BSR/ASHRAE/IES Addendum bx
to ANSI/ASHRAE/IES Standard 90.1-2022

Public Review Draft

Proposed Addendum bx to Standard 90.1-2022, Energy Standard for Sites and Buildings Except Low-Rise Residential Buildings

First Public Review (March 2025)
(Draft Shows Proposed Changes to Current Standard)

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(This foreword is not part of this standard. It is merely informative and does not contain requirements necessary for conformance to the standard. It has not been processed according to the ANSI requirements for a standard and may contain material that has not been subject to public review or a consensus process. Unresolved objectors on informative material are not offered the right to appeal at ASHRAE or ANSI.)

FOREWORD

Currently 90.1 requires labs to have some combination of VAV and/or exhaust air heat recovery (Option a or b) or to not fully condition lab spaces (Option C).

This addendum eliminates Option C because it encourages space conditions that would not meet minimum Standard 55, ASHRAE's comfort standard, and encourages inhuman conditions for lab workers.

The addendum essentially expands the VAV and/or heat recovery options to require both VAV and heat recovery (with some exceptions). This was justified with lifecycle cost analyses showing both are cost effective.

All of the lifecycle cost analyses for this addendum assume that all parts of the addendum are complied with, i.e. interactions among the proposal elements are accounted for.

The lifecycle cost analysis for the modified VAV requirement starts from the assumption that VAV (rather than heat recovery) is the base case system to meet the current 90.1 lab requirement in 6.5.7.3. The only increment cost, therefore, is the incremental cost to meet the new unoccupied ventilation setback requirement. Labs are already required to have occupancy sensors for lighting controls. Thus, the cost of implementing air change setbacks in labs is relatively low as it does not require new hardware. The only additional costs are some programming of the building automation system and commissioning to verify that the setback is working correctly. An incremental cost of $1 per square foot cost is based on communications with San Francisco Bay Area controls contractors and commissioning agents, who estimated $1000 per zone and 1,000 square feet per zone

Unoccupied air change setbacks from 1 cfm/ft2 (6 ACH) to 0.67 cfm/ft2 (4 ACH) at night were simulated using the lab prototype model in several representative climates.

Utility rates for analyses:

- 90.1 electric cost per KWH: $0.11
- 90.1 Natural Gas Cost ($/therm): $0.84

Results for VAV/Unoccupied Setback Analysis:

Zone	City	Baseline Elec (Kbtu)	Proposed Elec (Kbtu)	Baseline Gas (Kbtu)	Proposed Gas (Kbtu)	Baseline Energy Cost (Kbtu)	Proposed Energy Cost (Kbtu)	Energy Cost Savings ($/sf)	Pay-back
4A	New York	1,551,357	1,497,997	4,465,155	3,573,913	88,400	79,177	$ 0.52	1.9
5B	Denver	1,337,349	1,321,846	3,998,031	3,273,364	77,453	70,870	$ 0.37	2.7
3A	Atlanta	1,741,972	1,664,653	3,345,090	2,616,957	85,276	76,633	$ 0.48	2.1
4C	Seattle	1,266,221	125,811	4,214,659	3,273,458	76,931	31,569	$ 2.54	0.4
6A	Mineapolis	1,318,375	1,301,587	5,808,182	5,024,424	92,000	84,880	$ 0.40	2.5
2A	Tampa	2,308,510	2,074,353	2,331,149	1,841,501	95,395	83,597	$ 0.66	1.5
3B	San Diego	1,471,408	1,451,342	2,778,780	2,095,301	71,639	65,252	$ 0.36	2.8

Since VAV was assumed in the basecase for the VAV analysis, the basecase for the heat recovery analysis is no heat recovery. An actual lab construction project that includes heat recovery was recently bid by several general contractors. We redesigned the project without heat recovery and had one of the bidders re-estimate the project. The project has gas boilers. Therefore, we also redesigned it with heat pumps and had it estimated with and without heat recovery.

The analysis accounted for the following changes that make heat recovery less expensive:

- reduces capacity of chillers by approximately 23%
- reduces capacity of cooling coils
- reduces capacity of chilled water pumps
- reduces capacity of boilers/heat pumps by approximately 38%
- reduces capacity of hot water pumps
- reduces capacity of VAV box reheat coils

The analysis accounted for the following changes that make heat recovery more expensive:

- Add exhaust air heat recovery coil
- Add heat recovery coil bypass damper
- Increase the total pressure drop of the exhaust fans
- Add heat recovery pumps and associated piping
- Add heat recovery coil to the air handler
- Increase the total pressure drop of the supply fans
- $500/yr incremental maintenance (~$10,000 over the life of the system, based on an estimate for annual maintenance by a Bay Area HVAC service contractor.)

The net incremental cost for a gas boiler system and for an air source heat pump heating system are shown in the table below. The net cost for the heat pump baseline is negative because the reduction in heat pump capacity more than pays for the heat recovery system.

incremental costs in $/ft2	vs. Gas Baseline	vs. Heat Pump Baseline
Chillers	$ (1.38)	$ (1.38)
HR coil	$ 1.68	$ 1.68
HR piping	$ 1.68	$ 1.68
HR pumps/VFDs	$ 0.14	$ 0.14
CHW pumps/VFDs	$ (0.55)	$ (0.55)
HW pumps/VFDs	$ (0.15)	$ (0.15)
Exhaust fans/VFDs	$ 0.28	$ 0.28
Terminal units	$ (0.30)	$ (0.30)
HW piping	$ (0.13)	$ (0.13)
CHW piping	$ -	$ -
Controls	$ 0.20	$ 0.20
Boilers	$ (0.99)	$ -
ASHPs	$ -	$ (9.28)
NPV of Ann. Maint.	$ 0.19	$ 0.19
TOTAL $/ft2	**$ 0.67**	**$ (7.62)**

The simulation results below show that the payback for heat recovery with the gas baseline meets the ASHRAE 90.1 scalar requirement in all climates except San Diego, which is exempt from this requirement.

Zone	City	Baseline Elec (Kbtu)	Proposed Elec (Kbtu)	Baseline Gas (Kbtu)	Proposed Gas (Kbtu)	Baseline Energy Cost ($/sf)	Proposed Energy Cost ($/sf)	Energy Cost Savings ($/sf)	Payback (yrs)
4A	New York	1,570,968	1,555,810	4,264,207	3,698,292	$ 4.89	$ 4.59	$ 0.29	2.3
5B	Denver	1,350,294	1,333,513	3,999,498	3,320,416	$ 4.36	$ 4.01	$ 0.35	1.9
3A	Atlanta	1,763,774	1,743,686	3,295,261	2,989,059	$ 4.79	$ 4.61	$ 0.18	3.7
4C	Seattle	1,267,999	1,261,170	4,124,587	3,601,117	$ 4.26	$ 4.01	$ 0.26	2.6
6A	Mineapolis	1,330,998	1,317,904	5,564,016	4,908,328	$ 5.06	$ 4.72	$ 0.33	2.0
2A	Tampa	2,308,510	2,282,721	2,500,601	2,456,091	$ 5.42	$ 5.35	$ 0.07	9.8
3B	San Diego	1,465,337	1,462,504	2,766,761	2,723,198	$ 3.99	$ 3.97	$ 0.03	26.1

The addendum also adds a new requirement to minimize reheat in laboratories with multizone air handlers by requiring heating and cooling capacity at each zone. This reduces the need to cool at the air handler to a temperature needed to satisfy the worst case zone and then reheat at all the other zones. 4-Pipe VAV was priced by contractors as an add alternate on two recent Bay Area lab projects. The base design was 2-pipe VAV reheat.

Building 1: San Francisco (150,000 ft2)

Changes from the baseline (2-pipe) to proposed case (4-pipe) include the following changes that make the proposed case less expensive, red make the proposed case more expensive:

- Chillers downsized from (2) 210 ton to (2) 185 ton chillers
- Downsized CHW pumps from 2 @ 255 gpm to 2 @ 230 gpm
- AHU coil reduced from 8 rows to 4 rows (because no cooling needed at AHU)
- Eliminated CHW piping to AHU

- Downsized HW piping, including mains, risers, taps on each floor

Changes from the baseline (2-pipe) to proposed case (4-pipe) include the following changes that make the proposed case more expensive:

- Added CHW piping to zones
- Increased zone coils from 2-row to 8-row
- Added condensate drain pans to zone coils and condensate drain lines from drain pans to nearest discharge location
- Converted zone valves from 2-way HW valves to 6-way changeover valves.

Building 2: Pleasanton, 100,000 ft2 office/lab building with 50,000 ft2 of lab spaces.

Building 1 was estimated with a single change-over coil at each zone. Building 2 was estimated based on separate heating and cooling coils at each zone.

The net incremental cost, including incremental annual maintenance, was $12.04/ft2 for Building 1 and $16.29 for Building 2. These costs were averaged and then adjusted to national average costs using the RS Means 2024 Master Format City Cost Indexes for San Francisco (129.7) and San Jose (125.5).

Energy modeling assumptions for the reduce reheat measure:

1. 2025 lab prototype EnergyPlus model provided by the CEC. The prototype was adjusted to reflect a one-story building with five lab thermal zones: four perimeter zones, and one core zone.
2. Baseline case used a central multizone system; packaged variable air volume (PVAV) with DX cooling, hot water heating, and hot water reheat at terminal units (all hot water supplied a gas boiler)
3. Propose case was post-process in Excel using data exported from the model for: OADB, OAWB, AHU SAT, DX energy/CFM , boiler energy/CFM*dT, zone DATs, etc.
    1. Heating and cooling at the zone
    2. If the outside air dewpoint > 60F then each zone cools OA to 60F then reheats to the required zone discharge air temperature.
    3. Else each zone heat/cools OA to DAT.

The table below shows acceptable paybacks for the reduce reheat measure in all climate zones:

Climate Zone	City	Min OA (cfm/ft2)	Clg Svgs	Heat Svgs	Svgs $/sf	payback
1A	Miami	1.65	6%	15%	$ 1.66	6.2
2A	Houston	1.65	7%	9%	$ 1.39	7.5
3A	Atlanta	1.65	12%	9%	$ 1.48	7.0
4A	New York, NY	2	13%	5%	$ 1.35	7.6
5A	Chicago	2	16%	4%	$ 1.36	7.6
6A	Minneapolis	2	17%	4%	$ 1.19	8.7
2B	Phoenix, AZ	1	20%	37%	$ 1.77	5.8
3B	Las Vegas	1	23%	27%	$ 1.44	7.2
5B	Denver	1.65	33%	10%	$ 1.66	6.2
6B	Helena	2	39%	5%	$ 1.42	7.3
3C	San Francisco	1	58%	5%	$ 1.55	6.7
4C	Seattle	1.65	49%	4%	$ 1.59	6.5

This addendum also adds a new requirement for automatic sash closures. A detailed lifecycle cost analysis for automatic sash closures was conducted for Title 24-2019 and is available here: https://title24stakeholders.com/wp-content/uploads/2019/01/T24-2019-CASE-Study-Results-Report-Fume-Hoods_Final_with_Attachments.pdf . Excerpts from this analysis are included below. It was the judgement of the committee that the Title 24 analysis was sufficiently rigorous and applicable to other climates and thus a separate analysis was not necessary for this addendum.

The average incremental installed first cost was determined to be $3,250,

, the recurring maintenance and repair costs are:

- Annual functional testing and lubrication: 1 hour x $106.29/h r = $106.29
- Two replacements of motion sensor: $100 + 3 hours x $106.29/hr = $418.87
- Total 2020PV lifetime costs = $2,385.89

Average Sash Position (0.0 = closed, 1.0 = wide open)	0.42 occupied hours baseline 0.37 unoccupied hours baseline 0.12 occupied hours active use measure case 0.00 unoccupied hours measure case (IES, Inc. 2012) (D. T. Hitchings 1993) (SCE 2007) (Hilliard n.d.) (Vargas and Cheng 2016) (Phoenix Controls Corporation n.d.) (TSI, Inc. 2014)

Table 10: Lifecycle Cost-effectiveness Summary Per Fume Hood (Six-foot Equivalent) – New Construction and Alterations

Climate Zone	Benefits TDV Energy Cost Savings + Other PV Savings[a] (2020 PV $)	Costs Total Incremental PV Costs[b] (2020 PV $)	Benefit-to-Cost Ratio
1	$19,376	$5,636	3.4
2	$20,793	$5,636	3.7
3	$18,710	$5,636	3.3
4	$20,601	$5,636	3.7
5	$19,087	$5,636	3.4
6	$19,790	$5,636	3.5
7	$19,272	$5,636	3.4
8	$19,985	$5,636	3.5

[Note to Reviewers: This addendum makes proposed changes to the current standard. These changes are indicated in the text by underlining (for additions) and ~~strikethrough~~ (for deletions) except where the reviewer instructions specifically describe some other means of showing the changes. Only these changes to the current standard are open for review and comment at this time. Additional material is provided for context only and is not open for comment except as it relates to the proposed changes.]

Addendum bx to 90.1-2022

New Definition:

4-PIPE VAV. A multiple zone VAV system with VAV terminal units that have both heating and cooling capacity served by a VAV supply air handler with limited or no heating and cooling capability in accordance with Section 6.5.7.3.3.

6.5.7.3 Laboratory Systems. ~~*Buildings* with laboratory exhaust *systems* having a total exhaust rate greater than 5000 cfm shall include at least one of the following features:~~

a. ~~*VAV* laboratory exhaust and room supply *system* capable of and configured to reduce exhaust and makeup airflow rates and/or incorporate a heat recovery *system* to precondition *makeup air* from laboratory exhaust that shall meet the following:~~

~~$A + B \times (E/M) \geq 50\%$~~

~~where~~

~~*A* = percentage that the exhaust and makeup airflow rates can be reduced from *design conditions*~~
~~*B* = *sensible energy recovery ratio*~~
~~*E* = exhaust airflow rate through the heat recovery device at *design conditions*~~
~~*M* = makeup airflow rate of the *system* at *design conditions*~~

b. ~~*VAV* laboratory exhaust and room supply *systems* that are required to have minimum circulation rates to comply with code or accreditation standards shall be capable of and configured to reduce zone exhaust and makeup airflow rates to the regulated minimum circulation values or the minimum required to main- tain pressurization relationship requirements. *Systems* serving nonregulated zones shall be capable of and configured to reduce exhaust and makeup airflow rates to~~

~~50% of the zone design values or the minimum required to maintain pressurization relationship requirements.~~

~~c. Direct makeup (auxiliary) air supply equal to at least 75% of the exhaust airflow rate, heated no warmer than 2°F below room *set point*, cooled to no cooler than 3°F above room *set point*, no humidification added, and no simultaneous heating and cooling used for dehumidification control.~~

6.5.7.3.1 VAV Replacement and Exhaust Air

6.5.7.3.1.1 *Buildings* with laboratory exhaust *systems* having a total exhaust rate greater than 5000 cfm [2,360 L/s] shall be capable of and configured to reduce exhaust and *replacement air* flow to each laboratory *HVAC zone* to the larger of that required to meet the following:

a) real time cooling or heating loads
b) real time hood exhaust and *replacement air* requirements
c) occupied and unoccupied minimum ventilation airflow rates based on occupancy sensors as follows:

1. When occupant sensing controls sense occupants in the laboratory *HVAC zone*, or the *HVAC zone* is scheduled to be occupied, the minimum exhaust and makeup airflow rates shall not exceed the larger of:
   i. 1.0 cfm/ft^2 [5 l/s/m^2], or
   ii. the *required minimum outdoor air rate* when spaces are occupied
2. Not more than 20 minutes after no occupancy is detected by all occupant sensors in the *HVAC zone*, and the *HVAC zone* is not scheduled to be occupied, the minimum exhaust and makeup airflow rates shall not exceed the larger of:
   i. 0.67 cfm/ft^2 [3.4 l/s/m^2], or
   ii. the *required minimum outdoor air rate* when spaces are unoccupied

6.5.7.3.1.2 Exhaust and *replacement air* rates determined by section 6.5.7.3.1.1 shall be permitted to be adjusted as required to meet laboratory pressurization requirements.

Informative Note: ASHRAE Guideline 36 includes detailed sequences of control for laboratory replacement and exhaust air.

6.5.7.3.2 Exhaust Air Heat Recovery

Buildings with laboratory exhaust *systems* having a total exhaust rate greater than 10,000 cfm [4,725 L/s] shall include an exhaust air heat recovery system that meets all the following:

1. A *sensible energy recovery ratio* of at least 45% at heating design conditions in all climates except Climate Zones 0, 1, and 2.
2. A *sensible energy recovery ratio* of at least 35% at cooling design conditions in all climates except Climate Zones 3C, 4C, 5B, 5C, 6B, 7, and 8.
3. Heat is recovered from at least 75% of all design occupied lab exhaust airflow.
4. The system includes a means to disable heat recovery when heat recovery results in an increase in energy use.
5. The system includes a bypass damper or other means so that the exhaust air pressure drop through the heat exchanger does not exceed 0.4 in. w.g [100 Pa] when heat recovery is disabled.

Exceptions to 6.5.7.3.2:

1. Additions or alterations to existing laboratory exhaust systems that do not include exhaust air heat recovery.
2. Buildings where the total laboratory exhaust rate exceeds 20 cfm/ft2 [100 l/s/m^2], of roof area.
3. Building located in Climate Zone 3B and within 6 miles [10 km] of an ocean.
4. Buildings with an exhaust air heat recovery system and heat recovery chillers designed to provide at least 40% of the peak heating load from exhaust heat recovery.
5. Exhaust systems requiring wash down systems such as exhaust systems dedicated to perchloric acid fume hoods.

6.5.7.3.3 Reheat Limitations

Laboratory *HVAC zones* in buildings with greater than 20,000 cfm [9,450 L/s] of laboratory exhaust and with *design minimum outdoor air rates* equal to or greater than the values in Table 6.5.7.3.3 shall include zonal heating and cooling capacity, such as *4-pipe VAV,* to minimize cooling at the air handler and reheating at the zones. Zones shall not simultaneously heat and cool except when necessary to keep zone humidity from exceeding the limits defined in 6.4.3.6.1. Air handlers serving multiple laboratory zones with heating and cooling capacity shall not heat air handler supply air above 50.0ºF [10.0°C] and shall not mechanically cool air handler supply air to the zones below the following:

1. 74.0ºF [23.3°C] when outdoor air dewpoint is less than the limit defined in 6.4.3.6.1
2. The temperature required to maintain the zone humidity limit defined in 6.4.3.6.1 when outdoor air dewpoint is

greater than or equal to the limit defined in 6.4.3.6.1.

Table 6.5.7.3.3 Design Minimum Outdoor Air Rate* Triggering Zonal Heating and Cooling Capacity

Climate Zones 2B, 3B, 3C	Climate Zones 0, 1A, 2A, 3A, 5B, 4C	Climate Zones 4A, 5A, 6A, 6B, 7, 8
1.0 cfm/ft2 [5 l/s/m^2]	1.6 cfm/ft2 [8 l/s/m^2]	2.0 cfm/ft2 [10 l/s/m^2]

* the sum of the lab zone occupied *design minimum outdoor airflow rates* divided by the sum of the lab zone areas.

Exceptions to 6.5.7.3.3:

1. Additions or alterations to existing air handling systems serving existing zones without heating and cooling capacity.
2. Systems where the outdoor dewpoint temperature is greater than or equal to 68.0°F [20°C} at the ASHRAE 2% annual dehumidification design condition and that must maintain space relative humidity ≤ 60% for required certification or accreditation.
3. Systems dedicated to vivarium spaces or to spaces classified as Biosafety Level 3 or higher.
4. Laboratory zones served by air handlers also serving zones covered by ASHRAE Standard 170.

6.5.7.3.4 Fume Hood Automatic Sash Closure

Variable air volume laboratory fume hoods with vertical only sashes located in fume hood intensive laboratories as defined in Table 6.5.7.3.4, shall have an automatic sash closure system that complies with the following:

1. The automatic sash closure system shall have a dedicated zone presence sensor that detects occupants in the area near the fume hood sash and automatically closes the sash within 5 minutes of no detection.
2. The automatic sash closure system shall be equipped with an obstruction sensor that prevents the sash from automatic closing with obstructions in the sash opening. The obstruction sensor shall be capable of sensing transparent materials such as laboratory glassware.
3. The automatic sash closure system shall be capable of being configured in a manual closed mode where, once the sash is closed, detection of occupants in the area near the fume hood by the zone presence sensor does not open the fume hood sash.

Table 6.5.7.3.4 Fume Hood Intensive Laboratory Threshold (both must be true)

Occupied Minimum Ventilation ACH	≤ 4	> 4 and ≤ 6	> 6 and ≤ 8	> 8 and ≤ 10	> 10 and ≤ 12	> 12 and ≤ 14
Hood Density (linear feet per 10,000 ft^3 [283 m^3] of laboratory space	≥ 6	≥ 8	≥ 10	≥ 12	≥ 14	≥ 16

Add new normative reference to Section 13:

New reference standard for BSL-3 exception: https://www.cdc.gov/labs/bmbl/index.html