22 refrigerant or has a history of refrigerant leaks to be considered for replacement.
- Units with manual thermostats shall be upgraded to programmable thermostats.
- Units without a functional economizer to be considered for repair or economizer upgrade.
- Units with indoor fan motors not meeting the NEMA Premium Efficiency Electric Motor standard should be considered for a replacement with a NEMA Premium Efficiency Electric Motor.
- Units with a Fixed Orifice (FXO) to be considered for replacement with a unit with a Thermostatic Expansion Valve (TXV).

[15] "ASHRAE: Service Life and Maintenance Cost Database." *ASHRAE*, http://xp20.ashrae.org/publicdatabase

[16] 2017 Standard for Performance Rating of Unitary Air-Conditioning & Air-Source Heat Pump Equipment. AHRI, 2017.

[17] Kim, Woohyun and Braun, James E., "Impacts of Refrigerant Charge on Air Conditioner and Heat Pump Performance" (2010). International Refrigeration and Air Conditioning Conference. Paper 1122. http://docs.lib.purdue.edu/iracc/1122

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