Passive House Institute US

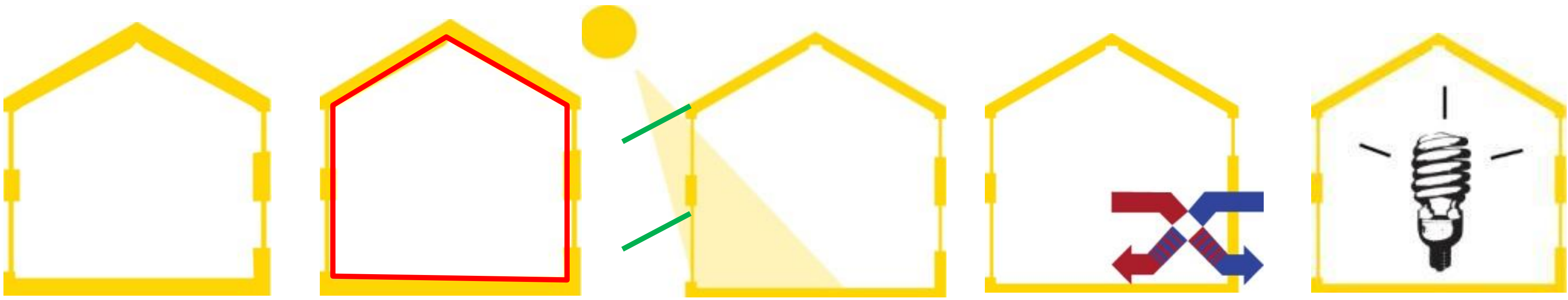
LATENT LOADS, PSYCHOMETRICS, AND THE SENSIBLE HEAT RATIO

Lisa White, PHIUS Certification Manager

AGENDA

1. BACKGROUND
2. PHIUS+ 2015 COMPLIANCE
3. CAPABILITIES OF WUFI PASSIVE/PLUS
4. CHALLENGES OF HANDLING LATENT LOADS

PASSIVE BUILDING PRINCIPLES



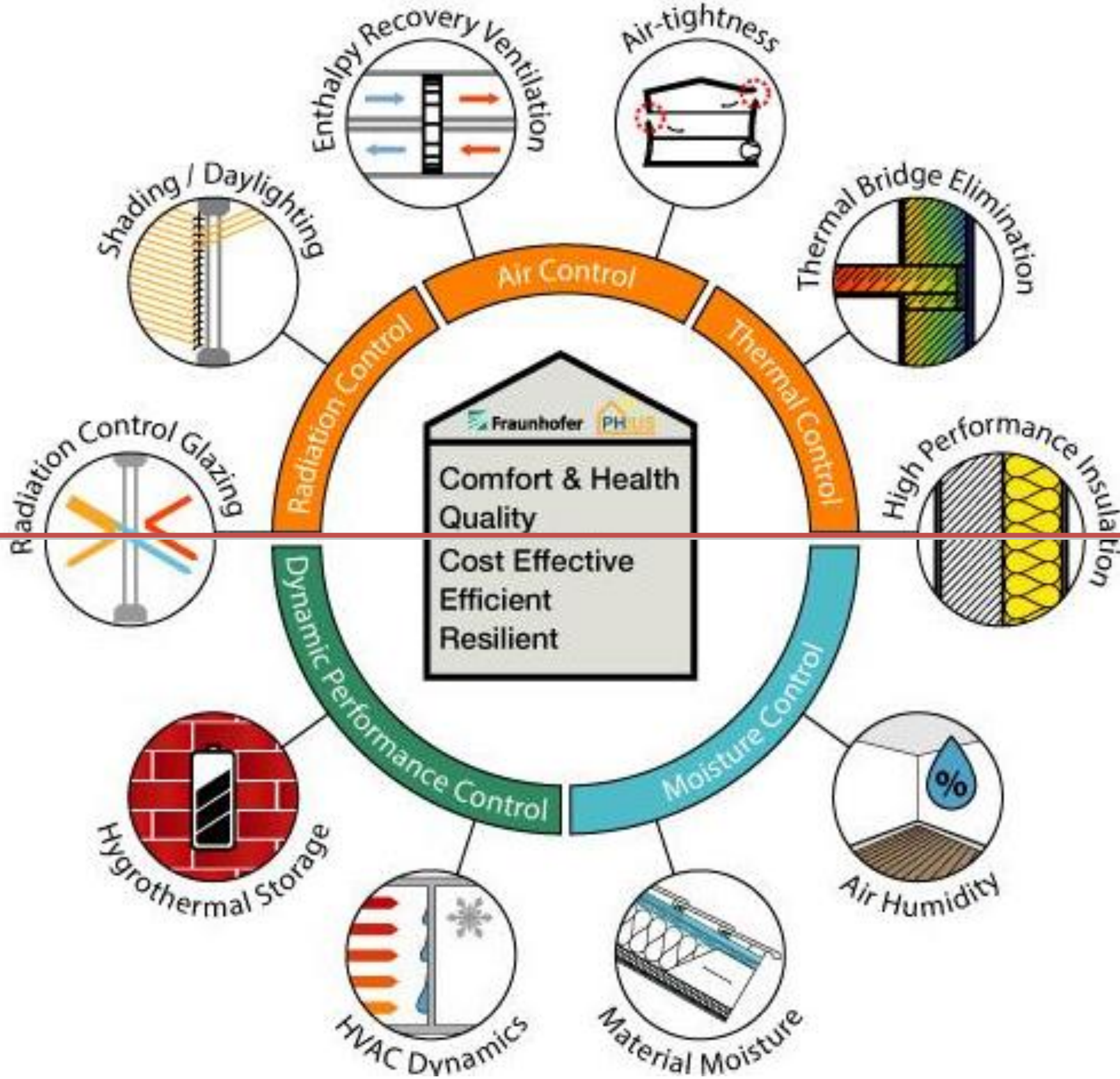
CONTINUOUS INSULATION

AIR-TIGHT CONSTRUCTION

OPTIMIZED WINDOWS & SOLAR GAINS

BALANCED VENTILATION WITH HEAT RECOVERY

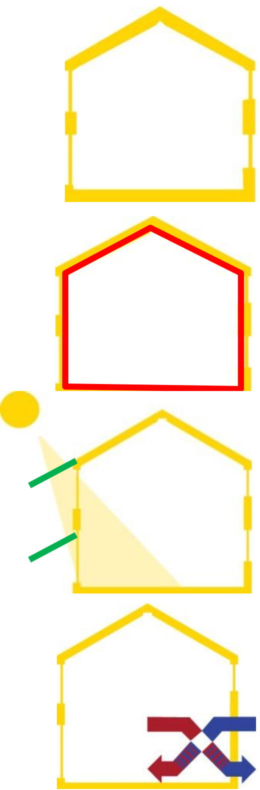
MINIMIZED MECHANICAL SYSTEMS



Enthalpy Recovery Ventilation
Air-tightness
Shading / Daylighting
Thermal Bridge Elimination
Air Control
Radiation Control
Thermal Control
Fraunhofer
Comfort & Health Quality
Cost Effective
Efficient
Resilient
Radiation Control Glazing
High Performance Insulation
Dynamic Performance Control
Moisture Control
Hygrothermal Storage
Air Humidity
HVAC Dynamics
Material Moisture

DRIVERS OF LATENT LOADS

- Internal loads
- Occupants
- Exchange through opaque partitions
- Natural Ventilation
- Mechanical Ventilation
- Infiltration



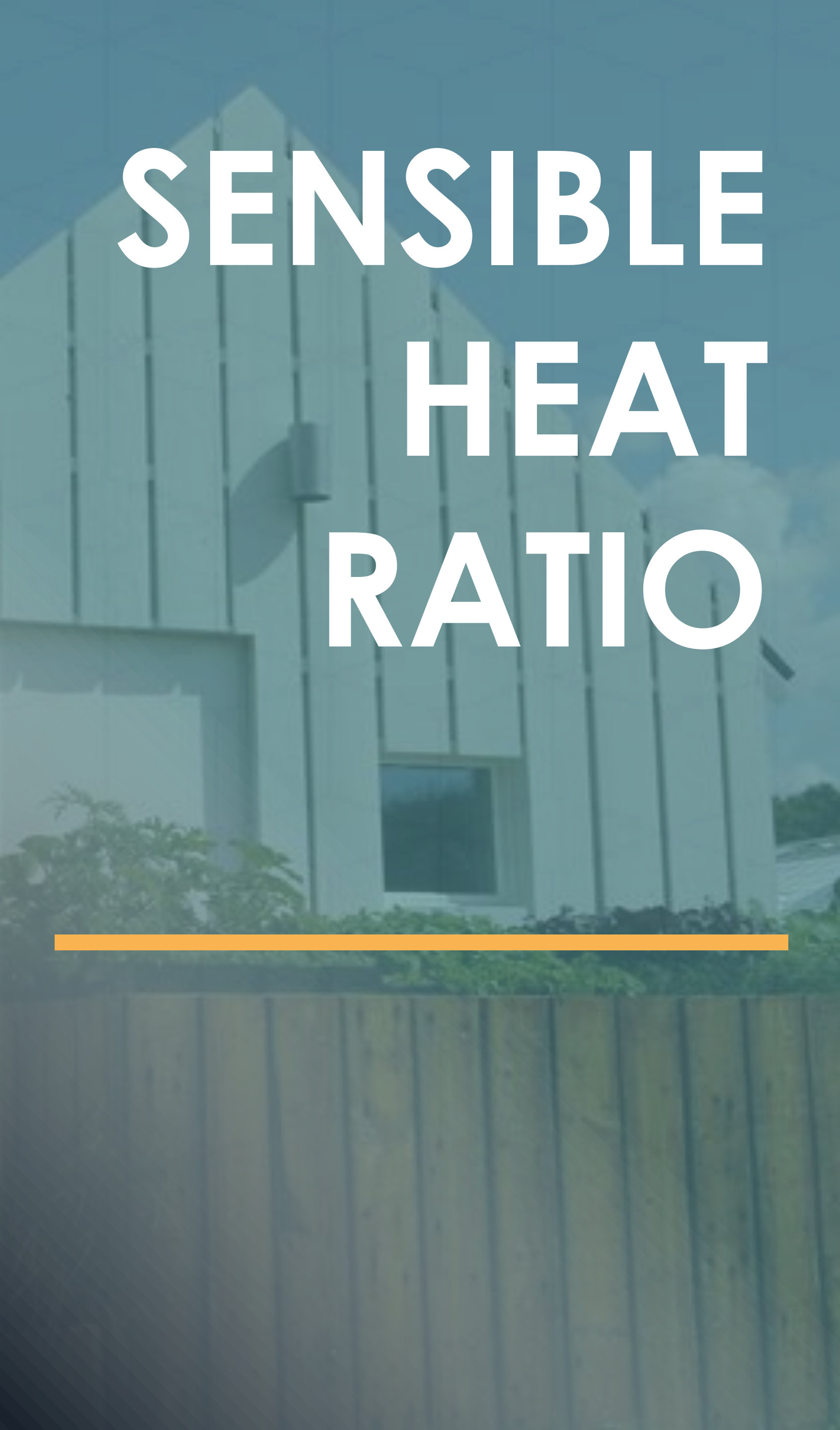
	Heating Load	Sensible Cooling Load	Latent Cooling Load
Continuous Insulation	↓	↓	⊘
Air-Tight Construction	↓	↓	↓
Optimized Windows/Shading	↓	↓	⊘
Balanced Ventilation w/Heat & Moisture Recovery	↓	↓	↓

RESULT OF APPLYING PASSIVE BUILDING PRINCPLES:

SENSIBLE COOLING LOAD ↓

LATENT COOLING LOAD ↑

SENSIBLE HEAT RATIO ↓



SENSIBLE HEAT RATIO

$$= \frac{Sensible\ Cooling\ Load}{Total\ Cooling\ Load}$$

SHR = 1, No latent load

HIGH SHR = Low latent load relative to total load

LOW SHR = High latent load relative to total load

VLI (Ventilation Load Index):

“the load generated by one cubic foot per minute of fresh air brought from the weather to space-neutral conditions over the course of one year”

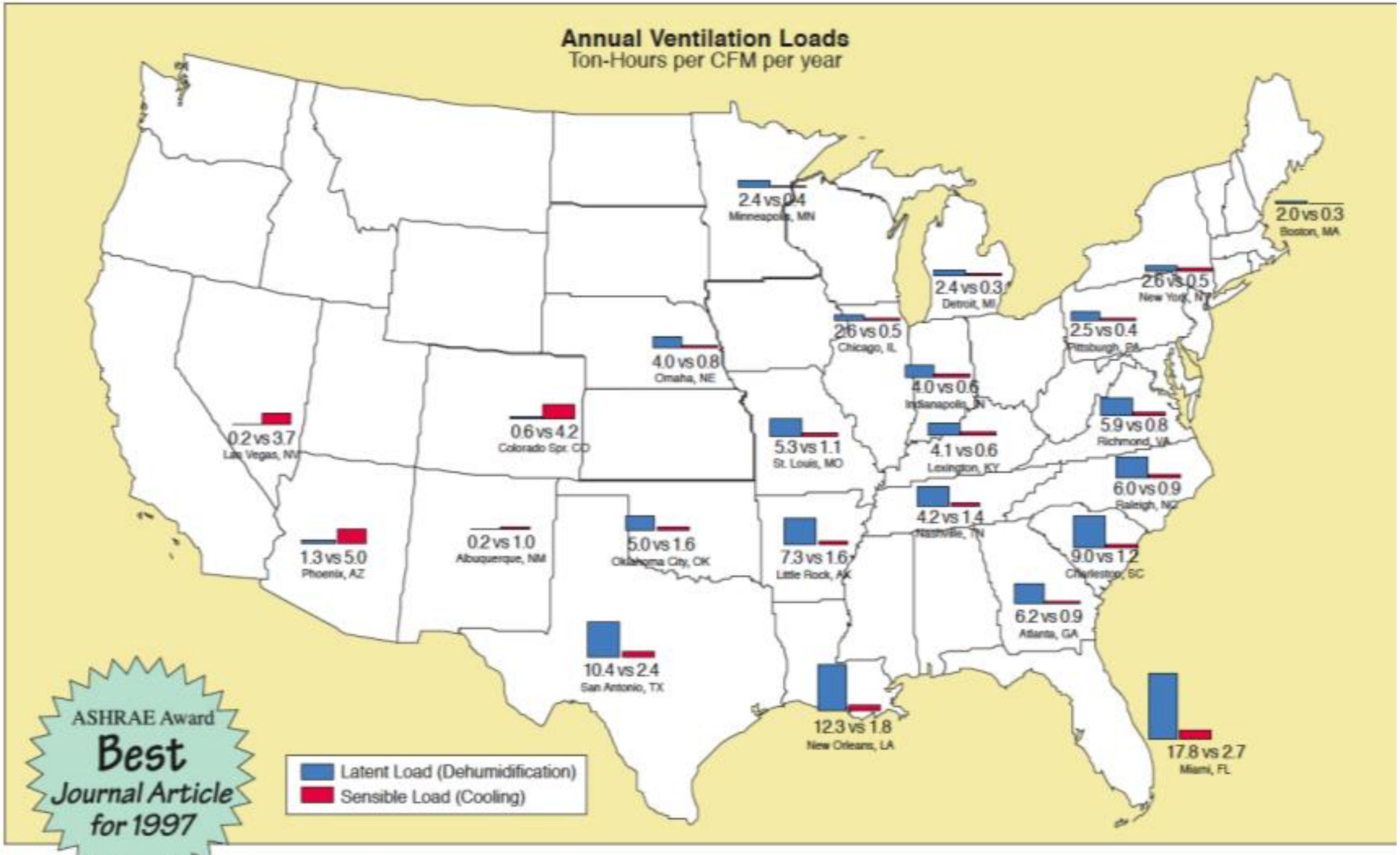


Fig. 1: Map of Ventilation Load Indexes (VLI) for selected continental U.S. locations

VLI (Ventilation Load Index):

City	State	Ventilation Load Index (Ton-hrs/scfm/yr) Latent + Sensible	Cumulative Load Ratio Total	Cumulative Load Ratio Latent:Sensible
Albuquerque	NM	0.2 + 1.0	1.2	0.2:1
Boston	MA	2.0 + 0.3	2.3	6.4:1
Detroit	MI	2.4 + 0.3	2.7	7.4:1
Minneapolis	MN	2.4 + 0.4	2.8	6.2:1
Pittsburgh	PA	2.5 + 0.4	2.9	5.8:1
New York	NY	2.6 + 0.5	3.1	5.1:1
Chicago	IL	2.6 + 0.5	3.1	5.0:1
Las Vegas	NV	0.2 + 3.7	3.9	0.04:1
Indianapolis	IN	4.0 + 0.6	4.6	6.6:1
Lexington	KY	4.1 + 0.6	4.7	7.4:1
Colorado Spr.	CO	0.6 + 4.2	4.8	0.1:1
Omaha	NE	4.0 + 0.8	4.8	5.3:1
Phoenix	AZ	1.3 + 5.0	6.2	0.3:1
St. Louis	MO	5.3 + 1.1	6.4	4.7:1
Oklahoma City	OK	5.0 + 1.6	6.6	3.2:1
Richmond	VA	5.9 + 0.8	6.7	7.2:1
Raleigh	NC	6.0 + 0.9	6.9	6.8:1
Atlanta	GA	6.2 + 0.9	6.9	6.7:1
Nashville	TN	6.2 + 1.4	7.6	4.6:1
Little Rock	AK	7.3 + 1.6	8.8	4.7:1
Charleston	SC	9.0 + 1.2	10.3	7.3:1
San Antonio	TX	10.4 + 2.4	12.8	4.4:1
New Orleans	LA	12.3 + 1.8	14.1	6.8:1
Miami	FL	17.8 + 2.7	20.5	6.7:1

PsyCalc

Hours between
65ºF DB
85ºF DB
>65 gr/lb

Chicago, IL
1760 hours

20% of year!

Description	Units	Minimum	Maximum	Wt Average	Mean
Dry bulb temperature	°F	65.66	84.92	74.22	75.29
Dew point temperature	°F	54.30	78.72	64.23	68.67
Wet bulb temperature	°F	59.23	79.04	67.25	69.13
Humidity ratio	gr/lb	65.32	151.13	92.47	108.22
Relative humidity	%	37.08	100.00	71.71	68.54
Enthalpy	Btu/lb da	26.11	43.39	32.27	34.75
Wind speed	mph	0.00	26.40	9.62	13.20
Wind direction	degrees	0.00	360.00	173.70	180.00
Atmospheric pressure	psia	14.17	14.56	14.37	14.37

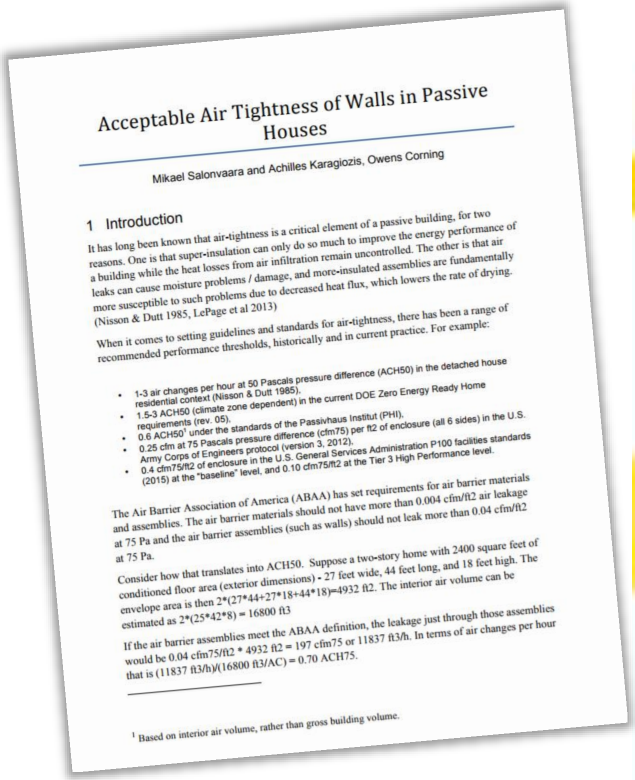
PHIUS+ 2015

Performance based standard with prescriptive requirements
→ Concerned with both energy and comfort

1. *Defines infiltration limit*
2. *Defines ventilation requirements*
3. *WUFI Passive software used for compliance*

AIR-TIGHTNESS

PHIUS+ 2015 Requirement



Acceptable Air Tightness of Walls in Passive Houses

Mikael Salonvaara and Achilles Karagiozis, Owens Corning

1 Introduction

It has long been known that air-tightness is a critical element of a passive building, for two reasons. One is that super-insulation can only do so much to improve the energy performance of a building while the heat losses from air infiltration remain uncontrolled. The other is that air leaks can cause moisture problems / damage, and more-insulated assemblies are fundamentally more susceptible to such problems due to decreased heat flux, which lowers the rate of drying. (Nisson & Dutt 1985, LePage et al 2013)

When it comes to setting guidelines and standards for air-tightness, there has been a range of recommended performance thresholds, historically and in current practice. For example:

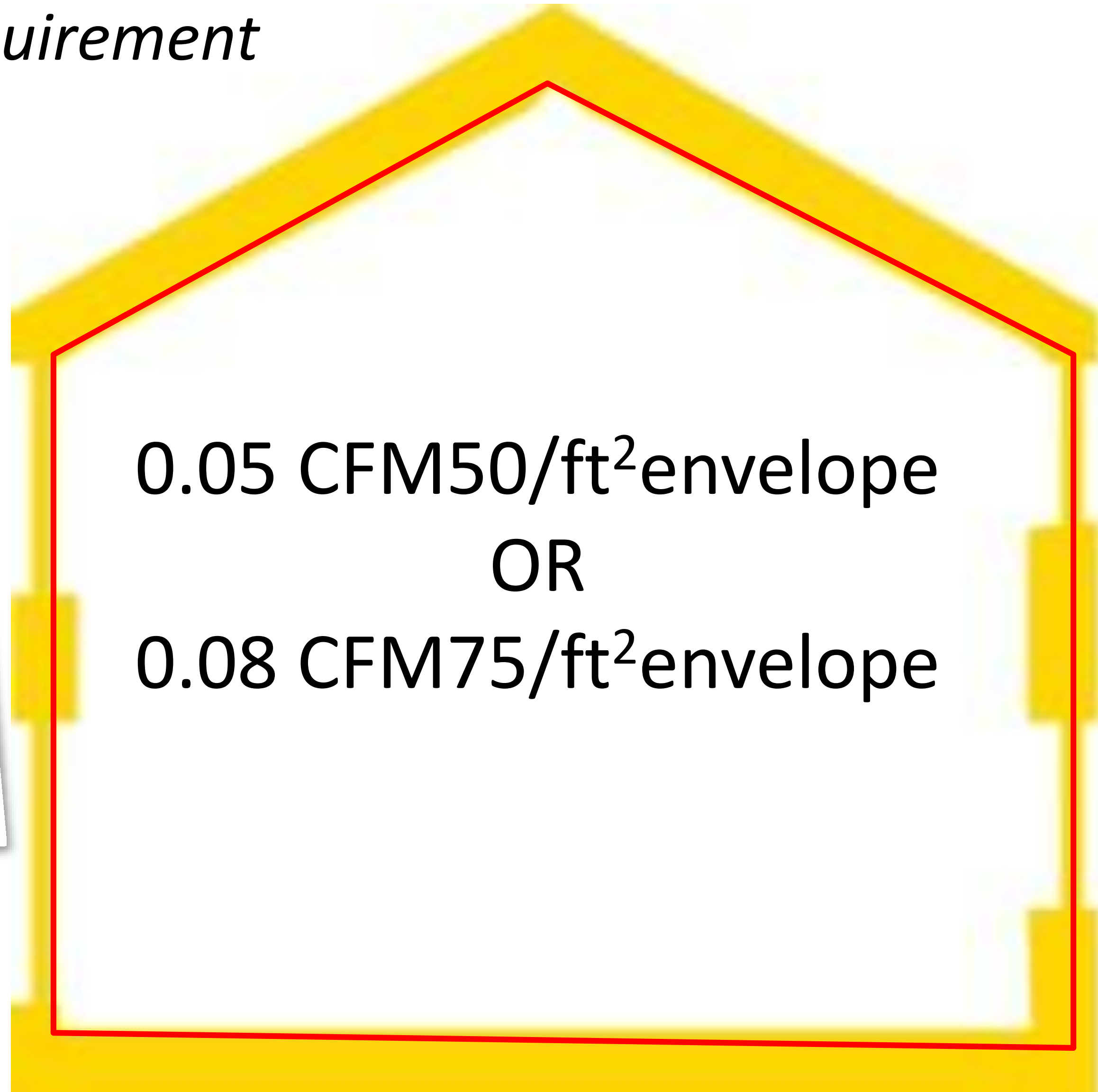
- 1-3 air changes per hour at 50 Pascals pressure difference (ACH50) in the detached house residential context (Nisson & Dutt 1985).
- 1.5-3 ACH50 (climate zone dependent) in the current DOE Zero Energy Ready Home requirements (rev. 05).
- 0.6 ACH50[1] under the standards of the Passivhaus Institut (PHI).
- 0.25 cfm at 75 Pascals pressure difference (cfm75) per ft2 of enclosure (all 6 sides) in the U.S. Army Corps of Engineers protocol (version 3, 2012).
- 0.4 cfm75/ft2 of enclosure in the U.S. General Services Administration P100 facilities standards (2015) at the "baseline" level, and 0.10 cfm75/ft2 at the Tier 3 High Performance level.

The Air Barrier Association of America (ABAA) has set requirements for air barrier materials and assemblies. The air barrier materials should not have more than 0.004 cfm/ft2 air leakage at 75 Pa and the air barrier assemblies (such as walls) should not leak more than 0.04 cfm/ft2 at 75 Pa.

Consider how that translates into ACH50. Suppose a two-story home with 2400 square feet of conditioned floor area (exterior dimensions) - 27 feet wide, 44 feet long, and 18 feet high. The envelope area is then 2*(27*44+27*18+44*18)=4932 ft2. The interior air volume can be estimated as 2*(25*42*8) = 16800 ft3

If the air barrier assemblies meet the ABAA definition, the leakage just through those assemblies would be 0.04 cfm75/ft2 * 4932 ft2 = 197 cfm75 or 11837 ft3/h. In terms of air changes per hour that is (11837 ft3/h)/(16800 ft3/AC) = 0.70 ACH75.

[1] Based on interior air volume, rather than gross building volume.



SUMMARY OF VENTILATION REQUIREMENTS

PHIUS+ Certification GuideBook v1.1

3.5.3 Ventilation

The ventilation system must be capable of at least 0.3 ACH (based on the net volume) on its maximum setting.

PHIUS+ Single Family Quality Assurance Workbook v4.0

1.11: Rater-measured bathroom exhaust rates meets one of the following: >= 20cfm continuous OR 50 cfm intermittent

1.13: Rater-measured kitchen exhaust rates meets one of the following: >=25 cfm continuous, 100 cfm intermittent for range hoods, or 5ACH based on kitchen volume

Balanced Ventilation Required

- Unbalanced has consequences for both energy modeling, building durability and IAQ
- Heat recovery is not required, or more than one fan necessarily, but air flow balance is required
- All air flow must be within 10% supply/exhaust, or below a 5 Pa pressurization / depressurization due to the whole-building ventilation.

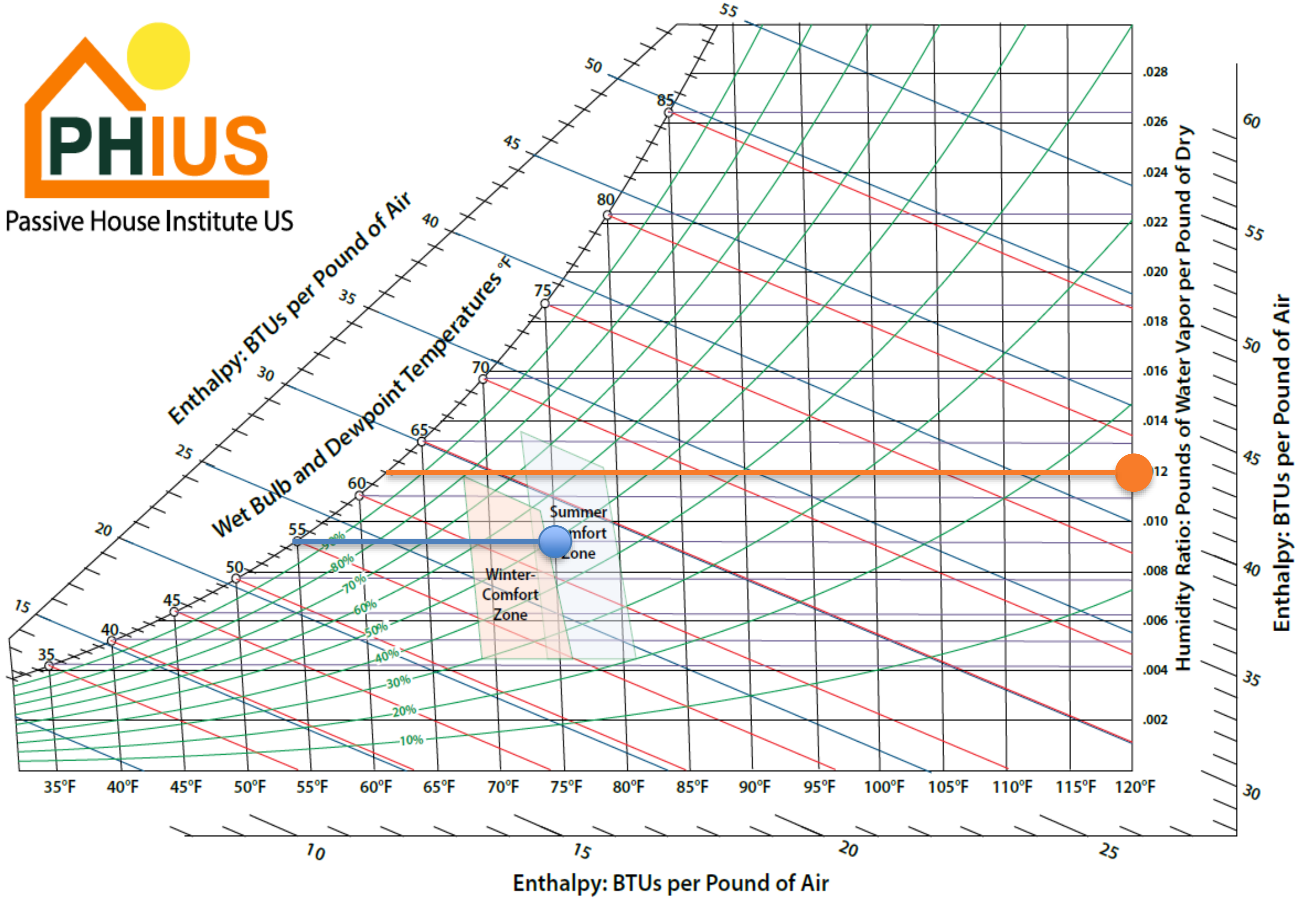
WUFI PASSIVE

ANNUAL LATENT COOLING DEMAND (kBTU/ft^2.yr)

Influenced by:

- *Natural ventilation (windows), day & night*
- *Mechanical ventilation*
  - *Includes latent recovery*
  - *Includes bypass/economizer mode*
- *Infiltration*
- *Maximum dehumidification ratio -- default = 0.012 lb/lb (can input different value)*
- *Internal sources – default value of 0.00041 lb/ft2.hr (can input different value)*

PHIUS
Passive House Institute US



PHIUS SET-POINT FOR MAX DEHUMIDIFICATION RATIO IS 0.012 lb/lb
(77F, 60% RH, 62F DP)

ASHRAE HANDBOOK HVAC APPLICATIONS – CHAPTER 62
(75F, 50% RH, 55F DP)

WUFI PASSIVE RESULTS WITH **0.012 lb/lb** MAX DEHUMIDIFICATION RATIO

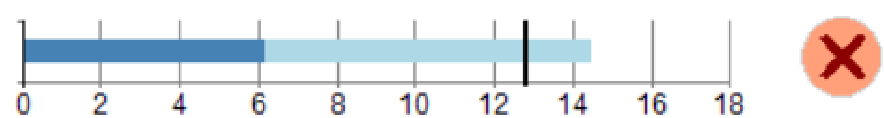
Cooling demand

sensible:	**6.19**	kBtu/ft²yr
latent:	**4.3**	kBtu/ft²yr
specific:	**10.49**	kBtu/ft²yr
target:	**12.8**	kBtu/ft²yr
total:	31,923.96	kBtu/yr

WUFI PASSIVE RESULTS WITH **0.009 lb/lb** MAX DEHUMIDIFICATION RATIO

Cooling demand

sensible:	**6.19**	kBtu/ft²yr
latent:	**8.27**	kBtu/ft²yr
specific:	**14.46**	kBtu/ft²yr
target:	**12.8**	kBtu/ft²yr
total:	43,999.2	kBtu/yr



Latent cooling demand estimated almost 2x higher with new set-point!!

WUFI PASSIVE

MANUAL J - LATENT COOLING LOAD (kBTU/hr)

General | Additional data | Foundation interface | Manual J

☑ Manual J-residential cooling load calculation

Climate / ventilation

Outdoor design temperature [°F]	95
Indoor design temperature (optional) [°F]	77
Outdoor - Indoor moisture difference [%]	50
Air changes per hour [1/hr]	0.05
Altitude correction factor [-]	1

Loads

Nr.	Internal load	Quantity
1	Small Plant	6
2	Coffee maker - warmer	6
3	Dishwasher	6
4	Microwave	6

New | Delete | after

Components

Nr.	Name	Cooling load temperature difference [-]	Heat transfer multiplier [-]	Shade line miultiplier [-]	Orientation	Area [ft²]	U-value [Btu/hr ft² °F]
1	Z.1, C. 1	10			S (34 %), E (18 %), W (15 %), N	6163.6	0.0282
2	Z.1, C. 2	5			Horizontal (100 %)	3116	0.019
3	Z.1, C. 3	5			Horizontal (100 %)	3116	0.0481
4	Z.1, C. 4: (SOUTH, Floor 2, Fixed)		1	0.6	S (100 %)	65.5	0.1572
5	Z.1, C. 5: (SOUTH, Floor 1, Fixed)		1	0.6	S (100 %)	65.5	0.1572
6	Z.1, C. 6: (SOUTH, Floor 1, Casement)		1	0.6	S (100 %)	81.5	0.1651

Results

Name	Sensible Cooling [Btu/hr]	Latent cooling load [Btu/hr]
Opaque components	2781.3	0
Fenestration	3363.5	0
Ventilation	6472.7	11114.8
Internal loads	18004.1	9210
Infiltration	1051.2	1805.2
Total	31672.9	22130

Interim results

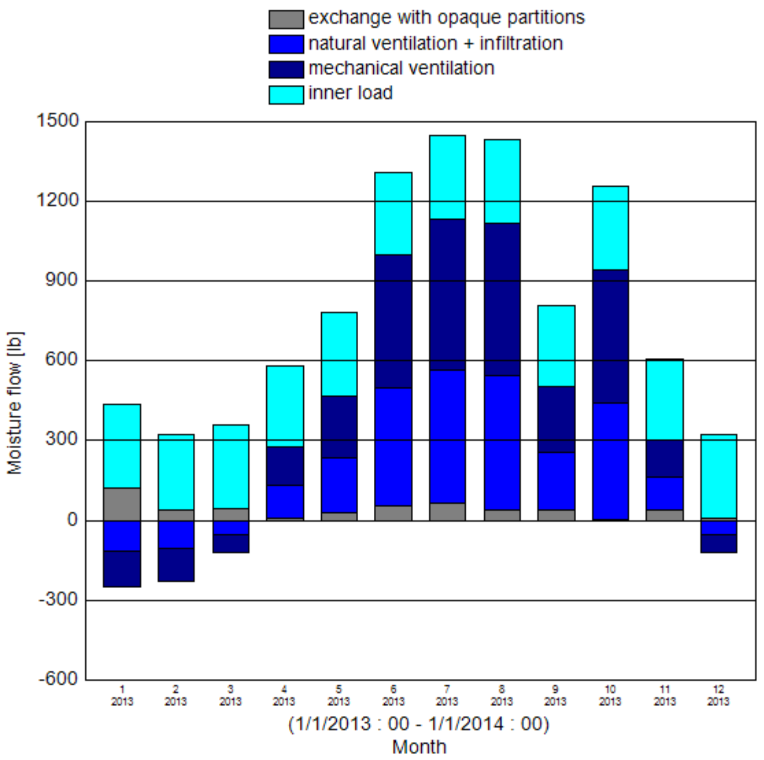
Cooling temperature difference [°F]	50
Average air change rate [1/hr]	1.5
Altitude building [ft]	610

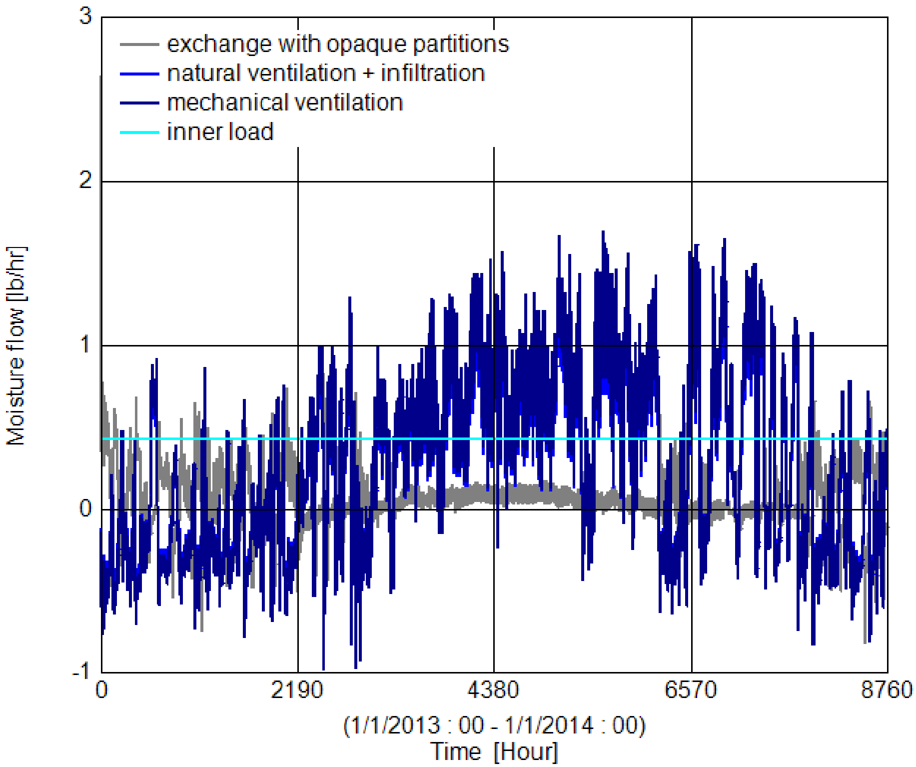
Status: OK

WUFI PASSIVE – Dynamic (WUFIplus)

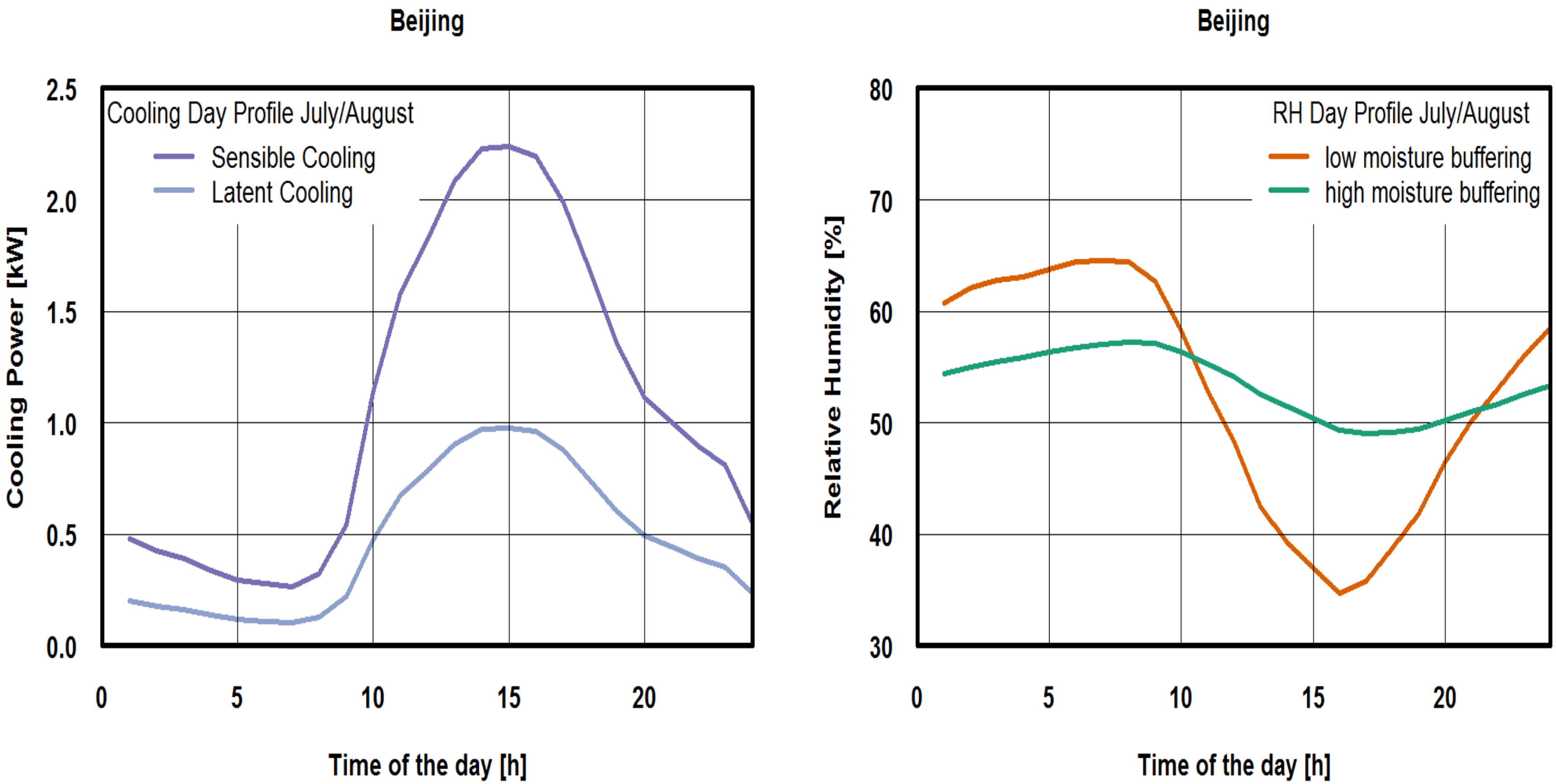
Abbate Case Study – Austin, TX

Moisture Flows





Moisture Buffering Effect on Daily RH Fluctuations



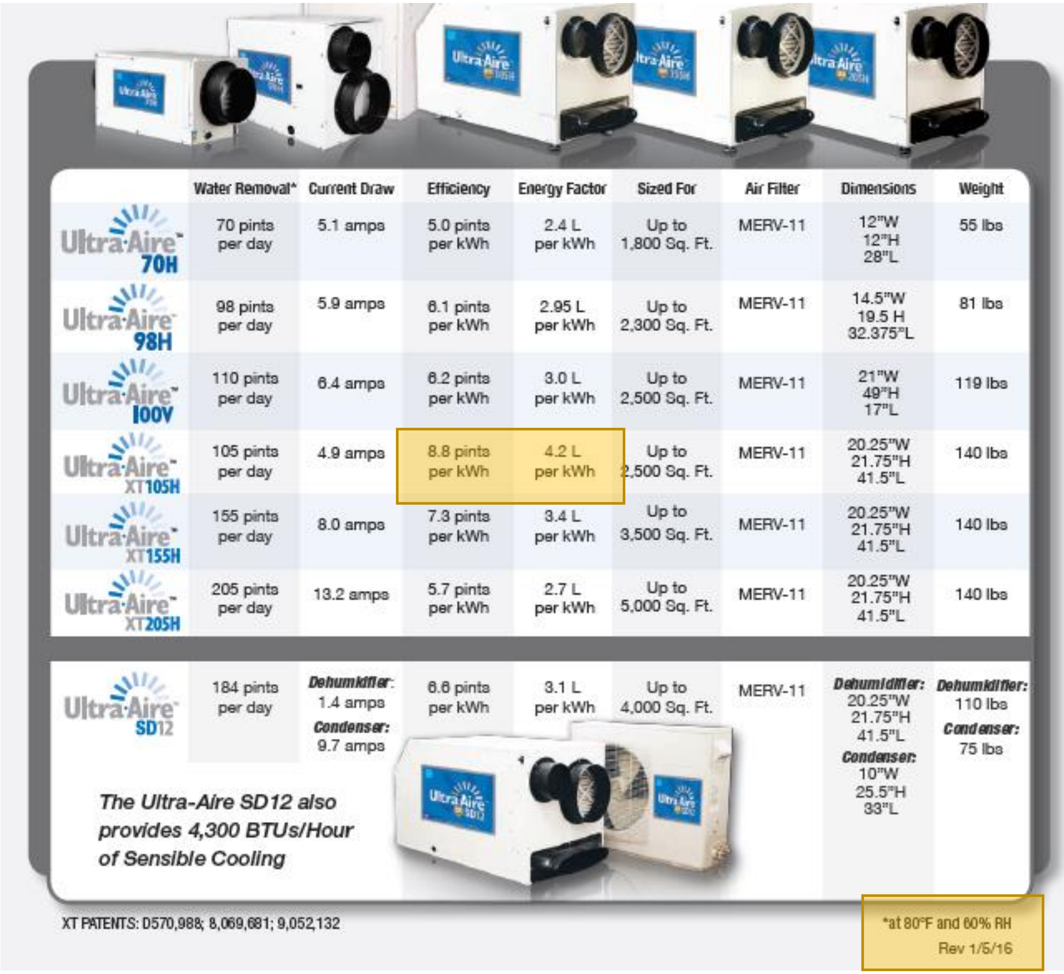
Moisture buffering capacity of the envelope dampens daily indoor RH cycles

Fraunhofer IBP

CHALLENGES WITH COMPLIANCE WITH PHIUS+ 2015 *IN HOT/HUMID CLIMATES*

1) *Dehumidify to lower RH = increased source energy use*

2) *Ventilating dehumidifier = difficult meeting heating demand & heating load targets for PHIUS+ 2015 without balanced ventilation with heat recovery*



	Water Removal*	Current Draw	Efficiency	Energy Factor	Sized For	Air Filter	Dimensions	Weight
Ultra-Aire 70H	70 pints per day	5.1 amps	5.0 pints per kWh	2.4 L per kWh	Up to 1,800 Sq. Ft.	MERV-11	12"W 12"H 28"L	55 lbs
Ultra-Aire 98H	98 pints per day	5.9 amps	6.1 pints per kWh	2.95 L per kWh	Up to 2,300 Sq. Ft.	MERV-11	14.5"W 19.5 H 32.375"L	81 lbs
Ultra-Aire 100V	110 pints per day	6.4 amps	6.2 pints per kWh	3.0 L per kWh	Up to 2,500 Sq. Ft.	MERV-11	21"W 49"H 17"L	119 lbs
Ultra-Aire XT105H	105 pints per day	4.9 amps	8.8 pints per kWh	4.2 L per kWh	Up to 2,500 Sq. Ft.	MERV-11	20.25"W 21.75"H 41.5"L	140 lbs
Ultra-Aire XT155H	155 pints per day	8.0 amps	7.3 pints per kWh	3.4 L per kWh	Up to 3,500 Sq. Ft.	MERV-11	20.25"W 21.75"H 41.5"L	140 lbs
Ultra-Aire XT205H	205 pints per day	13.2 amps	5.7 pints per kWh	2.7 L per kWh	Up to 5,000 Sq. Ft.	MERV-11	20.25"W 21.75"H 41.5"L	140 lbs
Ultra-Aire SD12	184 pints per day	*Dehumidifier:* 1.4 amps *Condenser:* 9.7 amps	6.6 pints per kWh	3.1 L per kWh	Up to 4,000 Sq. Ft.	MERV-11	*Dehumidifier:* 20.25"W 21.75"H 41.5"L *Condenser:* 10"W 25.5"H 33"L	*Dehumidifier:* 110 lbs *Condenser:* 75 lbs

The Ultra-Aire SD12 also provides 4,300 BTUs/Hour of Sensible Cooling

XT PATENTS: D570,988; 8,069,681; 9,052,132

*at 80°F and 60% RH
Rev 1/5/16

Best Unit:
4.2 L/kWh (8.8 pints/kWh) = COP 2.6!

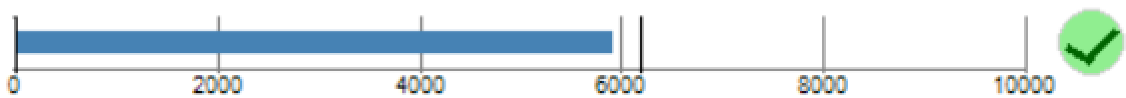
Most other high performance units with COP ~1.5-2

For heating equip: equivalent to HSPF ~8

For sensible cooling: equivalent SEER ~12

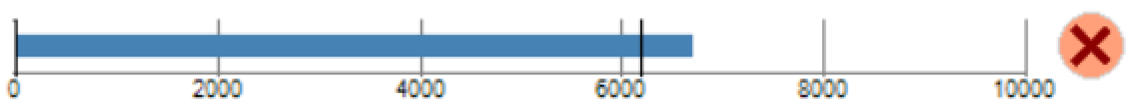
WUFI PASSIVE RESULTS WITH **0.012 lb/lb** MAX DEHUMIDIFICATION RATIO

Source energy: 5,931 kWh/Person yr



WUFI PASSIVE RESULTS WITH **0.009 lb/lb** MAX DEHUMIDIFICATION RATIO

Source energy: 6,723 kWh/Person yr



CHALLENGES OF AVAILABLE EQUIPMENT

1. AIR CONDITIONING UNITS NOT DESIGNED FOR LOW SENSIBLE HEAT RATIO

2. MOST COOLING SYSTEMS ONLY CONTROLLED BY DRY BULB

3. LIMITED EFFICIENCY OF MOISTURE REMOVAL /DEHUMIDIFICATION

4. LIMITED ERV LATENT RECOVERY EFFICIENCY

COMMON MISCONCEPTIONS

1. "ERV IS A DEHUMIDIFIER"

2. "VRF IS THE MAGIC BULLET FOR ALL SYSTEMS DESIGN"

3. "FULL DEHUMIDIFICATION LOAD CAN BE SATISFIED BY SLOWING DOWN SUPPLY AIRFLOW RATE"

WHAT WE NEED

1). An affordable, efficient, reliable, simple mechanical system solution that handles latent loads (ideally before introduced to the space).

2). Awareness and capability of AC systems to control latent loads

3). Re-think ventilation strategies and requirements?

4). WUFI Passive integrated calculation for latent cooling load and output of SHR

5). Deeper understanding of potential of hygric buffering

WHAT ARE THE SOLUTIONS??