**WHITE PAPER**

# Proposed Ventilation and Energy Efficiency Verification and Repair Program for Buildings

Prepared by
Christopher Ruch, NEMI – Director of Training
Theresa Pistochini, UC Davis Energy and Efficiency Institute – Engineering Manager
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The World Health Organization, the Centers for Disease Control and Prevention, and the American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) have all recommended that, in order to protect against the spread of COVID-19 when reopening commercial, office or other buildings where members of the public work or congregate, buildings should verify that their heating, ventilation and air conditioning (HVAC) systems provide sufficient outside air ventilation and filtration. Implementation of this guidance, however, has been lacking. To address this gap, this paper presents a proposal for a Building Reopening Ventilation and Energy Efficiency Verification and Repair Program that would certify that building ventilation and filtration systems meet recommendations to protect against the spread of COVID-19. This program provides concrete implementation steps to verify that building air ventilation and filtration systems meet or exceed Occupational Safety and Health Administration (OSHA) and California Energy Commission requirements and, to the extent feasible, that meet ventilation and filtration recommendations for reopening buildings set forth by the World Health Organization, the Centers for Disease Control, and ASHRAE, as well as any applicable local and state agency building-reopening guidance. The program would also ensure that systems are operating efficiently and would identify recommendations for future efficiency and safety upgrades.

This program would require recipients to (1) assess, maintain, adjust, and, if necessary, repair existing HVAC systems to verify proper and efficient operation, as well as compliance with health and safety standards; (2) install at least one carbon dioxide ($CO_2$) monitor in each zone of the building (where a zone is defined by an area of the building with temperature controlled by a thermostat) to verify that proper ventilation is maintained during building operation; 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. Buildings 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 buildings is common and negatively impacts occupant's health and productivity.

- A 2016 study in an environmentally controlled office space examined the effect of air quality on cognitive function. Participants were found to have higher cognitive function

when their indoor environment had higher ventilation rates, lower volatile organic compounds, and lower carbon dioxide.[1]

- A 2003 report by Fisk found a majority of existing literature indicated increasing ventilation will decrease respiratory illness and associated sick leave.[2]
- A 2012 study showed a decrease most decision making variables increases in indoor carbon dioxide concentrations.[3]

The California Building Energy Efficiency Standards sets minimum ventilation rates for building occupancies. Regulations adopted pursuant to Labor Code § 142.3 require workplace HVAC systems to be inspected at least annually, and for problems found during these inspections to be corrected within a reasonable time. Despite these requirements, poor performing HVAC systems and underventilation are a persistent problem in buildings.

Ensuring adequate ventilation rates in buildings is of particular concern as California looks to reopen 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 mix with room air, remaining airborne for extended periods.[4] Filtration and ventilation removes and dilutes these droplets, reducing the risk of infection for occupants. For that reason, the World Health Organization (WHO), the Centers for Disease Control (CDC) and ASHRAE recommends ensuring ventilation systems operate properly, increasing ventilation rates and installing filters with a minimum efficiency rating value (MERV) of 13 or better where possible in order to reduce the spread of

[1] J. Allen et.al., "Association of Cognitive Function Scores with Carbon Dioxide, Ventilation, and Volatile Organic Compound Exposures in Office Workers: A Controlled Exposure Study of Green and Conventional Office Environments," Environmental Health Perspectives 124, no.6 (2016):805-812

[2] Fisk WJ, Seppanen O, Faulkner D, Huang J (2003) Economizer system cost effectiveness: accounting for the influence of ventilation rate on sick leave. Proceedings of Healthy Buildings 2003, December 7 – 11 at the National University of Singapore.

[3] Satish, Usha, et al. "Is CO2an Indoor Pollutant? Direct Effects of Low-to-Moderate CO2Concentrations on Human Decision-Making Performance." *Environmental Health Perspectives*, vol. 120, no. 12, (2012), pp. 1671–1677., doi:10.1289/ehp.1104789.

[4] 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).

COVID-19.[5] A May 2020 report by Dr. Jovan Pantelic at U.C. Berkeley further recommends continuous $CO_2$ monitoring and maintaining relative humidity in the range of 40%-60%.[6]

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.[7] 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.[8]

The program would address this issue by requiring the use of qualified personnel to test, adjust, and if necessary, repair or replace building HVAC systems 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.

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[5] 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) 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, 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).

[6] Pantelic, Using IoT Environmental Sensing to Reopen Spaces, SenseWare (May 2020) (https://cdn2.hubspot.net/hubfs/5238584/White%20Paper%20Senseware%20Covid.pdf?utm_campaign=White%20Paper%20-%20Covid&utm_medium=email&_hsenc=p2ANqtz-8CCchuu-MGpVFoho9kHZF6ZbWa4Heve4CJQu3BxxJznJpqW9Zomc_ipfIN-mYcosX6pZ0fb6pAL3KlOoLlaSXfHdfIGQ&_hsmi=88251420&utm_source=hs_email&utm_content=88251420&hsCtaTracking=a5c1a092-2f23-441c-af08-d8192d9f1c07%7Cbaa70d26-140b-453f-a3cb-94f6edc96ab7).

[7] California Energy Commission, *Strategic Plan to Reduce the Energy Impact of Air Conditioners* (June 2008), CEC-400-2008-010, at p.
(v);Chris Neme, John Proctor, and Steve Nadel, *National Energy Savings Potential from Addressing HVAC Installation Problems* (Prepared for the U.S. EPA, February 1999.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/).

[8] 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/).

**PROPOSED REQUIREMENTS:**

**Building Ventilation and Efficiency Verification and Repair Program.** The Building Ventilation and Efficiency Verification and Repair Program shall prepare buildings to reopen with safely and efficiently operating HVAC systems that are tested, adjusted, and if necessary repaired, by qualified personnel in order to provide recommended ventilation rates and filtration levels to protect against the spread of COVID-19. The Program requires participants to: (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 $CO_2$ monitors with at least one sensor located in each zone (where a zone is defined by an area of the building with temperature controlled by a thermostat) with a density no less than one sensor per 10,000 $ft^2$ of floor space[9] to verify that proper ventilation is maintained throughout the occupied hours; 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. Buildings that comply with these requirements shall be provided a COVID-19 Reopening Ventilation Verification Certificate for posting in the building.

In order to qualify for a COVID-19 Reopening Ventilation Verification Certificate, the following tasks must be completed for all air handling units, roof top units and unitary and single zone equipment in that building'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 Building Readiness, MERV 13 or better filtration shall be installed in the facility's HVAC system where feasible. Qualified Testing 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 Testing Personnel shall test system economizer dampers per Section B of NRCA-MCH-05-A – Air Economizer Controls and any economizer dampers and controls that are not properly functioning shall be repaired by a skilled and trained workforce. Recommendations for additional maintenance, replacement or upgrades shall be recorded in the HVAC Assessment Report.

[9] Based on 2019 Building Energy Efficiency Standards, Section 120.1(d)4

## 3. Ventilation and Exhaust.

**A. Assessment.** Following the assessment of the filtration and economizer, Qualified Testing Personnel shall verify the ventilation rates in the offices, workspaces, lobbies, kitchens, common areas, wellness rooms, reception areas, conference rooms, fitness area, locker rooms, restrooms and other occupied areas to assess 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 occupancy rates and determined by the technician performing the testing. 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.[10]

(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, including restrooms. Document any discrepancies from system design.

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

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

**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, a certified design professional or Qualified Adjusting 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 Adjusting 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 by a skilled and trained workforce 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 Testing Personnel per Section B of NRCA-MCH-06-A – Demand Control Ventilation Systems Acceptance[11]. 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 local jurisdiction 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 Testing Personnel or a Skilled and Trained Workforce shall verify coil condition, condensate drainage, cooling coil air temperature differential (entering and leaving dry bulb), heat exchanger operation, and drive assembly. Critical repairs shall be performed by a Skilled and Trained Workforce. Recommendations for additional maintenance, replacement or upgrades shall be recorded in the HVAC Assessment Report.

**6. Operational Controls.** Qualified Testing Personnel shall review control sequences to verify systems will maintain intended ventilation, temperature and humidity conditions during

[11] 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.

operation. Previously unoccupied buildings shall perform the recommended practices of reopening a building as covered in the ASHRAE Building Readiness document – Restarting a Building. Verify a daily flush is scheduled for 2 hours before and after scheduled occupancy or demonstrate calculation of flush times per ASHRAE Guidance for Buildings Readiness – Ventilation Control 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 Buildings Readiness or otherwise applicable local or state guidance.

**7. Repairs.** If installed HVAC systems or system components are broken, fail to meet minimum ventilation requirements, unable to schedule pre and post occupancy purge recommendations, or are unable to operate to the original design and intent, corrective work must be completed prior to resumption of building operation. Repairs, upgrades, or replacements shall be performed by a skilled and trained workforce.

**(a) $CO_2$ Monitoring.** To ensure proper ventilation is maintained during building operation, at least one CO2 monitor shall per installed in each zone of the building (where a zone is defined by an area of the building with temperature controlled by a thermostat). The number of CO2 monitor must also meet or exceed at least one $CO_2$ monitor per 10,000 square feet of occupied floor space. $CO_2$ monitors shall:

(1) Be 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) Display the $CO_2$ readings to the occupants through a display on the device or other means such as a web-based application or cell-phone application.

(3) Notify the building operator 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 have exceeded 1,100 ppm.

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

(5) Have a range of 1 ppm to 2000 ppm or greater;

(6) Be 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 an occupied room $CO_2$ concentration exceeds 1,100 ppm more than once a week as observed by the occupants or operating engineer, the ventilation rates shall be adjusted by Qualified Adjusting Personnel to ensure peak $CO_2$ concentrations in the occupied rooms remain below the maximum allowable $CO_2$ PPM setpoint. Verification of the installation of $CO_2$ Monitors in all occupied rooms regardless of size with no less than one sensor per 10,000 $ft^2$ of floor space shall be included in the HVAC Assessment Report.

**(b) HVAC Assessment Report.** Qualified Testing Personnel shall prepare an HVAC Assessment Report that includes the following information:

(1) Name and address of the building and person 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 all requirements of this Section have been satisfied.

(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 offices, workspaces, lobbies, kitchens, common areas, wellness rooms, reception areas, conference rooms, fitness areas, locker rooms, restrooms and other occupied areas in the building, 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 offices, workspaces, lobbies, kitchens, common areas, wellness rooms, reception areas, conference rooms, fitness areas, locker rooms, restrooms and other occupied areas in the building, 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 inlet, outlet, 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 temperature differential (entering and leaving dry bulb), in comparison to design, which signal improper refrigerant charge.

(9) Documentation of 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.

(11) Verification that all work has been performed by qualified personnel, including the provision of the contractor's name and license, acceptance test technician name and certification number (where applicable), TAB technician name and certification number (where applicable) and verification that all construction work has been performed by a skilled and trained workforce.

The Building Operator shall maintain a copy of the HVAC Assessment Report and make it available to any building occupant or patron upon request.

**(c) COVID-19 Reopening Ventilation Verification Certificate.** Upon verification in the HVAC Assessment Report that all requirements of this Section have been satisfied, the Qualified Testing Personnel preparing the report shall provide the building a COVID-19 Reopening Ventilation Verification Certificate for posting in the verified building that states that the building meets the minimum 2019 Title 24 California Energy Commission requirements for ventilation.

**(d) Qualified Personnel Definitions**

**Certified Testing, Adjusting and Balancing (TAB) Technician**. A technician certified to perform testing, adjusting and balancing of HVAC systems by the Associated Air Balance Council (AABC), the National Environmental Balancing Bureau (NEBB), or the Testing, Adjusting and Balancing Bureau (TABB).

**Qualified Adjusting Personnel.** Qualified Adjusting Personnel shall either be: (1) a Certified TAB technician; or (2) a skilled and trained workforce under the supervision of a certified TAB Technician.

**Qualified Testing Personnel**. Qualified Testing Personnel shall either be: (1) an HVAC acceptance test technician certified by an Acceptance Test Technician Certification Provider (ATTCP) that is approved by the Energy Commission to provide such certification; or (2) a certified TAB technician.

**Skilled and Trained Workforce**. A skilled and trained workforce is a workforce that meets the definition requirements set forth in California Public Contract Code section 2601

**(e) 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. [12] 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.[13]
- Improper airflow and temperature differentials determined in the assessment should be diagnosed as they signal reduced energy efficiency.[14]
- 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).

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

[13] 2017 Standard for Performance Rating of Unitary Air-Conditioning & Air-Source Heat Pump Equipment. AHRI, 2017.

[14] 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