School Building Science Fridays™

Passive House and Schools

April 8, 2022

Welcome!

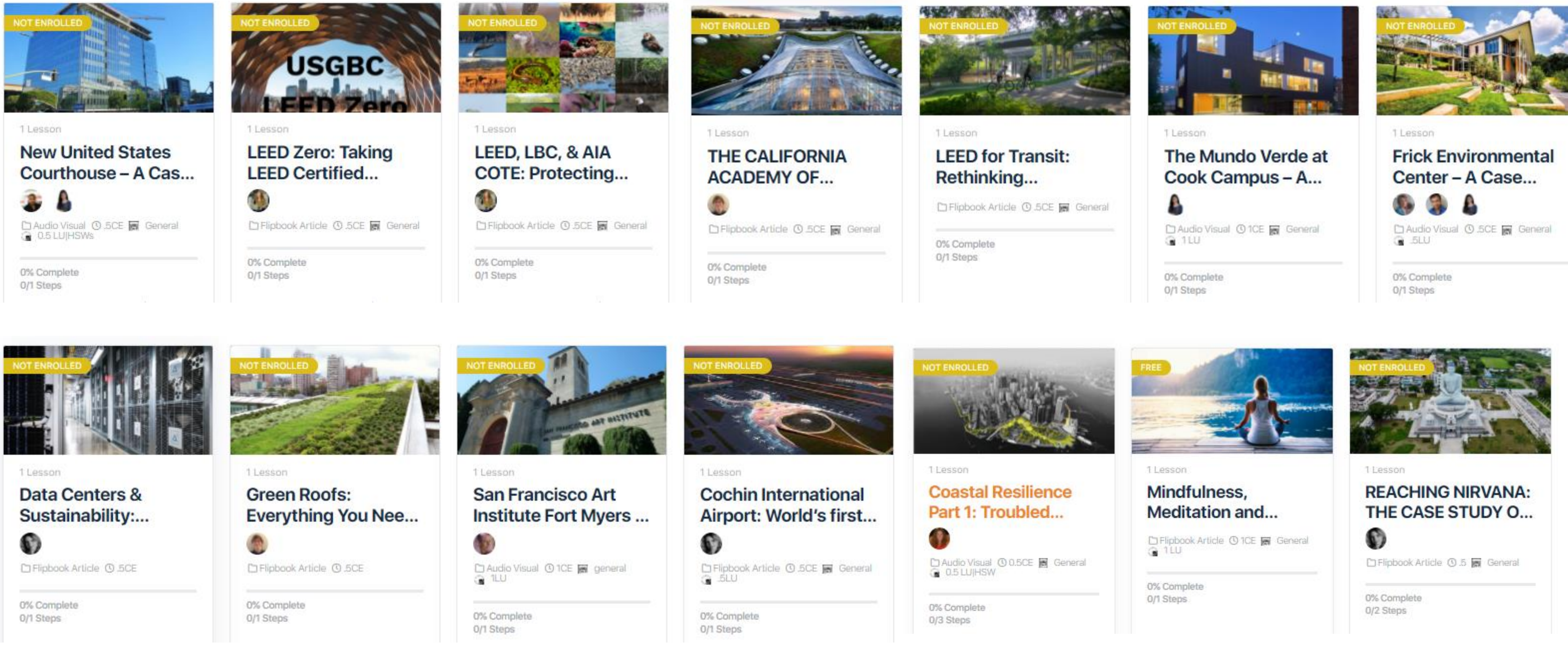
SUSTAINABILITY. EDUCATION. EMPOWERMENT
• GBRI •

COLLABORATIVE FOR HIGH PERFORMANCE
CHPS SCHOOLS®
Better buildings. Better students.

About GBRI


SUSTAINABLE DEVELOPMENT GOALS
U.S. GREEN BUILDING COUNCIL USGBC
EDUCATION PARTNER
INTERNATIONAL WELL BUILDING INSTITUTE™
The American Institute of Architects

About GBRI



Learn More: www.gbrionline.org/scholarship/

AIA Approved Continuing Education

Approved for 1 HSW LU

Green Building Research Institute
Provider Number: 40119134

A certificate of completion will be sent via email within 24 hours of today's session.

Today's Webinar

- Welcome & Introduction: Craig Schiller, CHPS
- Speaker Presentations:
    - Mike Woolsey, Swegon North America, Mike.Woolsey@swegon.com
    - Mir Ali, Swegon North America, Mir.Ali@swegon.com
- Audience Questions

With Gratitude to Our Sponsors

IN2 ARCHITECTURE

Group 14 ENGINEERING

PERKINS—EASTMAN

HEALTHY SCHOOLS NETWORK

Tarkett

Housekeeping

- Reminder: This session is being recorded.
- Post questions at any time in Q&A box and comments at any time in Chat box.
- Please stay on mute and turn off your video.
- Recording and slides will be emailed to registrants and will be available on-demand on both CHPS and GBRI websites.
- Resources at end of deck for further learning.

About CHPS

WHO WE ARE: A non-profit collaborative of school districts, architects, builders, building scientists, health professionals, and consultants dedicated to fostering healthy learning environments.

WHAT WE DO: Provide technical resources for school design, construction, operations and maintenance standards through our extensive criteria programs and project reviewers.

MEMBERSHIP: We rely on member support to do what we do. Please consider joining us.

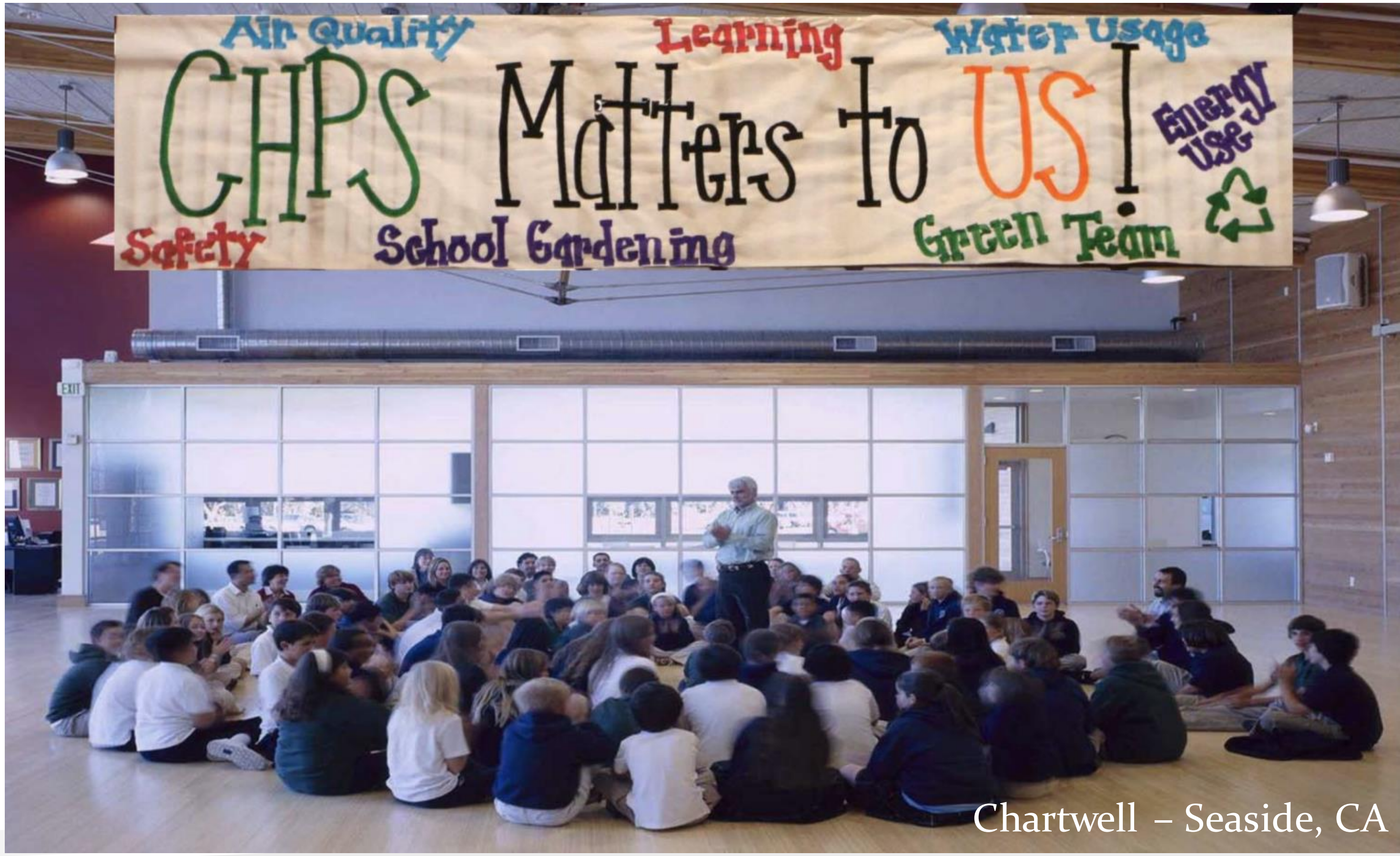
COLLABORATIVE FOR HIGH PERFORMANCE SCHOOLS
CHPS SCHOOLS®

Better buildings. Better students.

https://chps.net/join-us

Our Impact

- Over **700** schools have been recognized as meeting the CHPS Criteria
- CHPS Criteria is in use in **14** states and has been adopted as the construction standard in over **60** public school districts.



Chartwell – Seaside, CA

What Is *School Building Science*?

- The body of knowledge that informs the design, construction, operations, and occupancy of school buildings for the benefit of students, educators, staff, and the environment.

- The body of knowledge about the built environment that impacts how children learn and thrive.

Mapleton Adventure School – Mapleton, CO

Learning Objectives

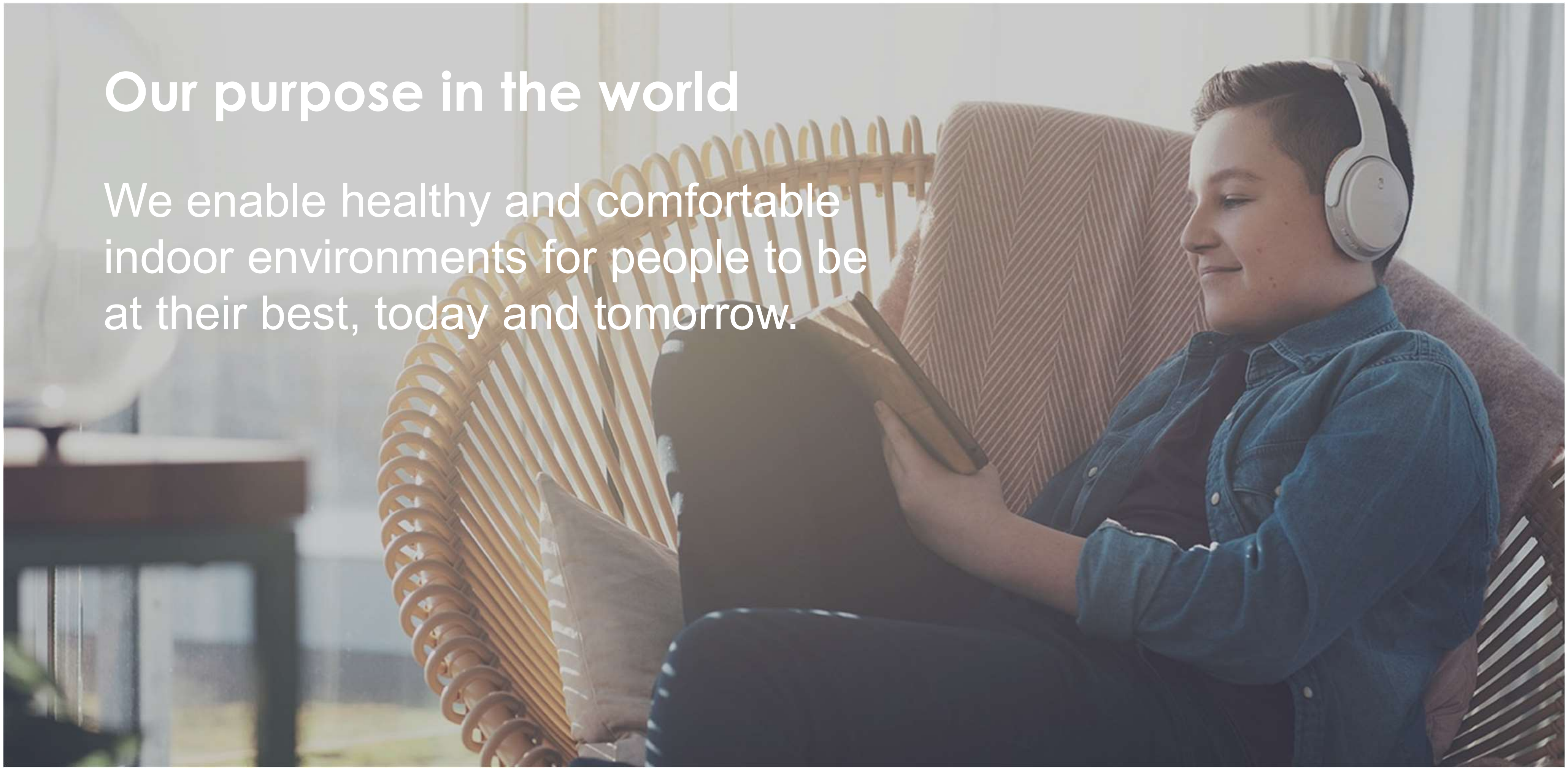
Approved Continuing Education

1. Explore the common goals of CHPS and Passive House.
2. Review the key characteristics of Passive House buildings.
3. Understand IAQ (ventilation, comfort, sound, materials, etc.) research.
4. Case studies and lessons learned.

Swegon

Continuing Education

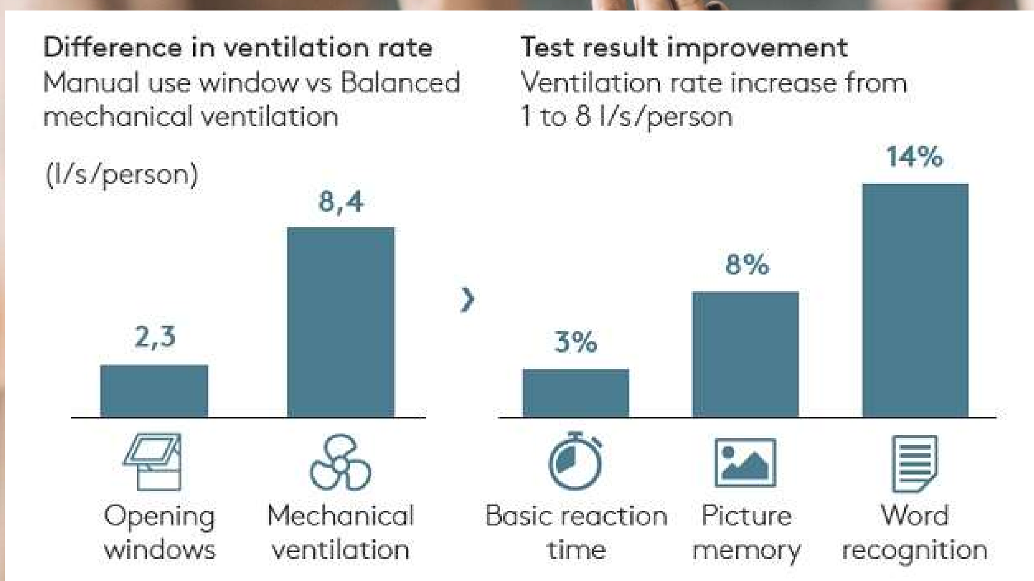
About Swegon



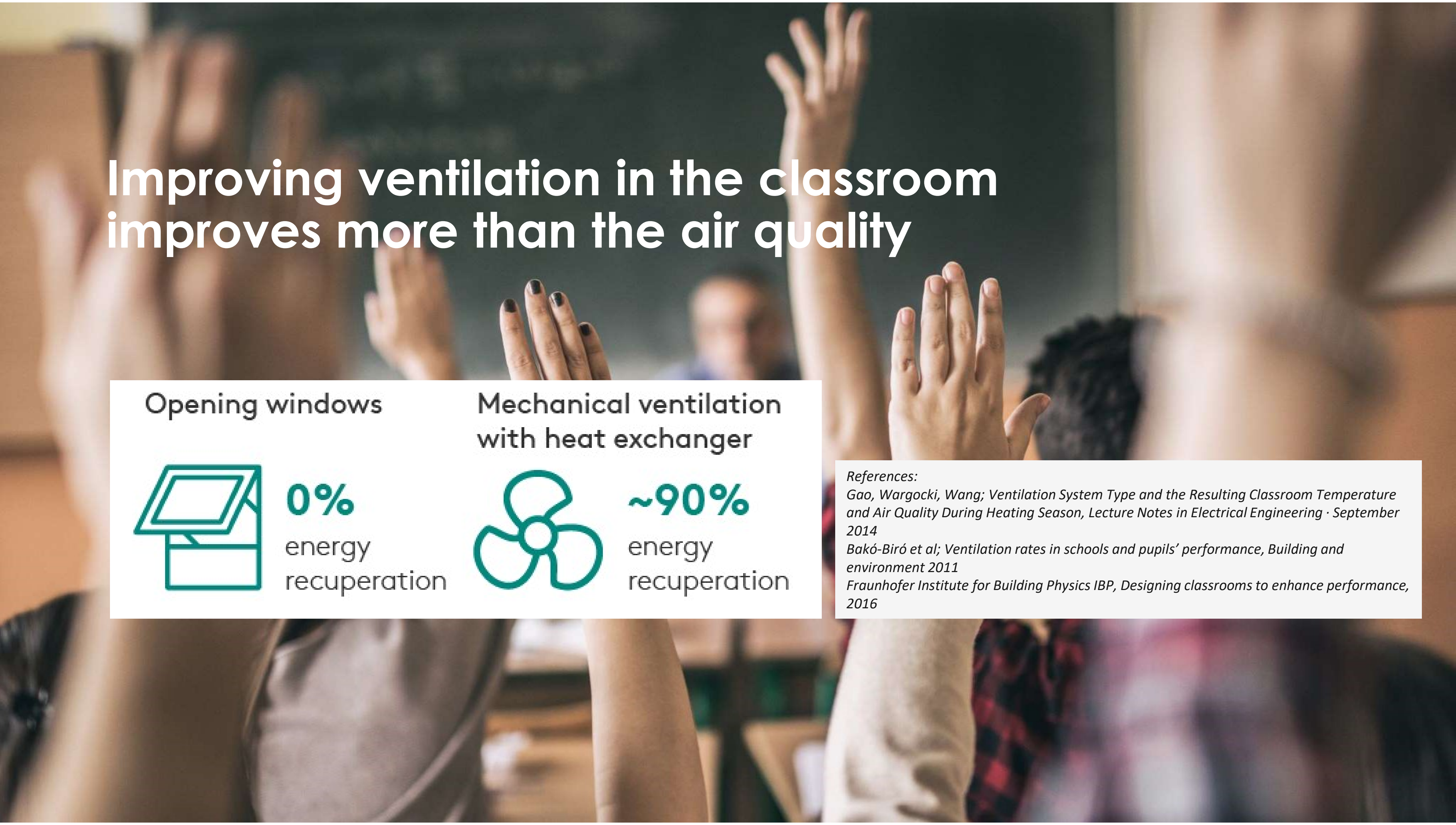
Our purpose in the world

We enable healthy and comfortable indoor environments for people to be at their best, today and tomorrow.

Improving ventilation in the classroom improves more than the air quality



References:
Gao, Wargocki, Wang; ***Ventilation System Type and the Resulting Classroom Temperature and Air Quality During Heating Season****, Lecture Notes in Electrical Engineering · September 2014*
Bakó-Biró et al; ***Ventilation rates in schools and pupils' performance****, Building and environment 2011*
Fraunhofer Institute for Building Physics IBP, ***Designing classrooms to enhance performance****, 2016*



Improving ventilation in the classroom improves more than the air quality

Opening windows	Mechanical ventilation with heat exchanger
0% energy recuperation	**~90%** energy recuperation

References:
Gao, Wargocki, Wang; Ventilation System Type and the Resulting Classroom Temperature and Air Quality During Heating Season, Lecture Notes in Electrical Engineering · September 2014
Bakó-Biró et al; Ventilation rates in schools and pupils' performance, Building and environment 2011
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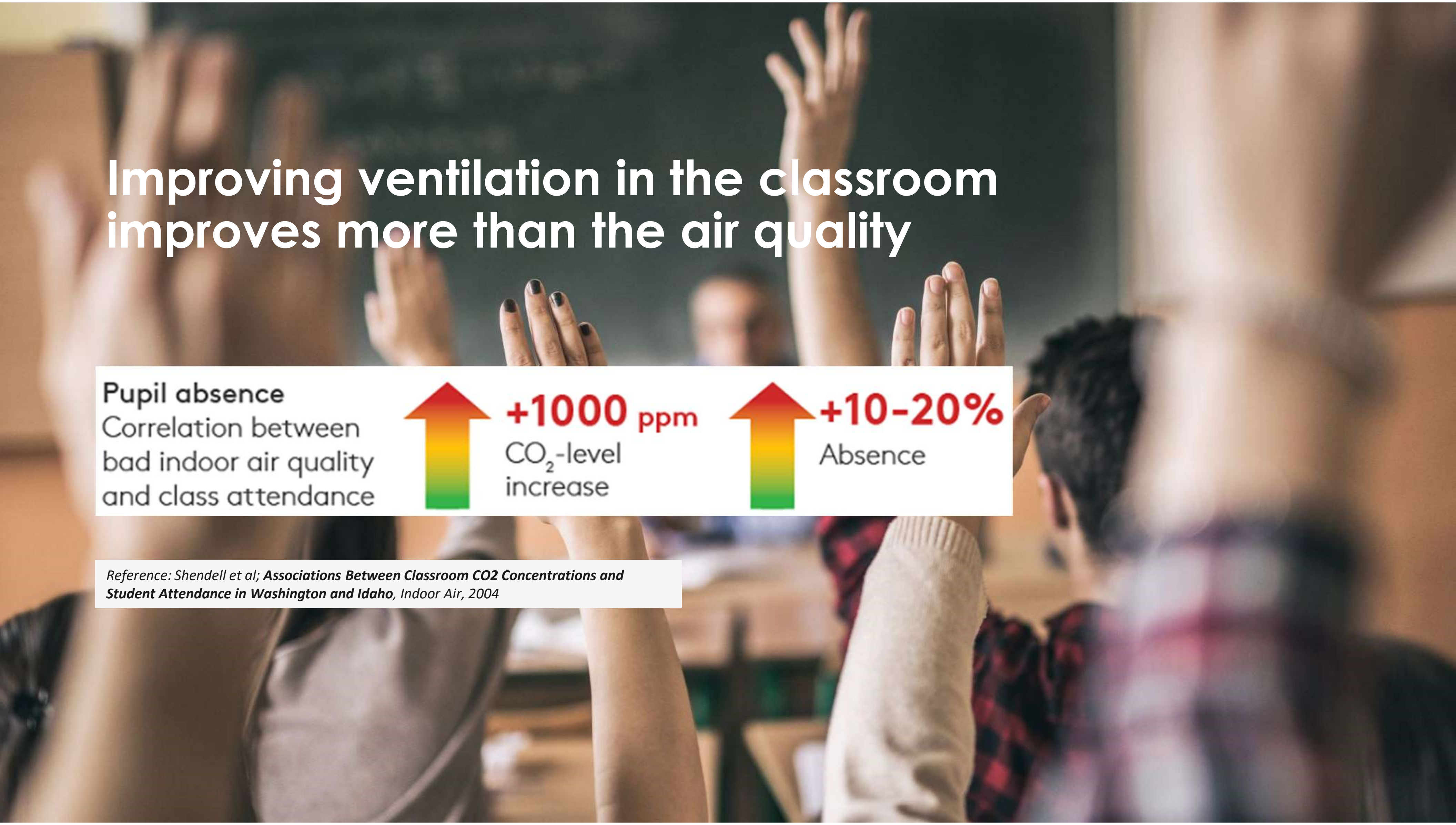


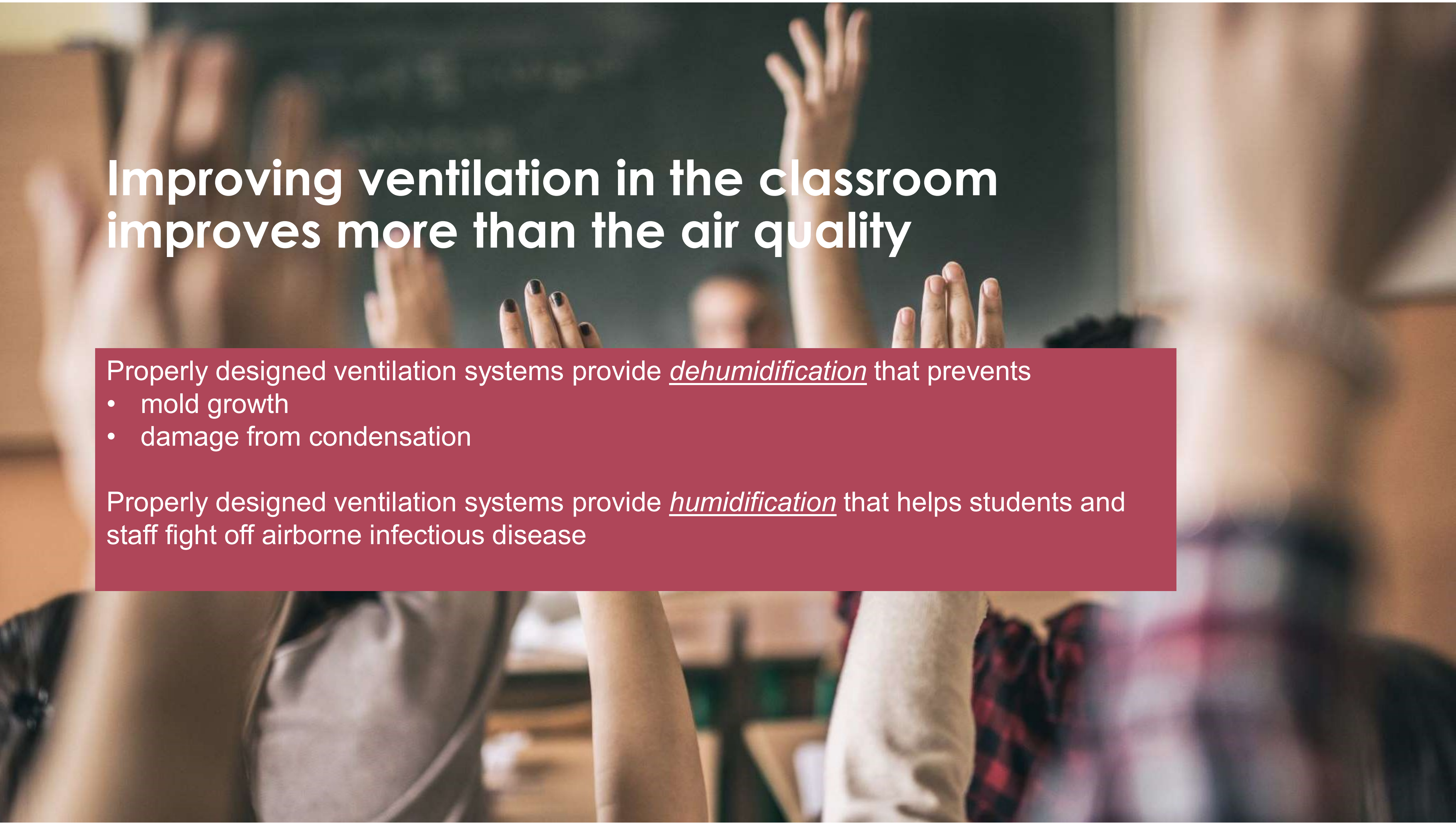
Improving ventilation in the classroom improves more than the air quality

Pupil absence
Correlation between bad indoor air quality and class attendance

+1000 ppm
CO_2-level increase

+10-20%
Absence

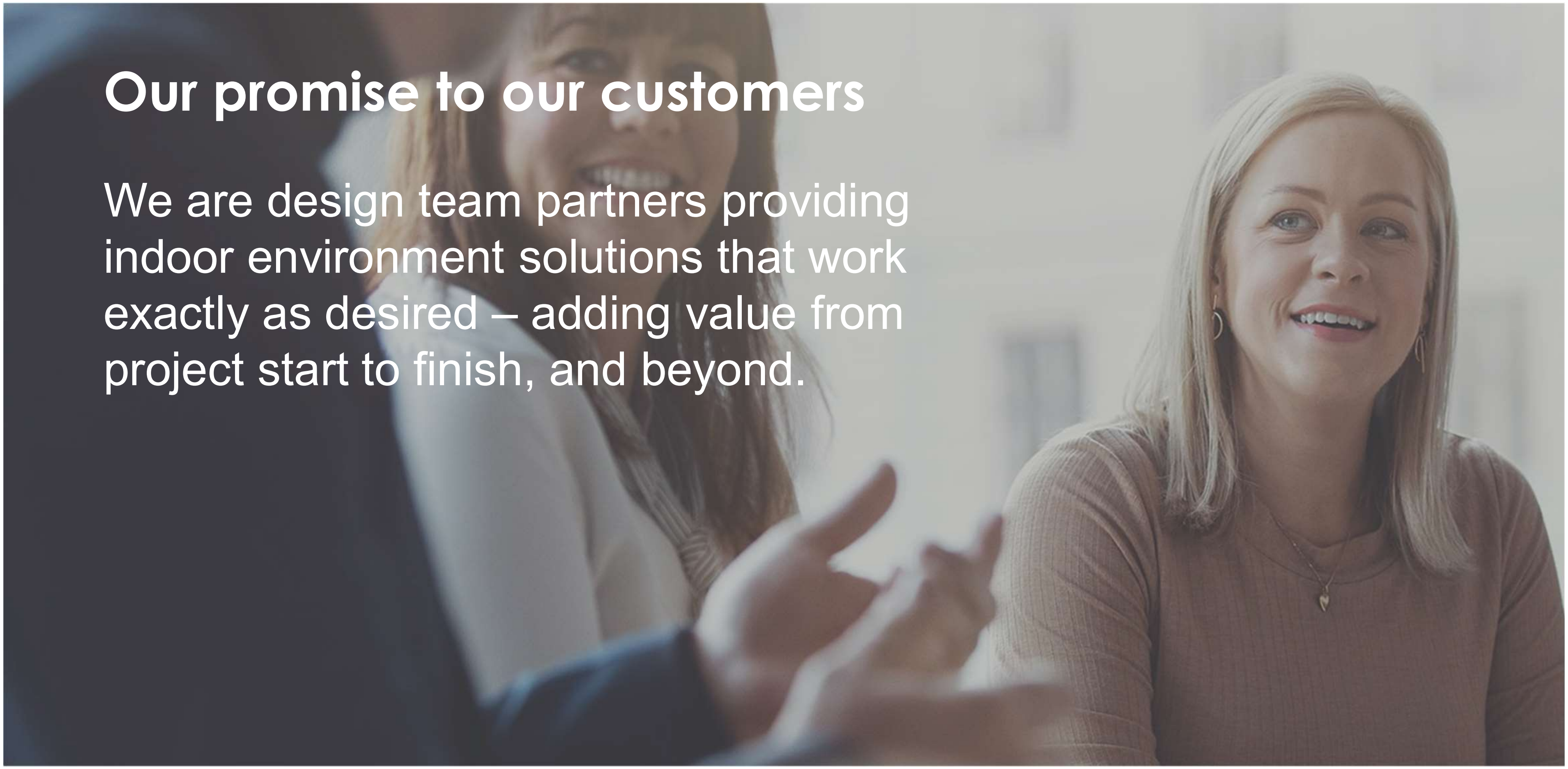
Reference: Shendell et al; ***Associations Between Classroom CO2 Concentrations and Student Attendance in Washington and Idaho****, Indoor Air, 2004*



Improving ventilation in the classroom improves more than the air quality

Properly designed ventilation systems provide *dehumidification* that prevents
- mold growth
- damage from condensation

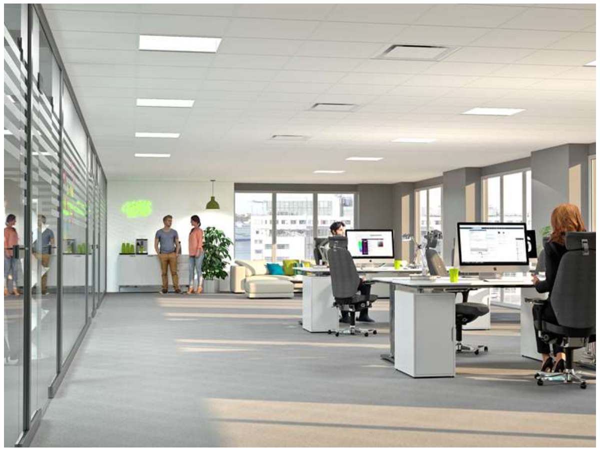
Properly designed ventilation systems provide *humidification* that helps students and staff fight off airborne infectious disease



Our promise to our customers

We are design team partners providing indoor environment solutions that work exactly as desired – adding value from project start to finish, and beyond.

Swegon Passive House Solution



- Air Handling / DOAS units
- Energy Recovery Ventilators
- Demand Control Ventilation systems
- Chilled beams
- Grilles, registers, diffusers
- Transfer grilles

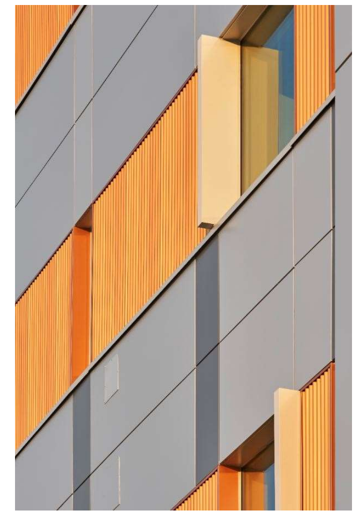
Passive House References

Multifamily

Commercial

Retail

Hospitality



Education

84 Passive Buildings in 11 countries use certified Swegon GOLD ERV:
<https://passivehouse-database.org/index.php?lang=en#k_Swegon>

Passive House Design in Schools

AIA-approved course *pending* 1.0 LU|HSW

Presenters:

Mike Woolsey Certified Passive House Designer, WELL AP, WELL Faculty
Business Development Manager *Swegon*
Voting Member *ASHRAE Standards Project Committee 227P Passive Building*
Member *iPHA*
Advisor *WELL Thermal Comfort Advisory*

Mir Ali
Application Engineer *Swegon*

Learning Objectives

1. Common goals of CHPS and Passive House.
2. Review the key characteristics of Passive House buildings.
3. Understand IAQ (ventilation, comfort, sound, materials, etc.) research, standards and design considerations.
4. Case studies and lessons learned.

CHPS and Passive House

Common Goals

Mir Mohsin Ali (Ali)

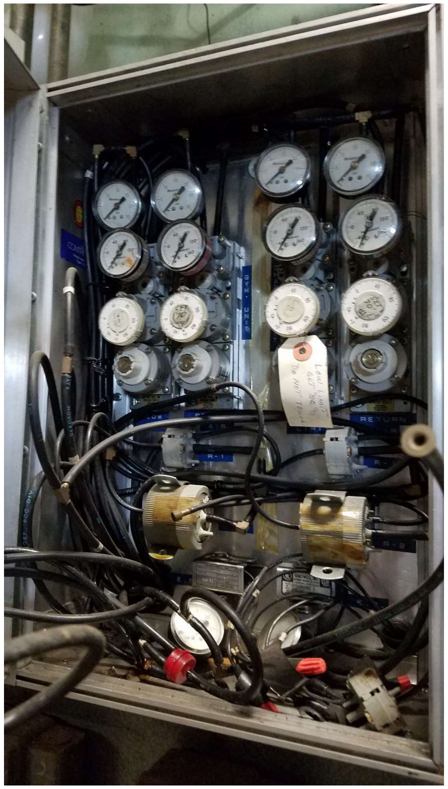
How are we doing with IEQ?

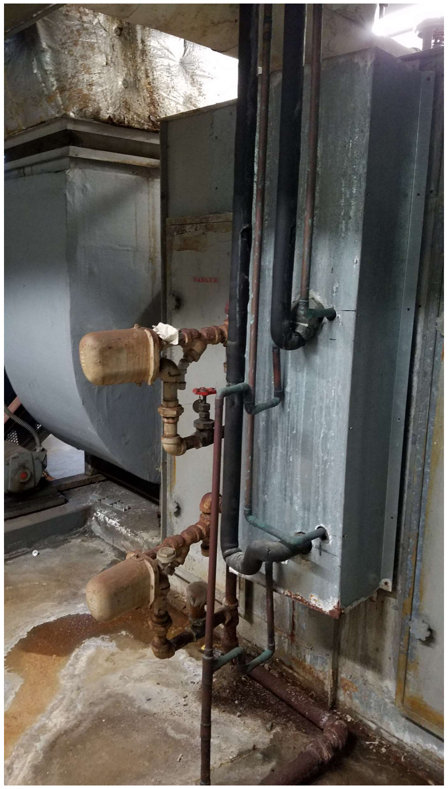
- Americans spend approx. 90% of their time indoors: (EPA)
- Complex building system, but low performance
- 3500 deficiencies in 224 building study
- Air distribution system problems
- 7000 energy related deficiencies
- Comfort problems, IAQ problems
- Half of complaints HVAC related

https://chps.net/sites/default/files/CHPS_V_2006.pdf

Typical Existing School in the USA

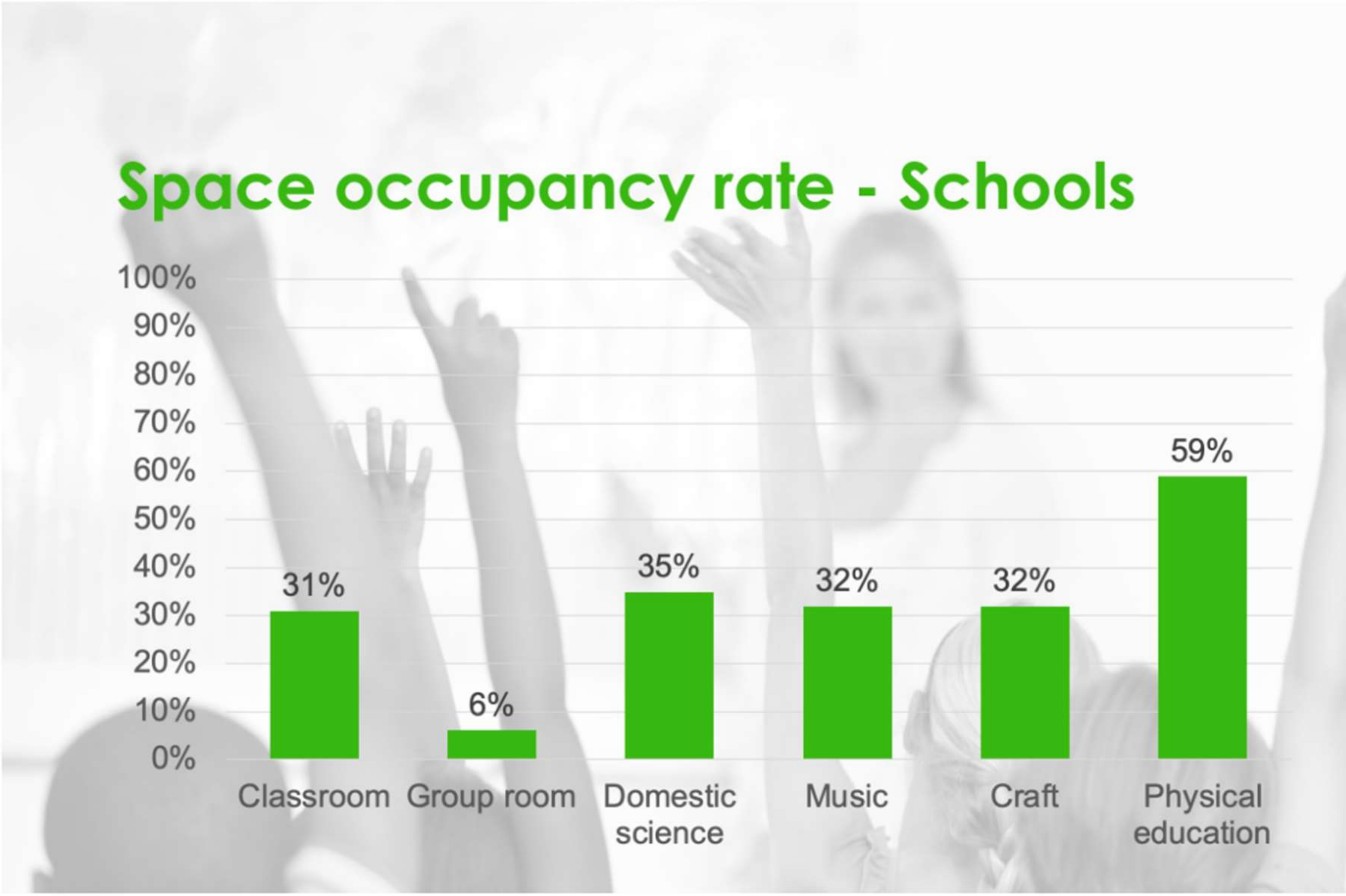
- 44 years old
- 12 years since major renovation
- Equipment has 30-year lifespan





Typical Existing School in the USA

- 4x the occupant density found in offices
- Classrooms only occupied 31% of the time
- *"Almost 100,000 public K-12 schools represent 5% of commercial building energy consumption, expend $8 billion in utility bills, and serve 50 million students plus 3 million teachers."* Energy.gov



Attendance in the classroom during school hours

TeknDr. Dennis Johansson, Presence in Buildings - Measurements and Estimates, 2010

New Schools in the USA

- Larger than existing schools
- No standardized footprint or aspect ratio
- (6200+) k-12 projects in design

Passive House vs CHPS intent

PASSIPEDIA
The Passive House Resource

PHIUS

COLLABORATIVE FOR HIGH PERFORMANCE
CHPS SCHOOLS.
Better buildings. Better students.

Passive House is a building standard that is truly **energy efficient, comfortable and** affordable at the same time.

Passive building comprises a set of design principles used to attain a quantifiable and rigorous level of **energy efficiency** within a specific quantifiable **comfort** level.

Goal: To nationally foster well-designed, operated, and maintained schools that enhance IEQ.
•CHPS Criteria defines high performance attributes in the categories of energy, water, sustainable sites, materials, indoor environmental quality, policy and operations.

CHPS Impact

- Over 700 completed CHPS schools across America.
- Approx. another 300 schools underway in the U.S. seeking CHPS recognition.
- 60 school district committed to build new schools to CHPS high performance building.
- Twelve states have state or region-specific high performance school building Criteria, including California, Washington, NY, etc.
- Participating districts include Los Angeles Unified School District.

https://chps.net/what-we-do

US-CHPS Criteria Framework

Table 1: Point Assignments in US-CHPS Criteria

Category	Total 2014 US-CHPS % (Points)
Integration (II)	8.5% (21)
Indoor Environmental Quality (EQ)	33% (82)
Energy (EE)	25% (63)
Water (WE)	8.0% (20)
Site (SS)	9.5% (24)
Materials & Waste Management (MW)	8.5% (21)
Operations & Metrics (OM)	7.5% (19)

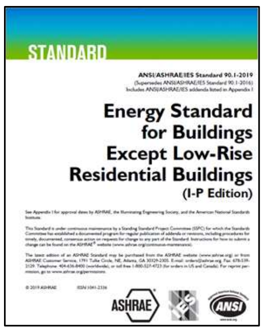
US-CHPS Criteria Organization

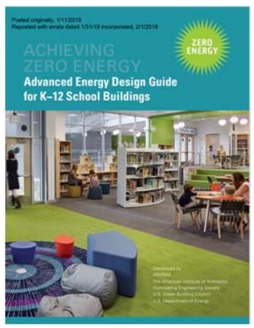
Table 2: Criteria Summary

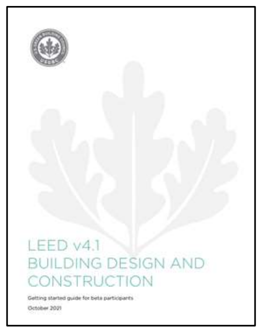
CRITERION	NUMBER	SECTIONS	PTS
Integration			
Integrated Design	II 1.0	Integrated Design	1
	II 1.1	Enhanced Integrated Design	2
District Level Commitment	II 2.1	District Level Commitment	2
School Master Plan	II 3.1	School Master Plan	2
High Performance Transition Plan	II 4.1	High Performance Transition Plan	1
Educational Display	II 5.1	Educational Display	1
Educational Integration	II 6.1	Educational Integration	2
Demonstration Area	II 7.1	Demonstration Area	1
Climate Change Action / Carbon Footprint Reporting	II 8.1	Climate Change Action / Carbon Footprint Reporting	3
Crime Prevention Through Environmental Design	II 9.1	Crime Prevention Through Environmental Design	2
Innovation	II 10.1	Innovation (CHPS Verified Projects Only)	4
Indoor Environmental Quality			
HVAC Design – ASHRAE 62.1	EQ 1.0	HVAC Design – ASHRAE 62.1	7
	EQ 1.1	Enhanced Filtration	2
	EQ 1.2	Dedicated Outdoor Air System	5
Pollutant & Chemical Source Control	EQ 2.1	Pollutant & Chemical Source Control	3
Outdoor Moisture Management	EQ 3.1	Outdoor Moisture Management	3
Ducted Returns	EQ 4.1	Ducted Returns	2
Construction Indoor Air Quality Management	EQ 5.1	Construction Indoor Air Quality Management	6
	EQ 5.2	Moisture Management	3
Post Construction Indoor Air Quality	EQ 6.1	Post Construction Indoor Air Quality	1
Low Emitting Materials	EQ 7.0	Low Emitting Materials	2
	EQ 7.1	Additional Low Emitting Materials	6
Low Radon	EQ 8.1	Low Radon	1
Thermal Comfort – ASHRAE 55	EQ 9.1	Thermal Comfort – ASHRAE 55	4
Controllability of Systems	EQ 10.1	Individual Controllability	2
	EQ 10.2	Controllability of Systems	1
Daylighting	EQ.11.0	Daylighting: Glare Protection	4
	EQ 11.1	Daylight Availability	5
Views	EQ 12.1	Views	3
Electric Lighting Performance	EQ 13.1	Electric Lighting Performance	2
	EQ 13.2	Superior Electric Lighting Performance	6
Acoustical Performance	EQ 14.0	Acoustical Performance	4
	EQ 14.1	Enhanced Acoustical Performance	6
Low-EMF Best Practices	EQ 15.1	Low-EMF Wiring	2
	EQ 15.2	Low-EMF Best Practices	2
Energy			
Energy Performance	EE 1.0	Energy Performance	5
	EE 1.1	Superior Energy Performance	40
Zero Net Energy (ZNE) Capable	EE 2.1	Zero Net Energy Capable	3
Commissioning	EE 3.0	Commissioning	5
	EE 3.1	Additional Commissioning Qualifications	1
	EE 3.2	Building Envelope Commissioning	2
Environmental Preferable Refrigerants	EE 4.1	Environmental Preferable Refrigerants	1
Energy Management System	EE 5.1	Energy Management System	2
	EE 5.2	Advanced Energy Management System and Submetering	2
Natural Ventilation & Energy Conservation Interlocks	EE 6.1	Natural Ventilation & Energy Conservation Interlocks	2

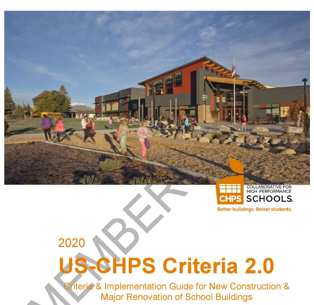
https://chps.net/sites/default/files/US-CHPS__Criteria_2014_2016%20update_170706.pdf

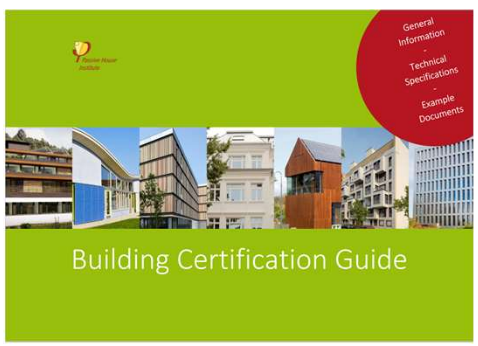
Standards for School Design - Energy





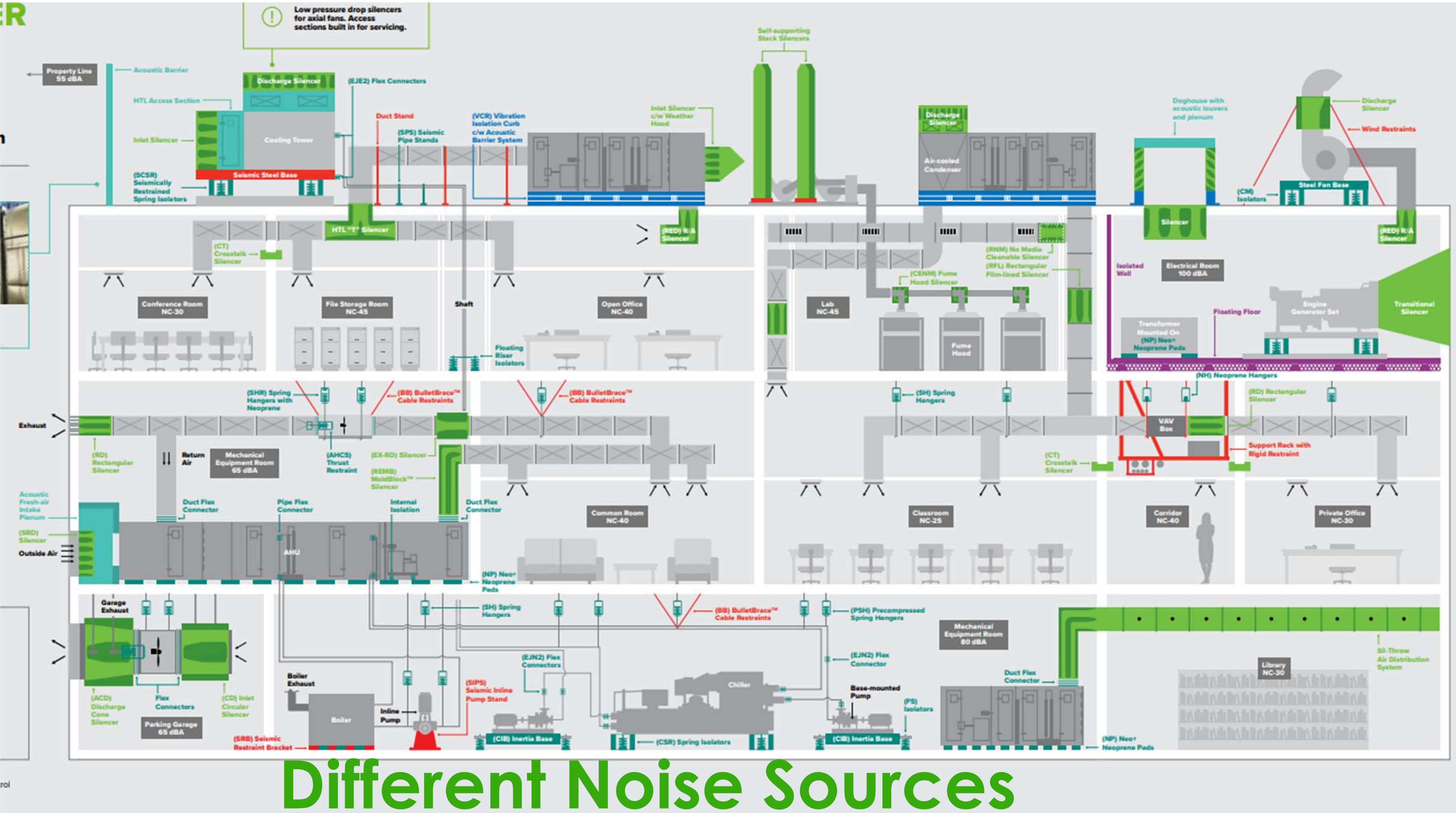






As adopted by the Authority Having Jurisdiction

- ASHRAE 90.1
- LEED v4.1
- CHPS
- Passive House



Different Noise Sources

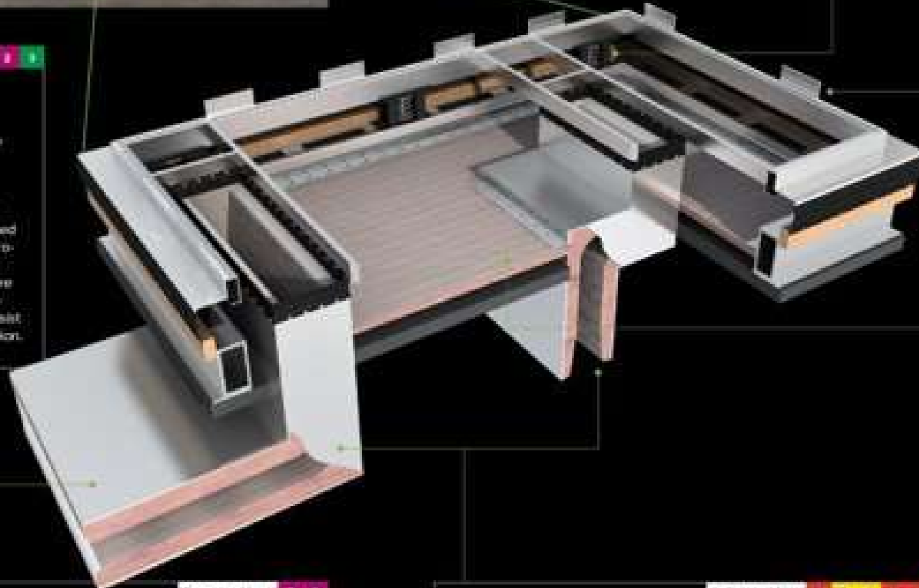
RTU NOISE CONTROL SOLUTION

RTU NOISE CONTROL SOLUTION

Vibro-Acoustics provides a no-obligation application engineering Lay-In Service to analyze project-specific RTU system design and provide an optimal solution.

WE PROVIDE an integrated NCC-VCR noise control curb system that addresses all noise sources and paths so that the project's sound criteria are achieved.

The noise control curb system enables the consulting engineer to reap the full benefits of locating RTUs over occupied spaces without the disadvantage of a noise problem. According to the project's needs, a number of customizable features are integrated into the curb. What the engineer receives is a single, amalgamated solution to address multiple areas of concern with single-source responsibility.



Targets problems 2 3

Intake and discharge silencers
To minimize environmental noise

Typical condenser fans have little static pressure to spare for silencing noise radiated to property lines. Vibro-Acoustics' intake and discharge silencers are designed to minimize pressure drop and resist environmental corrosion.

Targets problems 3

Noise Control Vertical Barrier
To minimize environmental noise

Vibro-Acoustics' noise barriers help prevent property line noise problems. They can act as architectural screening as well as effective noise control that does not reduce equipment performance.

Targets problems 13 14

Vibration Isolation
To dampen vibrations that cause structure-borne noise

Vibro-Acoustics isolates the entire RTU system externally. We take into consideration the location of the equipment in relation to neighboring occupied spaces, roof deflection, and sound criteria. This is the only sure way to address all vibration sources effectively.

Targets problems 1

Anchorage calculations with PE/P.Eng stamp
For seismic and wind loading

For code compliance, we perform all required anchorage calculations and provide connection details for the curb. Furthermore, the design and calculations are stamped by a professional engineer.

Targets problems 9 10

Noise Control Curb Barrier
To block radiated noise

Noise radiating from the bottom of the RTU is often overlooked. Located inside the Vibro-Acoustics noise control curb, the engineered barrier attenuates low frequency noise before it passes through the ceiling and into the occupied space.

Targets problems 7 8

HTL (High Transmission Loss) Casing
To address breakout noise

After performing a breakout analysis, HTL casing is provided to attenuate breakout noise. This is a better alternative to field-applied duct lagging because single-source responsibility is provided by Vibro-Acoustics.

Targets problems 4 5 6 11 12

Fit-the-System Silencers
To address airborne noise

Vibro-Acoustics silencers are built to the required shape and size to provide sufficient insertion loss while meeting space restrictions. Fit-the-system silencers also include flow-shaping internals which help keep pressure drop to a minimum.

Fit-the-system silencers also include flow-shaping internals to keep pressure drop at a minimum.

Passive House

Key Characteristics

Mike Woolsey

Passive House Schools

More than 100 K-12 Schools around the world have employed Passive House principles to provide energy savings and comfort

Passive House Requirements

Project structure

- Pass-fail certification with separate requirements for
  - new construction
  - Retrofit (unique phased process)
- Certified Passive House professionals:
  - Perform energy modelling
  - CPHC/CPHD guide the A/E team into pre-certification, approve the submittals
  - CPHT train contractors and closely guide the construction process**

Passive House Requirements

Project structure

- Quality control
  - 2 Airtightness tests
    - After airtight barrier established
    - After construction complete
  - Verifiers perform quality control confirmation of as-built structure.

Passive House Requirements

Features, Passive House Institute (PHI)

		Criteria	Alternate Criteria
AIRTIGHTNESS			
Infiltration / Exfiltration n50 ($n_{0.2}$)	ACH	≤ 0.6	
HEATING			
Annual Heating Demand	kBtu/ft²•yr	≤ 4.75	
Peak Heat Load	Btu/ft²•hr		≤ 3.17
COOLING			
Cooling	kBtu/ft²•yr	≤ 4.75 + dehumidification allowance	
Cooling Load	Btu/ft²•hr		≤ 3.17
THERMAL BRIDGING			
Ψ	Btu/(hr.ft.˚F)	<0.006	

Certified Passive House
Passive House Institute
classic | plus | premium

Passive House Requirements

comfort and energy consumption, PHI

		Criteria classic(plus/premium)	Alternate Criteria
COMFORT			
Indoor Temperature	°F	< 75 most of the year (90%)	
Energy Demand Goals			
Renewable Primary Energy Demand (PER)	kWh/ft^2·yr	19	
Non-renewable Primary Energy Demand	kWh/ft^2·yr		38

Passive House Requirements

Features, Passive House Institute (PHI)

			Criteria[1]			Alternative Criteria[2]
Airtightness						
Pressurization test result n_{50}	[1/hr]	≤	1.0			
Renewable Primary Energy (PER)[3]			Classic	Plus	Premium	
PER demand[4]	[kBTU/(ft²yr)]	≤	$19.02 + (Q_H - Q_{H,PH}) \cdot f_{ØPER,H} + (Q_C - Q_{C,PH}) \cdot 1/2$	$14.26 + (Q_H - Q_{H,PH}) + (Q_C - Q_{C,PH}) \cdot 1/2$	$9.51 + (Q_H - Q_{H,PH}) + (Q_C - Q_{C,PH}) \cdot 1/2$	±4.75 kBTU/(ft²yr) deviation from criteria...
Renewable energy generation[5] (with reference to projected building footprint)	[kBTU/(ft²yr)]	≥	-	19.02	38.04	...with compensation of the above deviation by different amount of generation

Passive House Requirements

Features, Passive House Institute (PHI)

Climate zone according to PHPP	Heating	Cooling
	Max. heating demand	Max. cooling + dehumidification demand
	[kBTU/(ft²yr)]	[kBTU/(ft²yr)]
Arctic	11.09	equal to Passive House requirement
Cold	9.51	
Cool-temperate	7.92	
Warm-temperate	6.34	
Warm	4.75	
Hot	-	
Very hot	-	

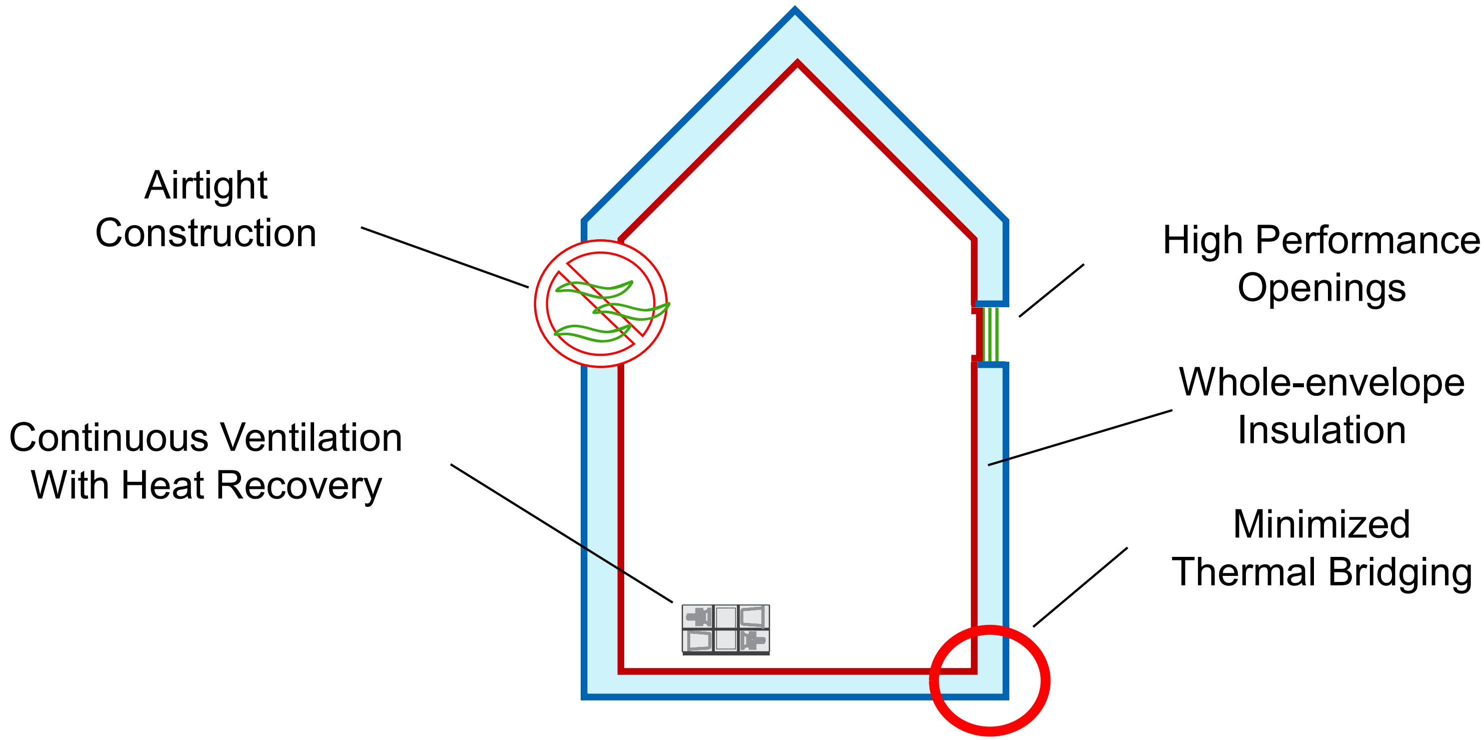
Passive House Results

Actual Passive House energy performance is 40-80% less than typical new building.

Sources

- Frappé-Sénéclauze , Tom-Pierre, et al. “Accelerating Market Transformation for High-Performance Building Enclosures .” Pembina , Sept. 2016, www.pembina.org/reports/passive-house-report-2016.pdf.
- Peper , Søren. “IPHA Fact Sheet 02 / 2019 .” IPHA Fact Sheet 02/2019: Heating Energy Consumption - Expectations Confirmed by Measurements in Practice, International Passive House Association (IPHA), Feb. 2019, news.passiv.net/archive/DGvow-aeM/_mcmHyFPT/pKN8V60HUJ.
- Johnston, David, et al. “Are the Energy Savings of the Passive House Standard Reliable? A Review of the as-Built Thermal and Space Heating Performance of Passive House Dwellings from 1990 to 2018.” Passivhaus Institut, 18 Mar. 2020, passivehouse.com/05_service/03_literature/0305_alle.php.
- “Multifamily Passive House: Connecting Performance to Financing.” Building Energy Exchange, 18 Mar. 2021, be-exchange.org/report/multifamily-passive-house-connecting-performance-to-financing/.

5 Key Passive House Characteristics



Insulation & Thermal Bridging

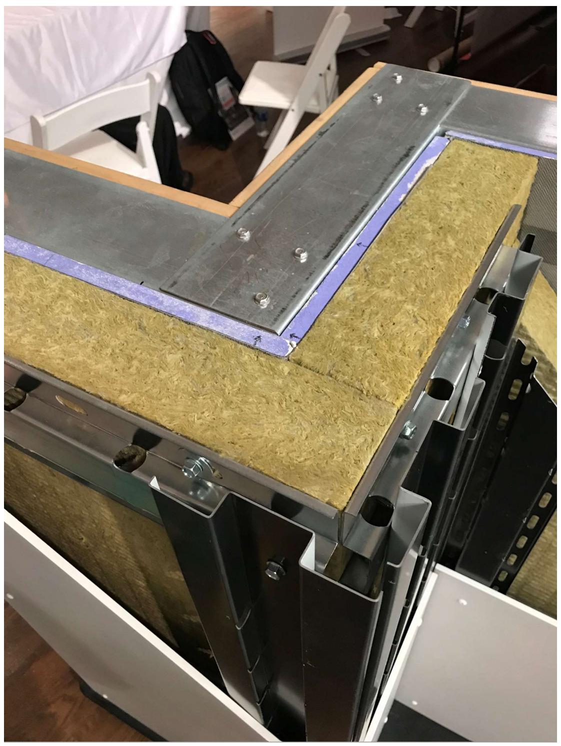
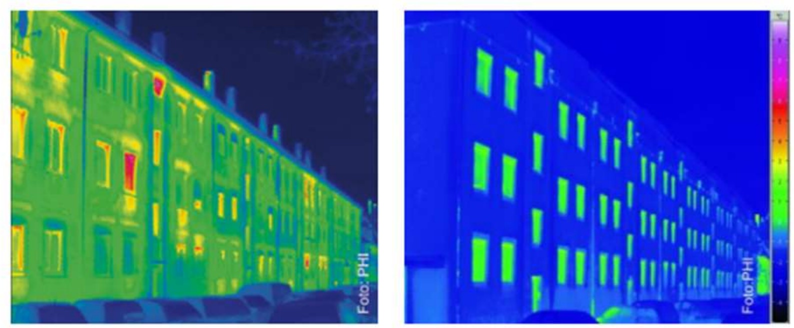


Photo courtesy of Rockwool

Climate-specific Insulation & Minimal Thermal Bridging

- Save energy by reducing heat flows into/out of the building
- Improve IEQ by keeping surface temperatures warmer in winter, cooler in summer
- Reduce heating/cooling equipment size



Windows

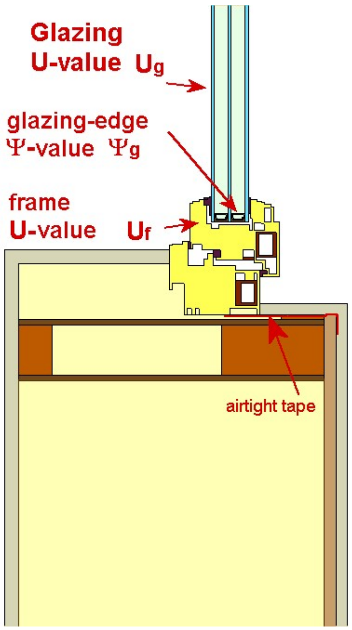
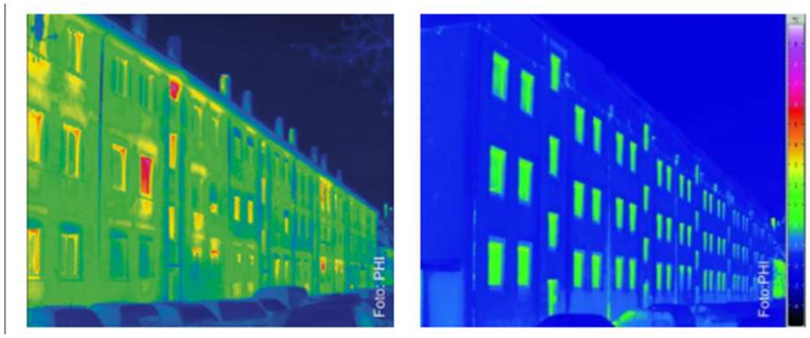


Photo courtesy of Passipedia

Comfort and energy-efficiency

- Save energy with low-e glazing, insulated frame
- Improve IEQ by keeping surface temperatures warmer in winter, cooler in summer



Airtight Construction

saves energy by reducing

- infiltration of unconditioned air
- exfiltration of conditioned air

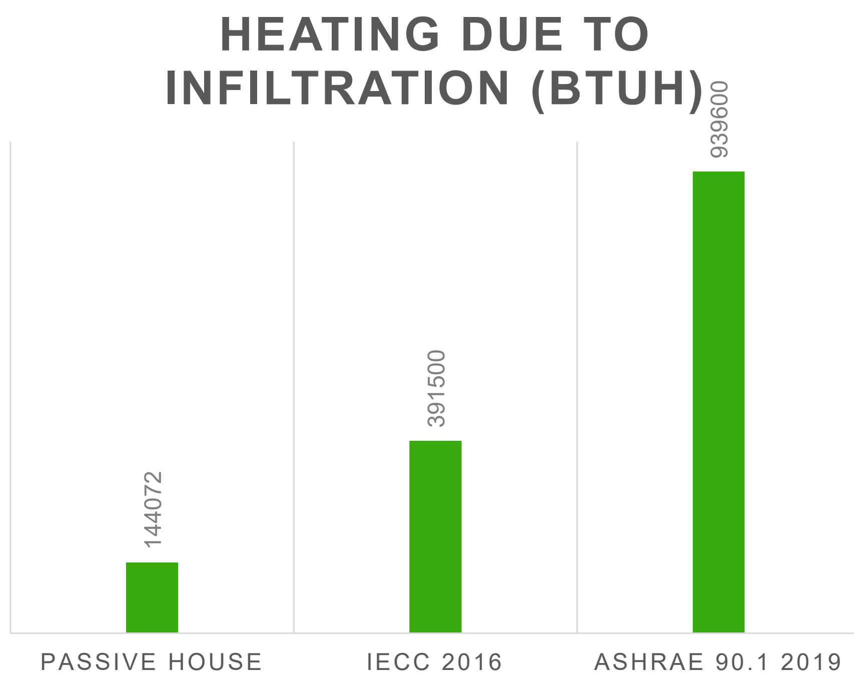
improves indoor environmental quality (IEQ) by

- reducing draftiness
- keeping fine airborne particles outside
- preventing noise migration from outdoors

Energy savings from Airtight Construction

Example

- Building dimensions
  - 100ft x 50ft x 50ft
- Occupied volume
  - 230,000ft^3
- Envelope area
  - 25,000ft^2
- Temperature,
  - indoors 68°F
  - outdoors 10°F



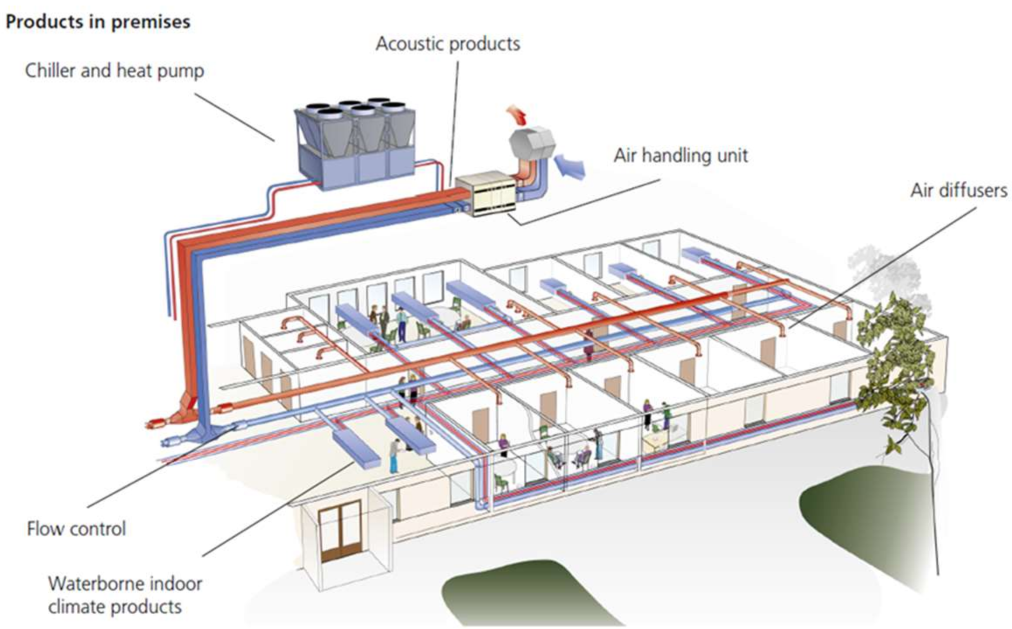
Airtight Construction *Consequences*

- Building must breathe
  - Fresh air no longer leaks in
  - H_2O, CO_2, VOC, odors, etc. in the air no longer leaks out
  - Continuous ventilation therefore required to flush out contaminants
- Can make ventilation air the dominant heating/cooling load
- Increases importance, and effectiveness, of energy-efficient ventilation strategies

Ventilation

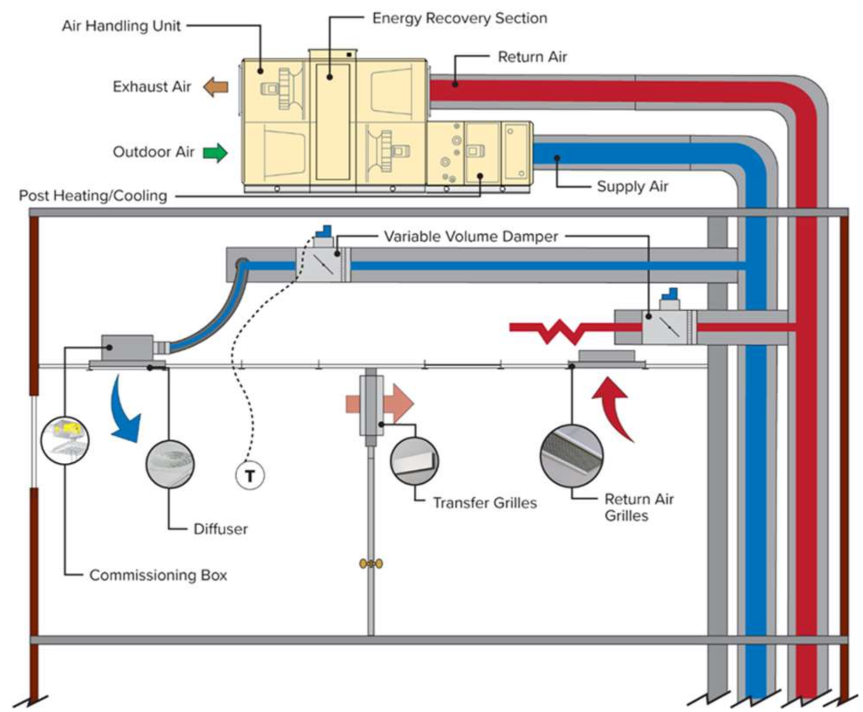
The process of supplying air to or removing air from a space for the purpose of controlling air contaminant levels, humidity, or temperature within the space.

See: https://xp20.ashrae.org/terminology/



Passive House Ventilation

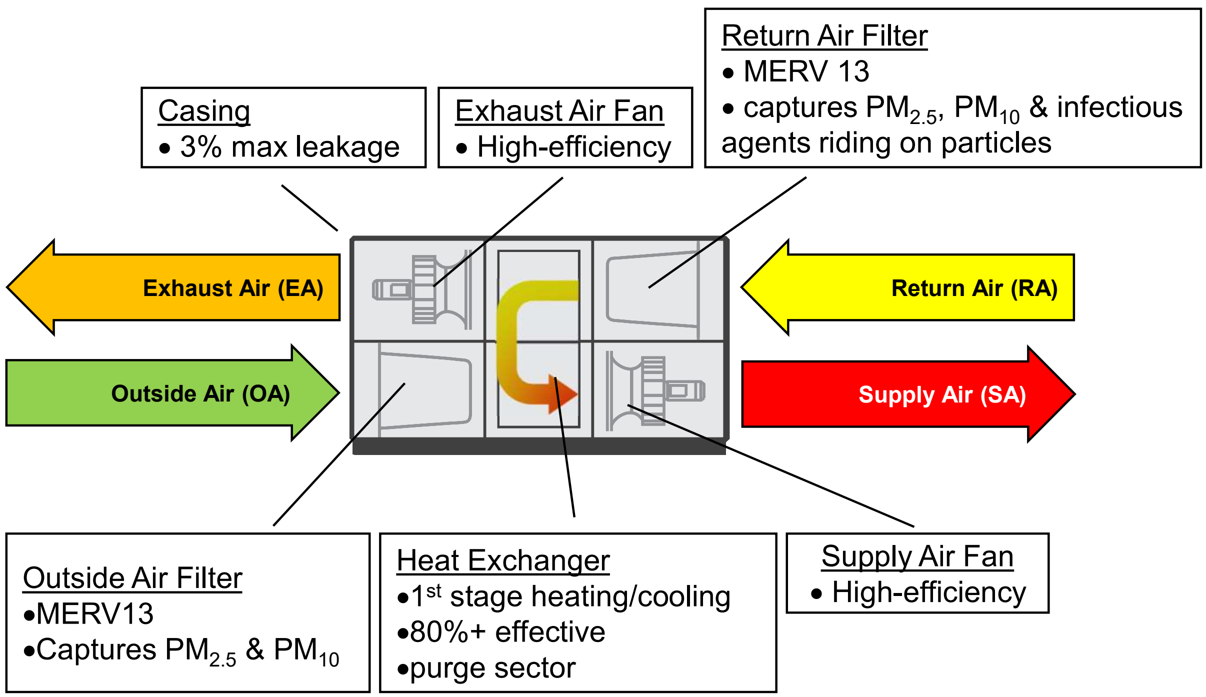
- Ventilation air provides comfort with less added heating or cooling
- Ventilation air may be post-heated or cooled for comfort
- High-efficiency energy recovery
- Energy recovery ventilation with high electrical efficiency



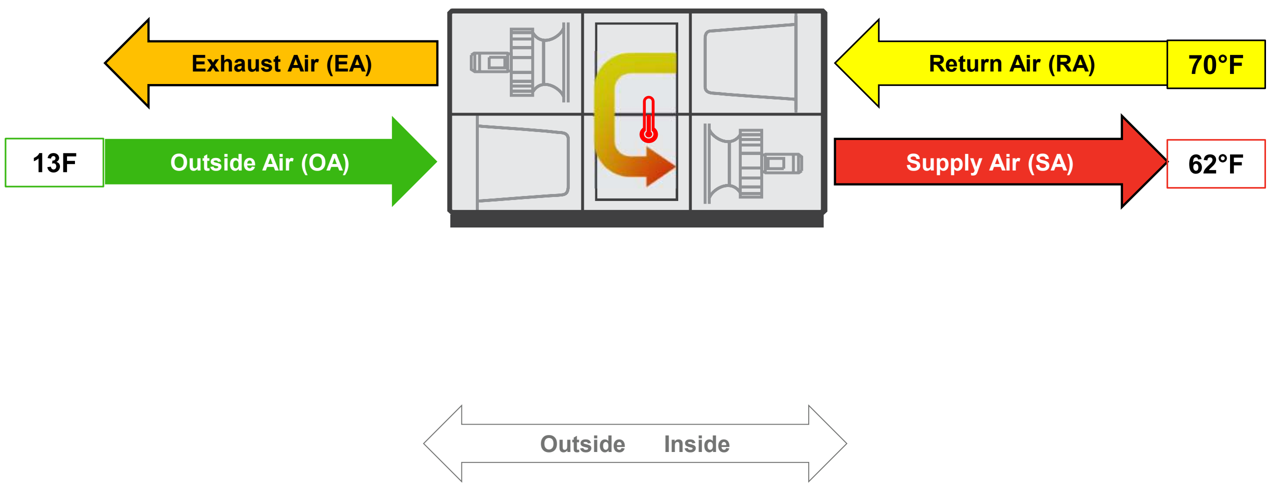
Passive House Ventilation – heat recovery

	Sensible Heat	Latent Heat	Equipment Type
“Heat Recovery”	☑		HRV
“Energy Recovery”	☑	☑	ERV
	Temperature of the air aka thermostat temperature	Moisture in the air aka Humidity	

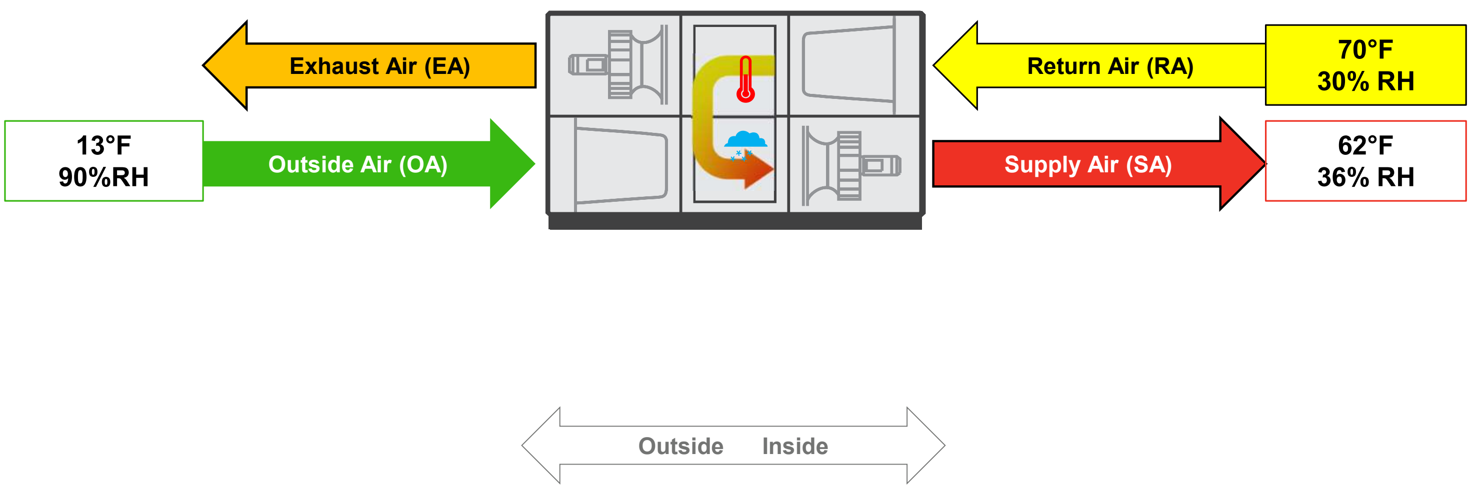
Energy Recovery Ventilator (ERV) Passive House features



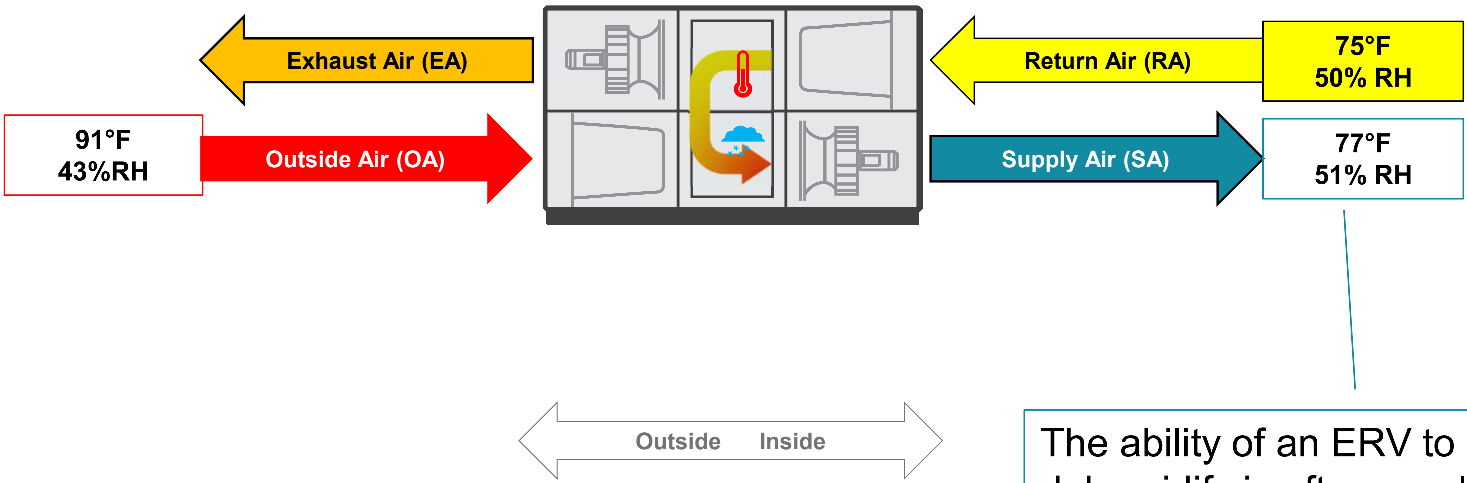
Heat Recovery Ventilator (HRV)
Typical Winter Performance, Boston



Energy Recovery Ventilator (ERV) Typical Winter Performance, Boston



Energy Recovery Ventilator (ERV) Typical Summer Performance, Boston



The ability of an ERV to cool and dehumidify is often overlooked.

Passive House HRV Value

Intent: optimize energy recovery with energy consumption

Sample PHPP input

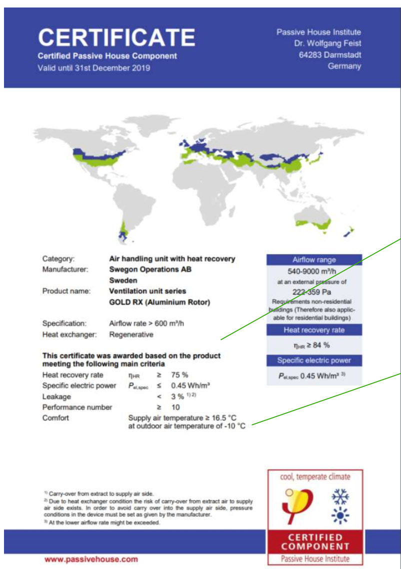
Selection of ventilation unit with heat recovery

Location of ventilation unit: **1-Inside thermal envelope**

		Heat recovery efficiency Unit η_{WRG}	Energy recovery η_{ERV}	Specific efficiency [W/cfm]	Application [cfm]	Frost power input
	Go to ventilation units list 1-Sorting: LIKE LIST					
Ventilation unit selection	**0569vl03-Swegon - GOLD RX 50**	0.85	0%	0.76	3178 - 5297	no

Passive House HRV Value

Certified heat recovery & electrical efficiency, leakage



CERTIFICATE

Certified Passive House Component

Valid until 31st December 2019

Passive House Institute
Dr. Wolfgang Feist
64283 Darmstadt
Germany

Category:	**Air handling unit with heat recovery**
Manufacturer:	**Swegon Operations AB** **Sweden**
Product name:	**Ventilation unit series** **GOLD RX (Aluminium Rotor)**
Specification:	Airflow rate > 600 m³/h
Heat exchanger:	Regenerative

This certificate was awarded based on the product meeting the following main criteria

Heat recovery rate	η_{HR}	≥	75 %
Specific electric power	$P_{el,spec}$	≤	0.45 Wh/m³
Leakage		<	3 % [1) 2)]
Performance number		≥	10
Comfort	Supply air temperature ≥ 16.5 °C at outdoor air temperature of -10 °C		

Airflow range: 540-9000 m³/h at an external pressure of 222-359 Pa. Requirements non-residential buildings (Therefore also applicable for residential buildings)

Heat recovery rate: $\eta_{HR} \geq 84$ %

Specific electric power: $P_{el,spec}$ 0.45 Wh/m³ [3)]

1) Carry-over from extract to supply air side.
2) Due to heat exchanger condition the risk of carry-over from extract air to supply air side exists. In order to avoid carry over into the supply air side, pressure conditions in the device must be set as given by the manufacturer.
3) At the lower airflow rate might be exceeded.

cool, temperate climate

CERTIFIED COMPONENT

Passive House Institute

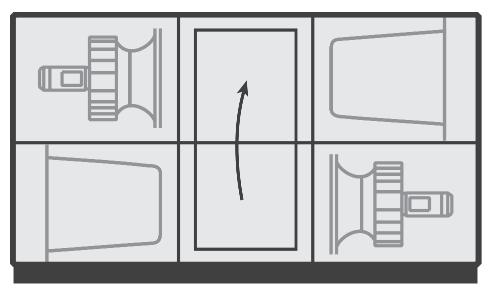
www.passivehouse.com

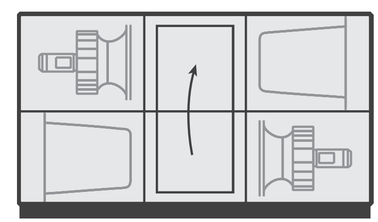
This certificate was awarded based on the product meeting the following main criteria

Heat recovery rate	η_{HR}	≥	75 %
Specific electric power	$P_{el,spec}$	≤	0.45 Wh/m³
Leakage		<	3 % [1) 2)]

Passive House HRV Value

Selection	PHI-certified HRV	AHRI-certified HRV
Airflow (CFM)	3450	3450
Size	35	20
Specific electrical power (W/CFM)	0.62	1.03 (+66%)
Value	Lowest life-cycle cost	Lowest first cost





Passive House ERV Value

Less overall energy use, sample project

	HRV selected		
Annual Energy Consumption	**lowest first cost (kWh)**	**PHI-certified (kWh)**	**VALUE of PHI-certification**
Fans (3450 CFM)	10,396	6,235	41% less fan
Recovery Wheel	146	146	No change
Cooling	7,419	7,128	4% less cooling
Heating	23,790	24,402	3% **more** (reheat) heating energy,
Moisture control	1,268	997	21% less moisture control energy
TOTAL	**43,020**	**38,908**	***9.6% less Total Energy use***

Passive House in K-12 Schools

Case Studies and Lessons Learned

Passive House Schools

Worldwide

- 119 pre-k/kindergarten
- 169 secondary school | campus | university
- 24 residence halls

K-12 Passive House Schools

Select reference projects, Central Europe

Project	Type	Country	ventilation	Treated Floor Area (ft^2)	Primary Energy Demand (kbtu/sf/yr)
kindergarten	kindergarten	France	ERV, passive house certified	3000	38
Creche Muel	kindergarten	France	ERV, passive house certified	5000	36
Le Cerf Volant	kindergarten	France	ERV, passive house certified	5000	44
Le Moulin de Beauté	kindergarten	France	ERV, passive house certified	6500	33
Ecole Auriol	high school	France	ERV, passive house certified	15000	36
Collège Georges Chepfer	middle school	France	ERV, passive house certified	28000	32
Ecole Maternelle	kindergarten	France	ERV, passive house certified	7500	32
Nouvelle Ecole	kindergarten	France	ERV, passive house certified	12000	32
Ecole Albert Camus	high school	France	ERV, passive house certified	18000	28
Ecole - Templeuve	elementary	France	ERV, passive house certified	16000	25
Salzmanschule	Dormitory	Germany	ERV, passive house certified	7000	38
KiTa Königsblick	kindergarten	Germany	ERV, passive house certified	7500	30
Oranienschule	High School	Germany	ERV, passive house certified	5000	31
Gemeinschaftschule	high school	Germany	ERV, passive house certified	4000	31

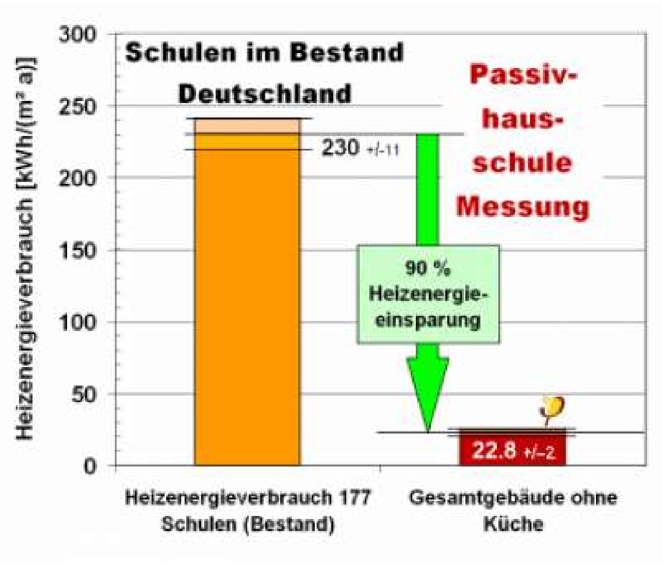
K-12 Passive House Schools

Riedberg Passive House School, Frankfurt, Germany

K-12 Passive House Schools

Riedberg Passive House School, Frankfurt, Germany

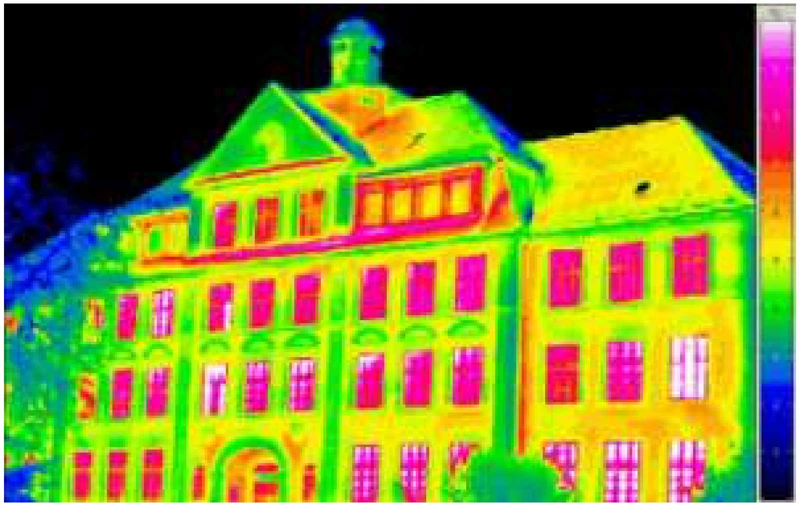
- Riedberg Passive House School energy performance is 90% better than 177 similar schools in Germany

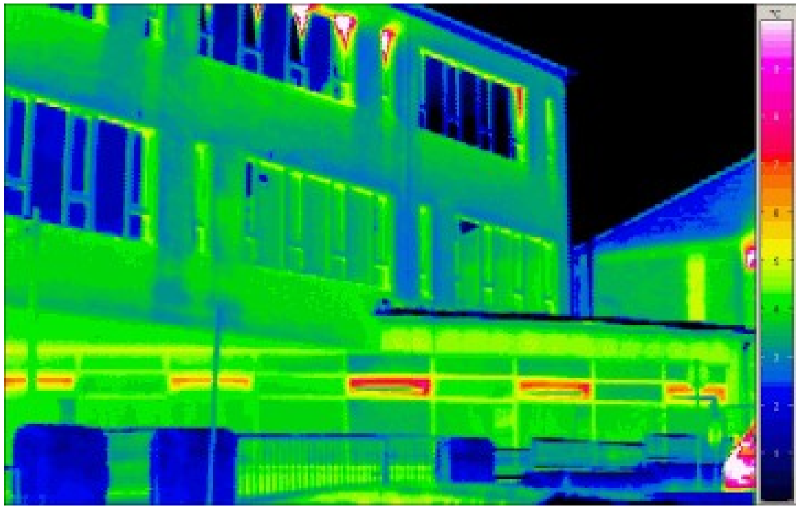


Read more: [Riedberg Passive House School, Frankfurt, Germany [ ] (passipedia.org)]

Passive House in Schools

Effect of Passive House retrofit on heat transfer





K-12 Passive House Schools

Select reference projects, around the world

Project	Type	Country	ventilation	Treated Floor Area (ft2)	Primary Energy Demand (kbtu/sf/yr)
Brage Förskola	kindergarten	Sweden	ERV, passive house certified	20000	33
Norrgårdens förskola	kindergarten	Sweden	ERV, passive house certified	15000	30
Humlan	kindergarten	Sweden	ERV, passive house certified	9000	37
Lustigkulla	kindergarten	Sweden	ERV, passive house certified	14000	28
Skövde Förskola	kindergarten	Sweden	ERV, passive house certified	9000	31
Adolfsbergsskola	middle school	Sweden	ERV, passive house certified	60000	41
Internationale Schule	Kindergarten, elementary school	Sweden	ERV, passive house certified	94000	30
Schule - Knivsta	classrooms	Sweden	ERV, passive house certified	50000	28
Oakmeadow Primary School	classrooms	UK	ERV, passive house certified	22000	36
Bushbury Hill Primary School	classrooms	UK	ERV, passive house certified	17000	37
King's Hawford Junior School	gym	UK	ERV, passive house certified	4500	36
Richmond Hill Primary School	classrooms	UK	ERV, passive house certified	35000	36
Mosaic UPK Q368	kindergarten	USA	ERV, passive house certified	470	36

Photo credit: CTA Architects

Mosaic Pre-K

- Owner:
  New York City School Construction Authority
- Architect:
  CTA, Think!
- M/E/P Engineer:
  Lilker Associates
- Passive House Consultant:
  AEA

Photo credit: CTA Architects
Source: Mosaic Pre-K Center, by CTA Architects | Architect Magazine

Mosaic Pre-K

- Location: Queens NY
- Area: 4,700 ft^2
- Built within a 39,000 ft^2 Senior Residence
- Passive House Institute PHI Certified *Classic*

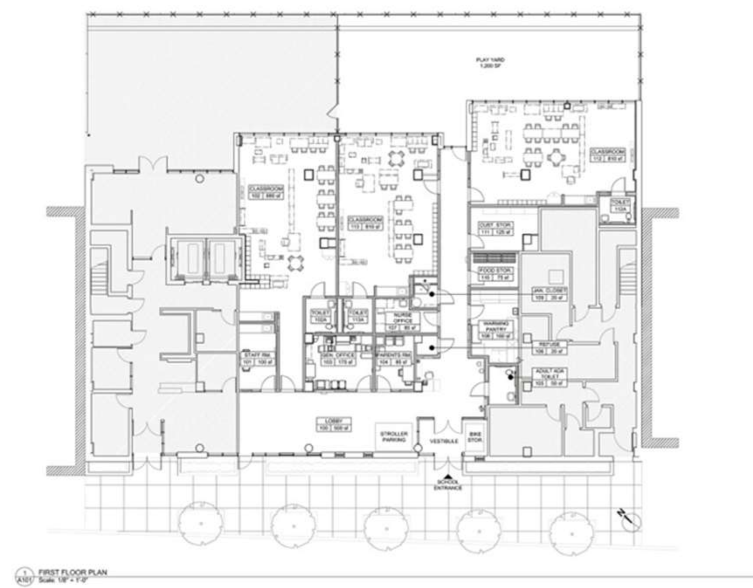


Photo credit: CTA Architects
Source: [Mosaic Pre-K Center, by CTA Architects | Architect Magazine]

PHI-Certified Building Characteristics

Building quality		This building		Criteria	Alternative criteria
Heating					
Heating demand	[kWh/(m²a)]	13	≤	15	-
Heating load	[W/m²]	15	≤	-	10
Cooling					
Cooling + dehumidification demand	[kWh/(m²a)]	13	≤	19	19
Cooling load	[W/m²]	14	≤	-	12
Frequency of excessively high humidity	[%]	6	≤	10	
Airtightness					
Pressurization test result (n_{50})	[1/h]	0.4	≤	0.6	
Non-renewable primary energy (PE)					
PE demand	[kWh/(m²a)]	115	≤	120	

Certified
Passive House
Passive House Institute
| classic | plus | premium |

Passive House Pre-K

Centralized DOAS units

- School
- Common Areas/Corridors
- heat recovery: **86% efficient**
- electrical efficiency: **0.72 W/CFM**

Decentralized ERV

- Apartments
- heat recovery: **85% efficient**
- electrical efficiency: **0.70 W/CFM**

Passive House Consultant

Lessons Learned - Schematic Design stage

- push hard on tough PH energy targets
- using high-efficiency recovery ventilation isn't enough
- think hard where you need ventilation and where you don't
- Pay attention to all PH principles:
  - robust insulation
  - high performance fenestration
  - Elimination of all thermal bridging

Passive House Consultant

Lessons Learned - Schematic Design stage

Ventilation Rate

- specifications, code and Passive House all have their own unique ventilation rate guidelines
- Don’t assume one of these will be more stringent and don’t be surprised if some of these guidelines will conflict each other.
- Analyze this early so you can negotiate any conflicts, if present.

Passive House Consultant

Lessons Learned - Schematic Design stage

- Given high level recovery ventilation >70-75% and often above 90% thermal efficiency, supplying recovered air directly to space and having conditioning system separate is typically acceptable.

Passive House Consultant

Lessons Learned - CD stage

- make sure the HRV/ERV and duct system air-sealing and commissioning is part of scope.
- Dunnage or curbs for Rooftop equipment should be thermally isolated to prevent thermal bridging.

Passive House Consultant

Lessons Learned - Commissioning

- Decentralized HRV/ERV- pay attention to making sure ducts between each unit and space adhere to standard patterns including radii that would ensure adequate flow.
- For units place inside conditioned space pay attention to air sealing where outside ducts penetrate the envelopes.
- Centralized HRV/ERV/DOAS pay attention to insulating outdoor ducts.
- PH certification process requires documentation that design air flow rates are met s on ALL supply registers. TAB and leakage remediation should be part of subcontractor scope.
- make sure filtration media replacement schedule is clear to maintenance team and they are trained with how to physically perform system shutdown, and subsequent restart.


Photo credit:
Architecture Resource Office
Alloy Development

100 Flatbush Primary and High School

- Location: Brooklyn NY
- Area: 146,000 ft^2
- Under construction
- Passive House Certification intended
- Brooklyn’s first all-electric skyscraper

9 Passive House Institute recommendations

for Passive House School design

1. Simplify the geometry
   - Surface Area / Volume ratio <0.4 m3/m2
2. Apply appropriate insulation
3. Eliminate thermal bridges
4. Establish airtightness
   - Aim for 0.3 ACH in large buildings
5. Use Passive House quality windows
   - U_w less than 0.8 W/(m^2K)

9 Passive House Institute recommendations

for Passive House School design

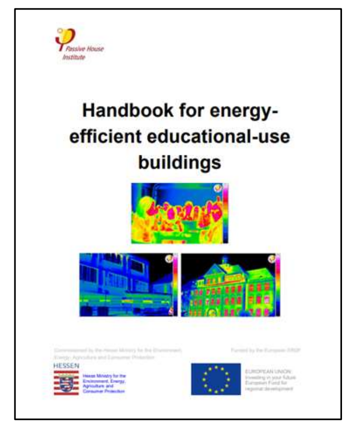
6. Ventilation
   - >15 – 20 l/s/person
   - >80% Hreff
   - <0.4 Wh/m3
   - Include free-cooling control
   - Include time-based of Demand control
7. Heat using Supply Air
8. Include sun shades and night ventilation to save cooling costs
9. Design cooling strategies to address unique Passive House properties
   - lower balance temperature
   - more cooling hours

Read more: Passive House schools – How to go about it [ ] (passipedia.org)

Passive House Schools

Reference Material

- Passive House Schools - Boundary Conditions [ ] (passipedia.org)
- Passive House schools – How to go about it [ ] (passipedia.org)
- Handbook for energy-efficient educational-use buildings



Audience Questions

Please type your questions in Q&A box.

For More Information on CHPS

https://chps.net

- Studies & reports on high performance schools: https://chps.net/knowledge-library
- School Building Science Fridays Webinars: https://chps.net/school-building-science-fridays
- Our Criteria for New Construction & Major Renovation: https://chps.net/chps-criteria
- Membership info: https://chps.net/join-us

Thank you to Mike and Mir.

Thank you all for joining us today!

Please join us for the next free session in our School Building Science Fridays series:

Equity and the Physical Environment

May 13, 2pm Eastern

Watch for registration link here: https://chps.net/school-building-science-fridays