Designing Residential Ventilation for Indoor Air Quality and Thermal Comfort

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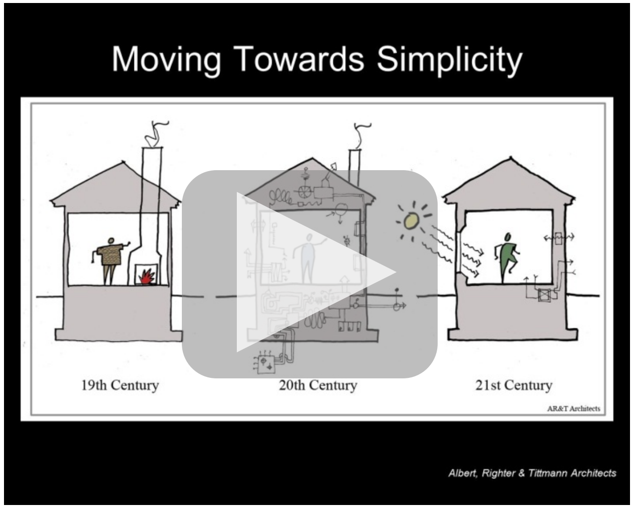

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Course Description

Well-designed housing uses ventilation to maintain a healthy indoor environment and to provide thermal comfort with a low carbon footprint. However, the methods for achieving these goals—be they natural/passive or mechanical/active—impose significantly different design requirements on the form, fenestrations, and internal zoning of the residence.

Course Description

With that in mind, presenters, Thomas A. Gentry, AIA, LEED AP, CDT and Robert W. Cox, Ph.D. define the basic methods for providing effective ventilation and explore their implications in the overall design process. They also describe design aids ranging from computational fluid dynamics (CFD) software to rules-of-thumb, and briefly review ANSI/ASHRAE 62.2-2010 - Ventilation and Acceptable Indoor Air Quality in Low-Rise Residential Buildings. Lastly, they describe the work being done at the University of North Carolina Charlotte to couple whole-house fan-forced ventilation with real time power monitoring to reduce air conditioning loads. They will describe how this method could be well suited for existing and new housing throughout much of the United States.

This presentation draws from ongoing research at the University of North Carolina Charlotte that is funded in part by a U.S. Department of Energy Weatherization Innovation Pilot Program (WIPP) grant.

Learning Objectives

1. Explain key terminologies used in the design of residential ventilation.
2. Identify the appropriate ventilation methods for specific ventilation needs, be it for indoor air quality or thermal comfort.
3. Explain key resources for determining the spatial requirements of ventilation systems, both natural/passive and mechanical/active.
4. Discuss how ventilation can make a design more socially and environmentally sustainable.

Robert Cox, PhD
Associate Professor
Department of Electrical and Computer Engineering
University of North Carolina Charlotte
Speaker

Thomas Gentry, AIA
Assistant Professor
School of Architecture
University of North Carolina Charlotte
Speaker

Stephen Schreiber, FAIA
University of Massachusetts Amherst
Moderator

Submit a question to the moderator via the Chat box. They will be answered as time allows.

As part of the

ACSA / AIA Housing Research Webinar Series

Designing Residential Ventilation for Indoor Air Quality and Thermal Comfort

Produced by the

Laboratory for Innovative Housing

University of North Carolina Charlotte

Presented by

Robert Cox, PhD | Electrical & Computer Engineering

Thomas Gentry, AIA | Architecture

UNC CHARLOTTE

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The learning objectives are …

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- Develop a working vocabulary;

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- Develop a working vocabulary;
- Develop the ability to identify appropriate ventilation methods;

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- Develop an understanding of key resources for determining the spatial requirements of ventilation systems; and

The learning objectives are …

- Develop a working vocabulary;
- Develop the ability to identify appropriate ventilation methods;
- Develop an understanding of key resources for determining the spatial requirements of ventilation systems; and
- Develop an understanding of how ventilation can make a design more socially and environmentally sustainable.

The four types of air are …

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- **Supply air,** which is the air entering the room to maintain indoor air quality and/or provide thermal comfort;

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- **Return air,** which is the air leaving the room and returning to the ventilation equipment;

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- **Exhaust air,** which is the portion of the return air that is exhausted outside the building; and

The four types of air are …

- **Supply air,** which is the air entering the room to maintain indoor air quality and/or provide thermal comfort;
- **Return air,** which is the air leaving the room and returning to the ventilation equipment;
- **Exhaust air,** which is the portion of the return air that is exhausted outside the building; and
- **Make-up air,** which is the fresh outside air that is brought into the building to replace the exhaust air.

What is ventilation?

What is ventilation?

"Ventilation: the process of supplying outdoor air to or removing indoor air from a dwelling by natural or mechanical means. Such air may or may not have been conditioned."

[ASHRAE 62.2, 4]

What is ventilation?

“Ventilation: the process of supplying outdoor air to or removing indoor air from a dwelling by natural or mechanical means. Such air may or may not have been conditioned.”

[ASHRAE 62.2, 4]

“Ventilation includes the intentional introduction of air from the outside into a building; it is further subdivided into natural ventilation and forced ventilation.”

[ASHRAE Fundamentals, 26.1]

Natural ventilation …

"… is the flow of air through open windows, doors, grilles, and other planned building envelope penetrations, and it is driven by natural and/or artificially produced pressure differentials."

[ASHRAE Fundamentals, 26.1]

Natural ventilation ...

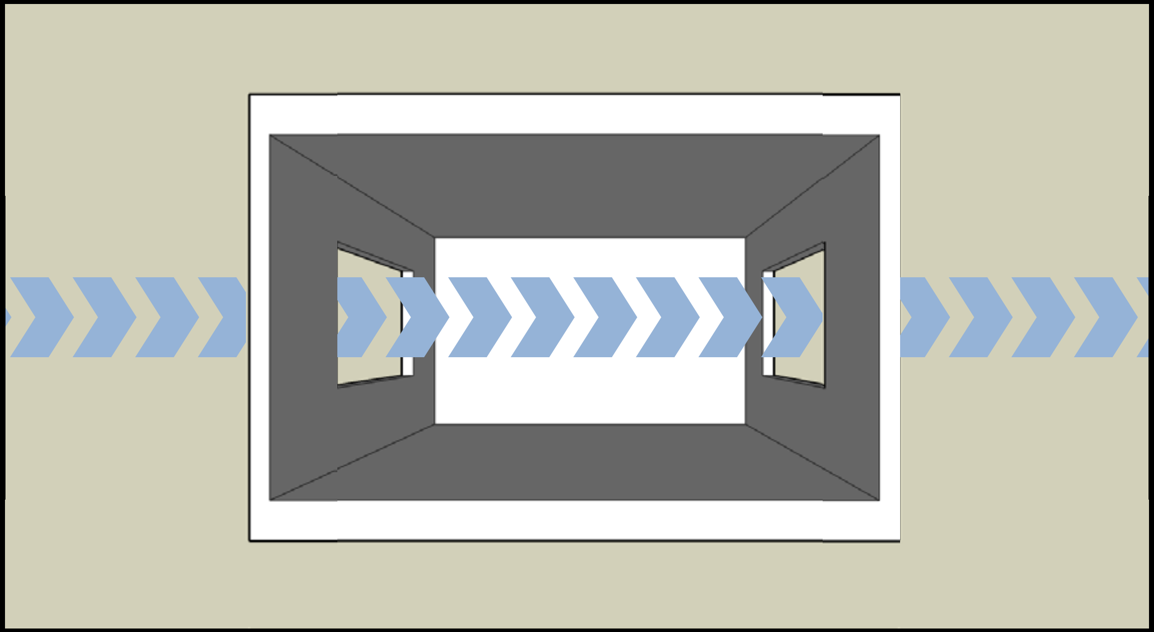
"... is the flow of air through open windows, doors, grilles, and other planned building envelope penetrations, and it is driven by natural and/or artificially produced pressure differentials."

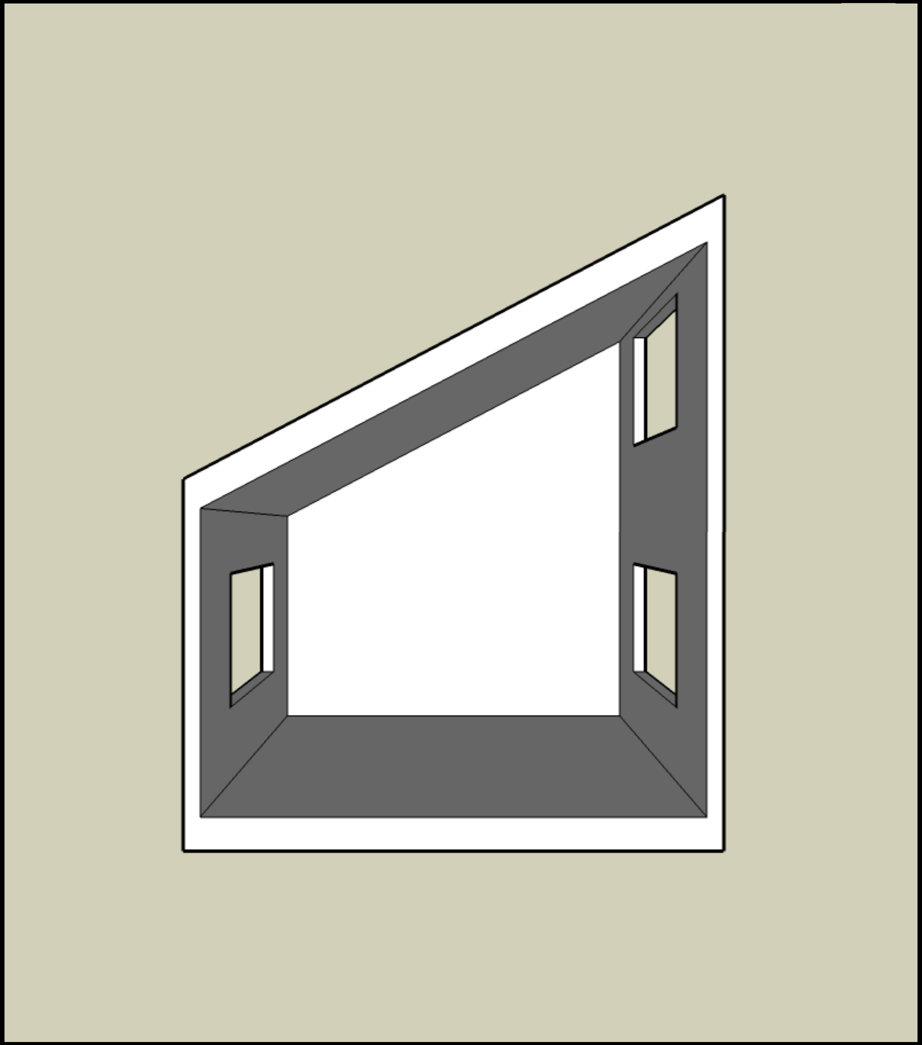
[ASHRAE Fundamentals, 26.1]

Natural ventilation is also called passive ventilation because it does not use external energy to drive fans and blowers.

Natural ventilation ...

... is further subdivided into, wind induced ventilation, which relies on the pressure differential created by wind to move air into and out of the building; and,





... stack effect ventilation, which relies on an indoor air temperature differential and buoyancy to exhaust air out of the building creating negative pressure that draws fresh make-up air into the building.

Natural ventilation ...

... methods are architecturally form giving, when they are the primary means of ventilation. In other words, the house is the ventilation system.

Marika-Alderton House
Northern Territory, Australia
1991-1994
Glenn Murcutt, Architect
[World Architecture Community]

Forced ventilation …

"… is the intentional movement of air into and out of a building using fans and intakes and exhaust vents; it is also called mechanical ventilation [and active ventilation]."

[ASHRAE Fundamentals, 26.1]

Forced ventilation …

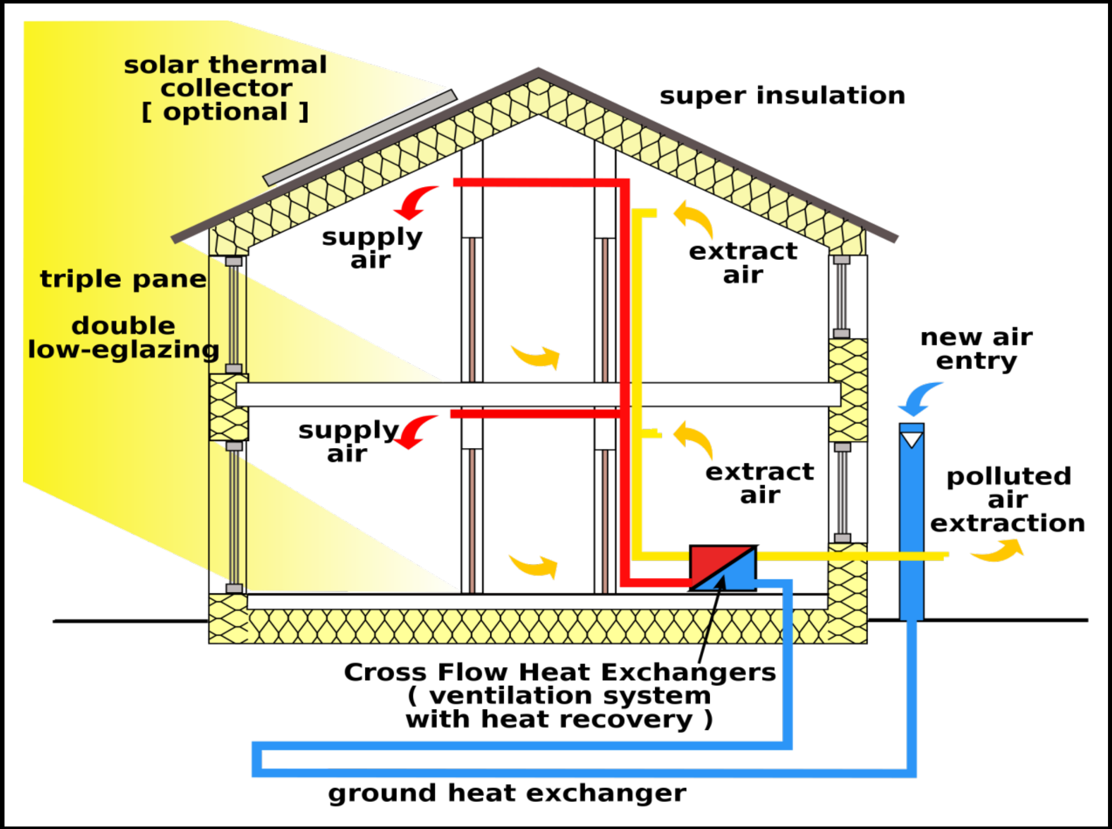
… relies on mechanical equipment and not the architectural form of the house.

Passivhaus standards call for an air-tight, hyper-insulated building envelope coupled with forced ventilation to produce energy-efficient housing.

Passivhaus-Büro
Langenhart, Germany
[www.flickr.com, trainbird]

Forced ventilation ...

... relies on mechanical equipment and not the architectural form of the house.



Passivhaus standards call for an air-tight, hyper-insulated building envelope coupled with forced ventilation to produce energy-efficient housing.

[Passive, commons.wikimedia.org]

Ventilation is not …

Ventilation is not …

…infiltration.

"Infiltration is the flow of outdoor air into a building through cracks and other unintentional openings and through the normal use of exterior doors for entrance and egress."

[ASHRAE Fundamentals, 26.1]

Ventilation is done to …

… maintain indoor air quality

and/or

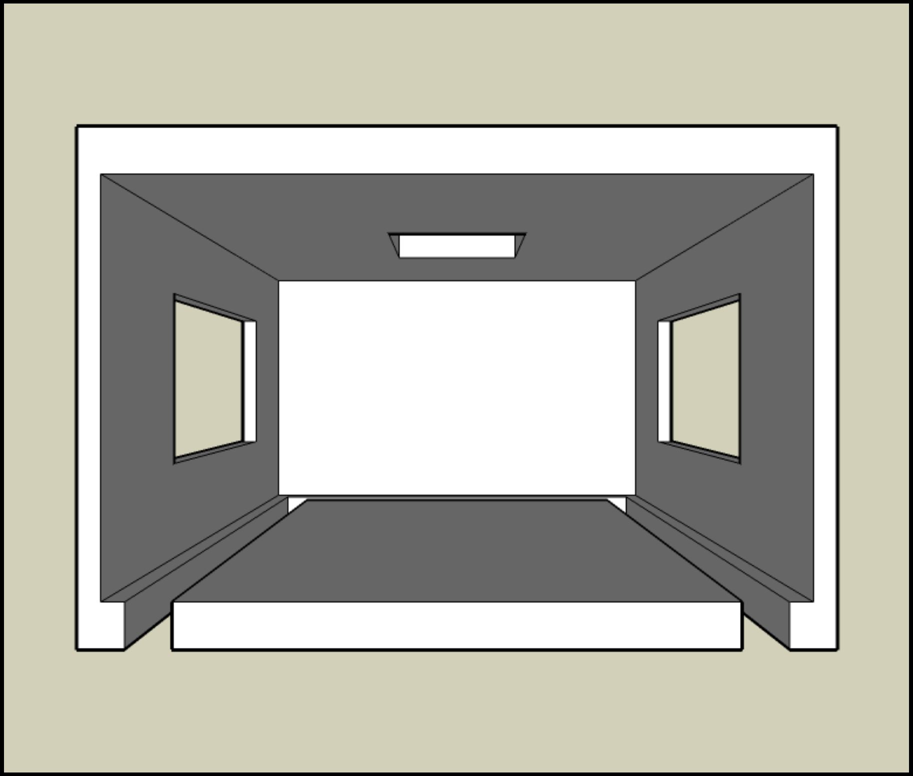
provide thermal comfort.

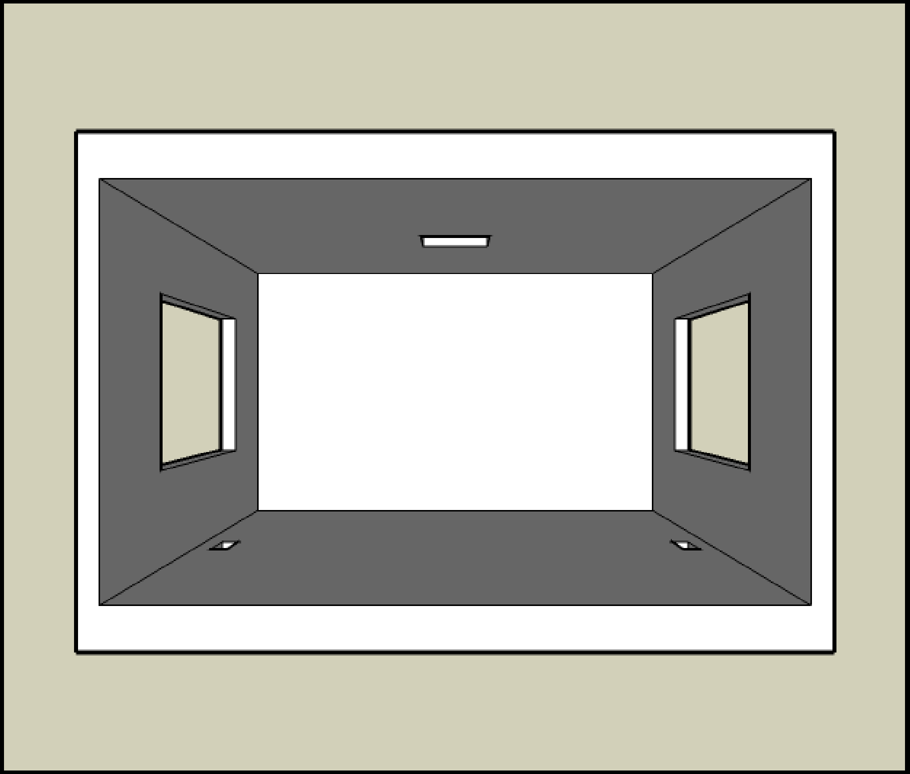
… maintain indoor air quality

We will first discuss the simpler
of the two to implement.

Indoor Air Quality

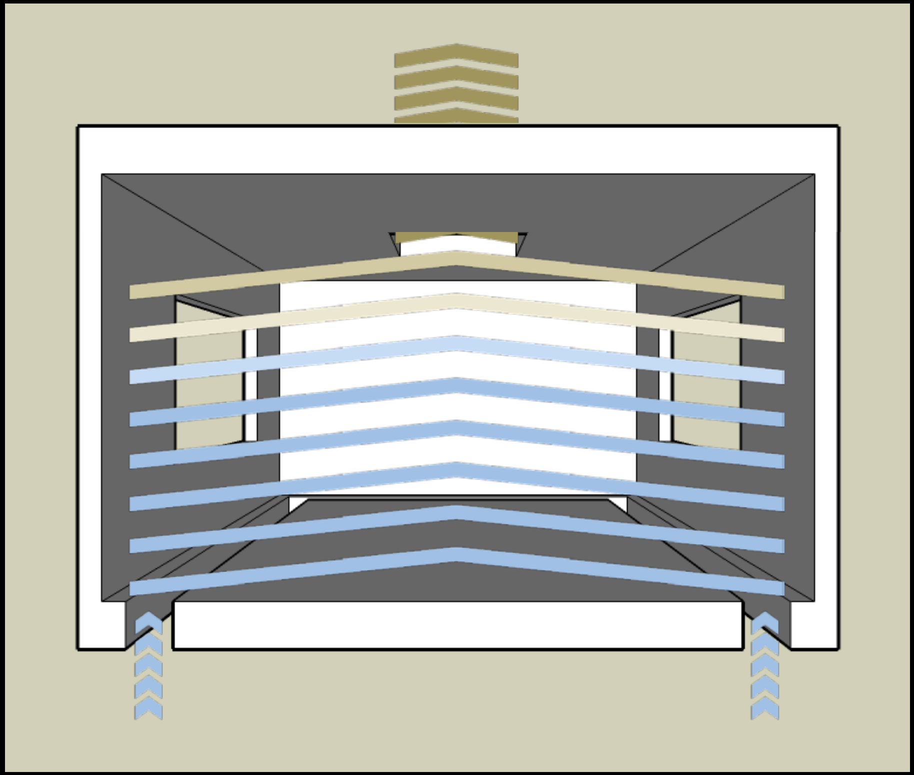
Maintaining good indoor air quality with forced ventilation is accomplished by two different methods, displacement or dilution.





Indoor Air Quality

The displacement method brings make-up air into the room at a low velocity to push the exhaust air out.



The objective is to minimize the mixing of the two air types.

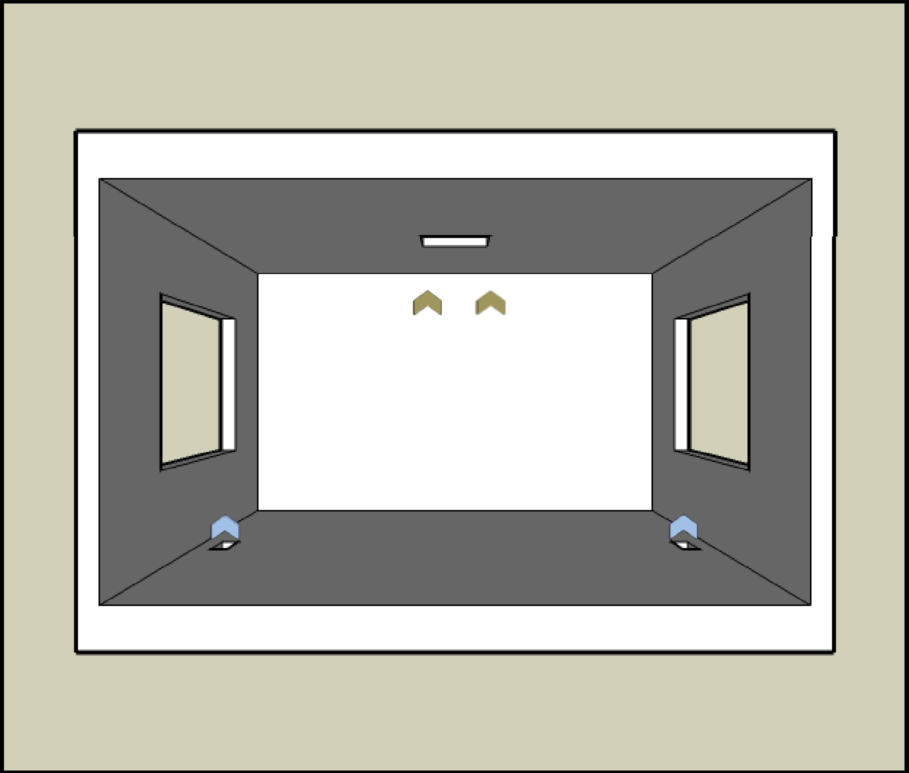
This method requires significantly more supply and return register area than the dilution method.

Indoor Air Quality

The dilution method brings make-up air into the room at a high velocity to mix with the room air, thereby diluting the concentration of contaminants.

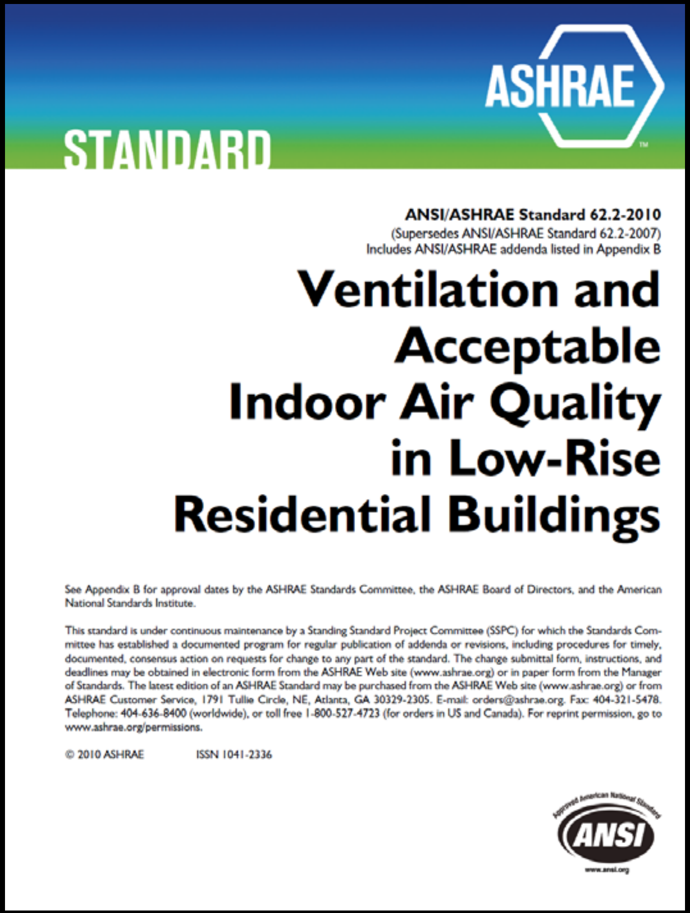
This method requires significantly less supply and return register area than the displacement method.

This is the more commonly used method for housing.



Indoor Air Quality

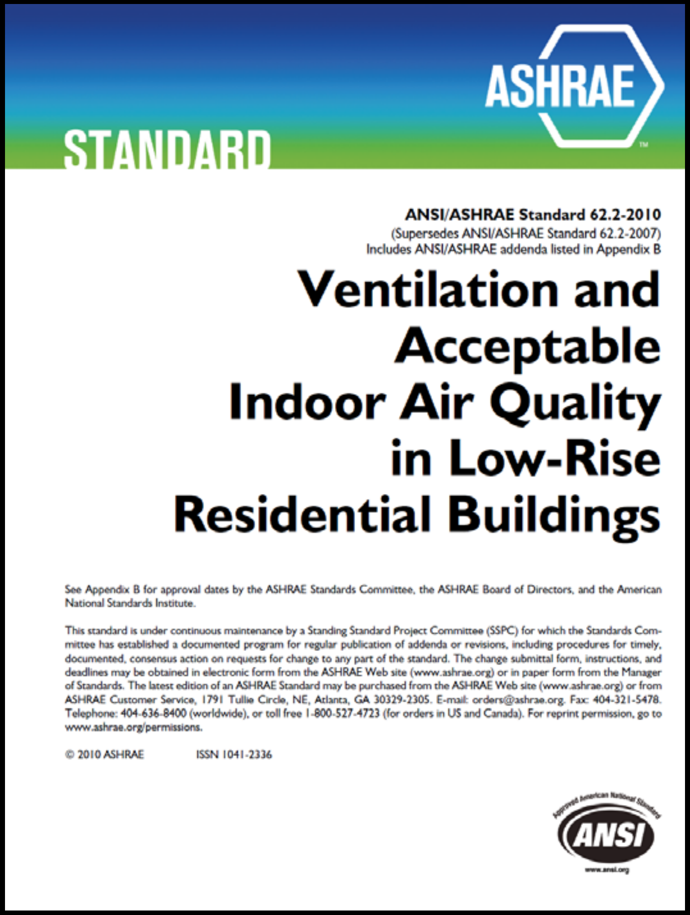
Regardless of which method is used – displacement or dilution – the objective is to maintain a ventilation rate that meets or exceeds a prescribed ventilation rate.



Ventilation Rate

Regardless of which method is used – displacement or dilution – the objective is to maintain a ventilation rate that meets or exceeds a prescribed ventilation rate.

ANSI/ASHRAE Standard 62.2-2010 prescribes the ventilation rates for low-rise residential buildings.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ASHRAE

ANSI/ASHRAE Standard 62.2-2010
(Supersedes ANSI/ASHRAE Standard 62.2-2007)
Includes ANSI/ASHRAE addenda listed in Appendix B

Ventilation and Acceptable Indoor Air Quality in Low-Rise Residential Buildings

See Appendix B for approval dates by the ASHRAE Standards Committee, the ASHRAE Board of Directors, and the American National Standards Institute.

This standard is under continuous maintenance by a Standing Standard Project Committee (SSPC) for which the Standards Committee has established a documented program for regular publication of addenda or revisions, including procedures for timely, documented, consensus action on requests for change to any part of the standard. The change submittal form, instructions, and deadlines may be obtained in electronic form from the ASHRAE Web site (www.ashrae.org) or in paper form from the Manager of Standards. The latest edition of an ASHRAE Standard may be purchased from the ASHRAE Web site (www.ashrae.org) or from ASHRAE Customer Service, 1791 Tullie Circle, NE, Atlanta, GA 30329-2305. E-mail: orders@ashrae.org. Fax: 404-321-5478. Telephone: 404-636-8400 (worldwide), or toll free 1-800-527-4723 (for orders in US and Canada). For reprint permission, go to www.ashrae.org/permissions.

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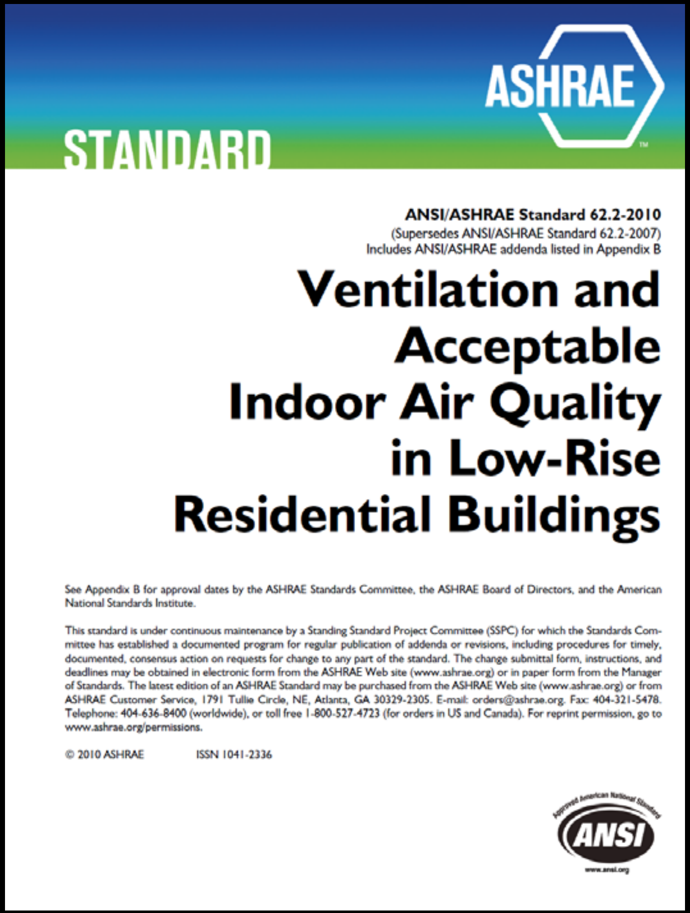
Ventilation Rate

The required whole house ventilation rate is calculated by the following equation.

$$Q_{fan} = 0.01 A_{floor} + 7.5\left(N_{br} + 1\right)$$

Q_{fan} = fan flow rate, cfm
A_{floor} = floor area, ft^2
N_{br} = number of bedrooms; not to be less than one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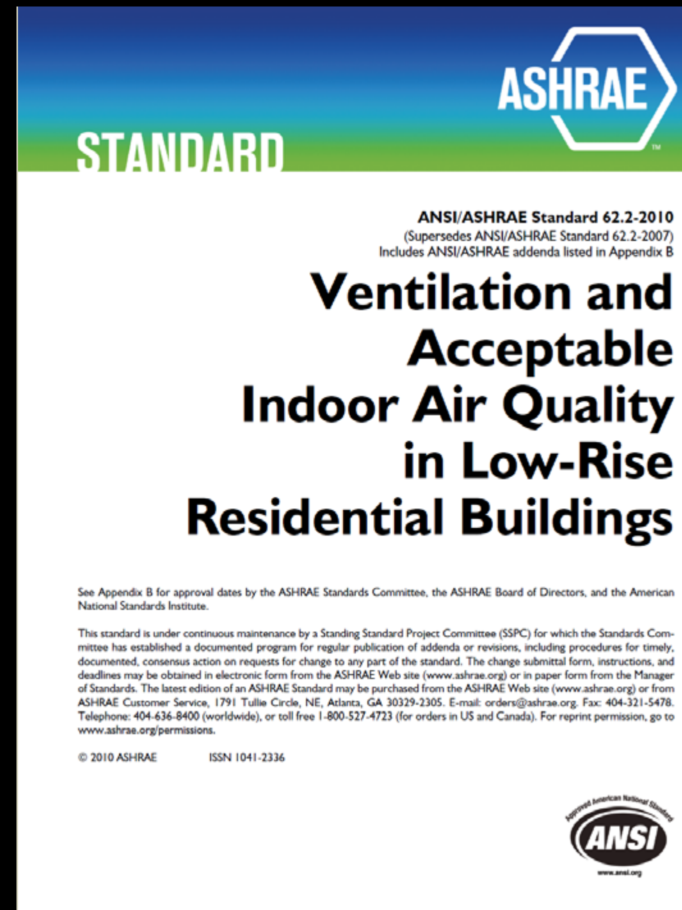
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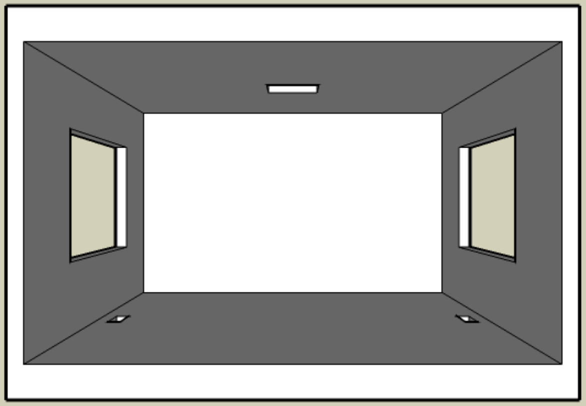


A_{floor} = 1,600 ft^2

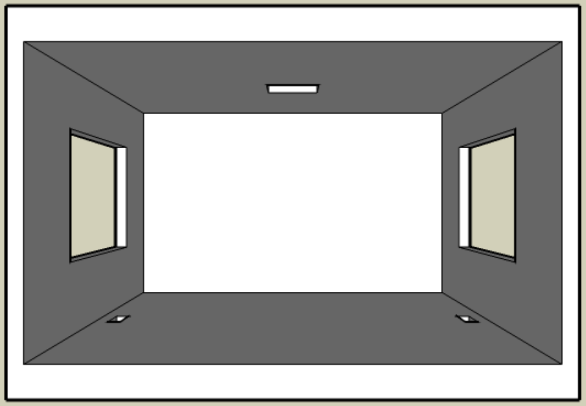
N_{br} = 3

$A_{living\ room\ floor}$ = 230 ft^2

Ventilation Rate

$$Q_{fan} = 0.01A_{floor} + 7.5(N_{br} + 1)$$

What size exhaust fan is required to provide whole house ventilation for the house described to the right?



$A_{floor} = 1{,}600\ ft^2$

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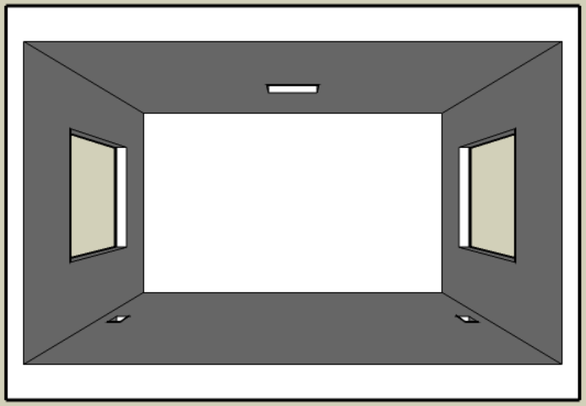
Ventilation Rate

$$Q_{fan} = 0.01A_{floor} + 7.5\left(N_{br} + 1\right)$$

$$Q_{fan} = 0.01(1{,}600) + 7.5\left(3 + 1\right)$$



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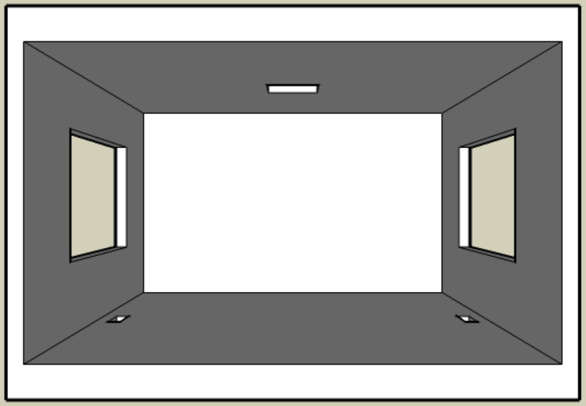
Ventilation Rate

$$Q_{fan} = 0.01A_{floor} + 7.5(N_{br} + 1)$$

$$Q_{fan} = 0.01(1{,}600) + 7.5(3 + 1)$$

$$Q_{fan} = 46 \text{ cfm}$$



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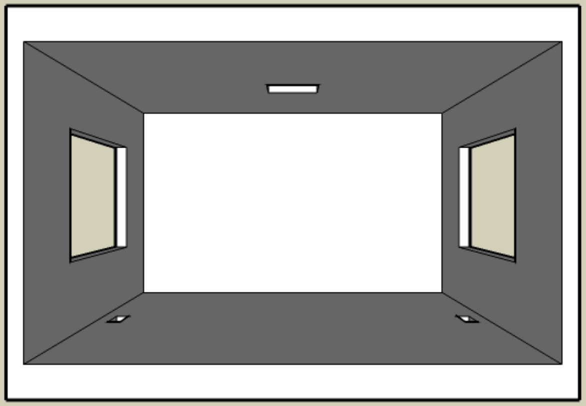
∴ A 50 cfm exhaust fan is adequate to ventilate the whole house.



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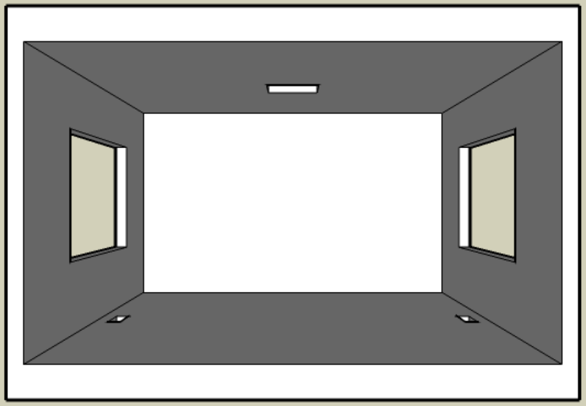

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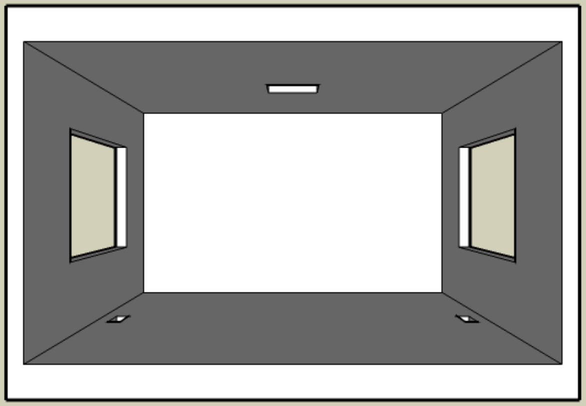
$N_{br} = 3$

$A_{living\ room\ floor} = 230 \text{ ft}^2$

Ventilation Rate

$$Q_{fan} = 46 \text{ cfm}$$

What portion of the required ventilation is attributed to the living room?



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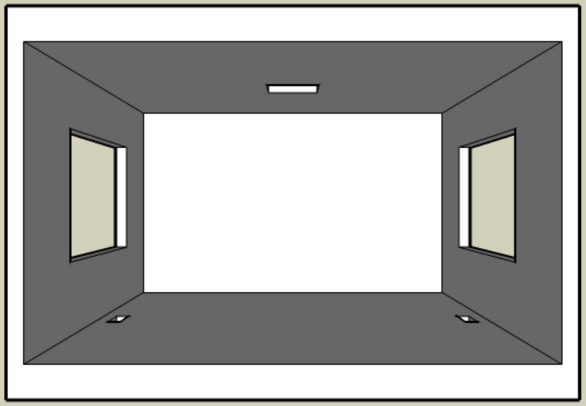
What portion of the required ventilation is attributed to the living room?

$$Q_{living\_room} = 46\left(\frac{230}{1{,}600}\right)$$



$$A_{floor} = 1{,}600 \text{ ft}^2$$
$$N_{br} = 3$$
$$A_{living\ room\ floor} = 230 \text{ ft}^2$$

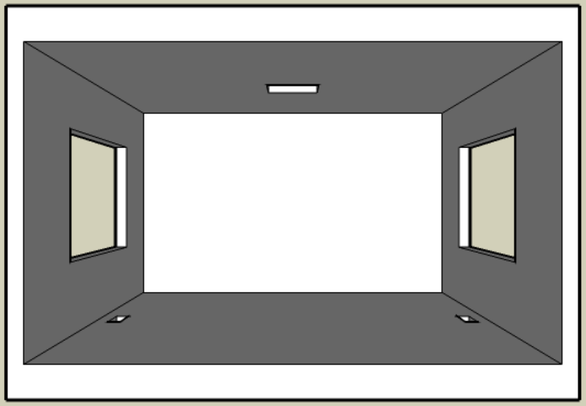
Ventilation Rate

$$Q_{fan} = 46 \text{ cfm}$$

What portion of the required ventilation is attributed to the living room?

$$Q_{living\_room} = 46\left(\frac{230}{1,600}\right)$$

$$Q_{living\_room} = 6.61 \text{ cfm}$$



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What portion of the required ventilation is attributed to the living room?

$$Q_{living\_room} = 46\left(\frac{230}{1,600}\right)$$

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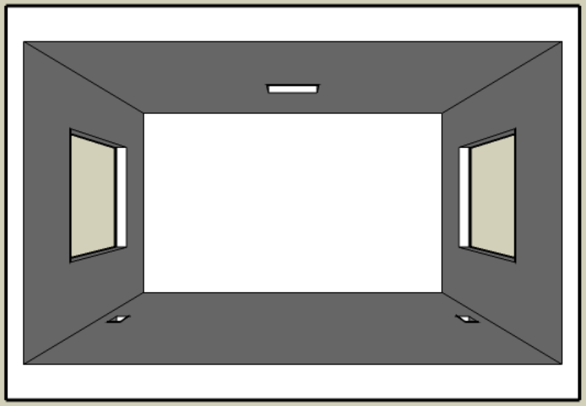

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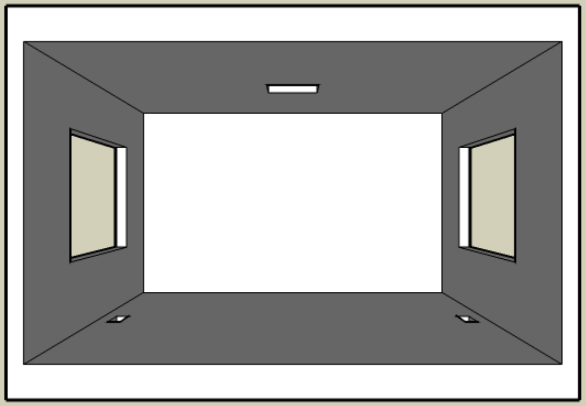
$$A_{living\ room\ floor} = 230 \text{ ft}^2$$

Ventilation Rate

$$Q_{fan} = 46 \text{ cfm}$$

$$Q_{living\_room} = 6.61 \text{ cfm}$$

Keep these numbers in mind for comparison when we calculate the volumetric flow rate of air (Q) required to provide thermal comfort.



$$A_{floor} = 1{,}600 \text{ ft}^2$$
$$N_{br} = 3$$
$$A_{living\ room\ floor} = 230 \text{ ft}^2$$

Local Exhaust

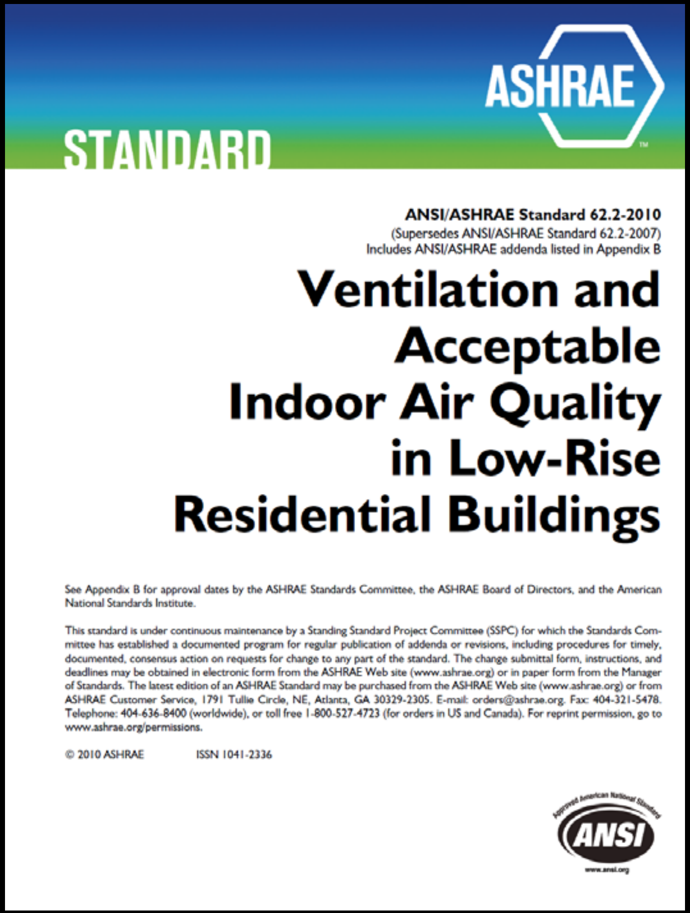
A key part of maintaining good indoor air quality is to provide local exhaust at point sources of air contamination.

ASHRAE 62.2-2010 requires a 50 cfm exhaust fan in bathrooms and a 100 cfm exhaust fan / range hood in kitchens.

Broan Heavy-Duty Operation with Light Exhaust Fan
[www.broan.com]

ASHRAE 62.2-2010

ASHRAE 62.2-2010 provides additional information for determining the ventilation required to maintain indoor air quality, but that information is beyond the scope of this presentation.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providing thermal comfort

What is thermal comfort?

"Thermal comfort is that condition of mind which expresses satisfaction with the thermal environment."

[ISO 7730, 10]

What is thermal comfort?

"Thermal comfort is that condition of mind which expresses satisfaction with the thermal environment."

[ISO 7730, 10]

Important: Thermal comfort is described by a range – a zone - of dry bulb temperatures (T_{DB}) and relative humidity (RH) values, rather than a specific dry bulb temperature and relative humidity; and, the size and shape of the zone varies based on gender, age, health, level of activity, clothing, and more.

What is thermal comfort?

The psychrometric [sahy-kr*uh*-**me**-tik] chart is, among other things, a graphic representation of the relationship between dry bulb temperature (T_{DB}) and relative humidity (RH).

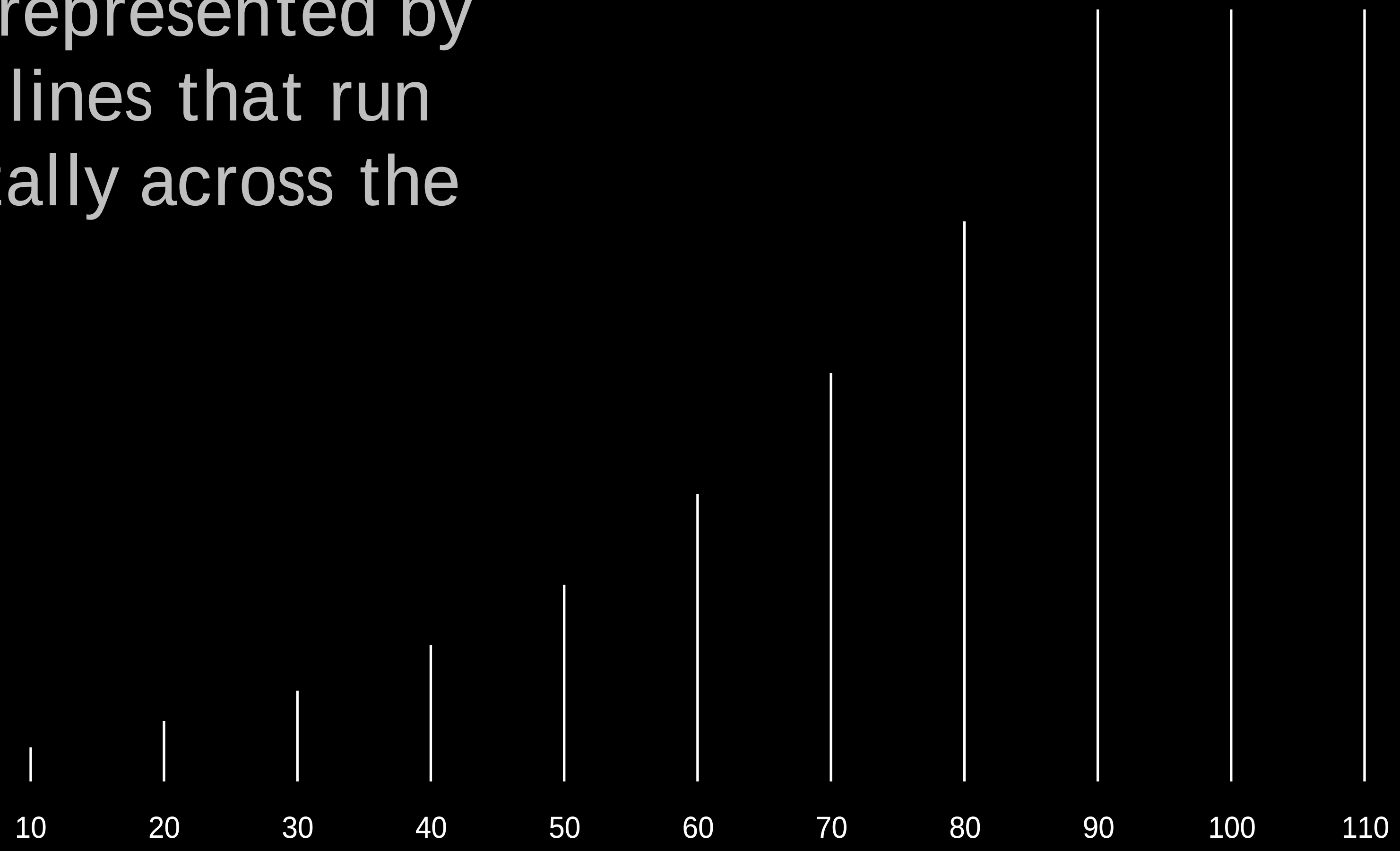
[*uh*] about, animal, problem, circus
[dictionary.reference .com]

Psychrometric Chart

The dry bulb temperature scale is represented by vertical lines that run horizontally across the chart.

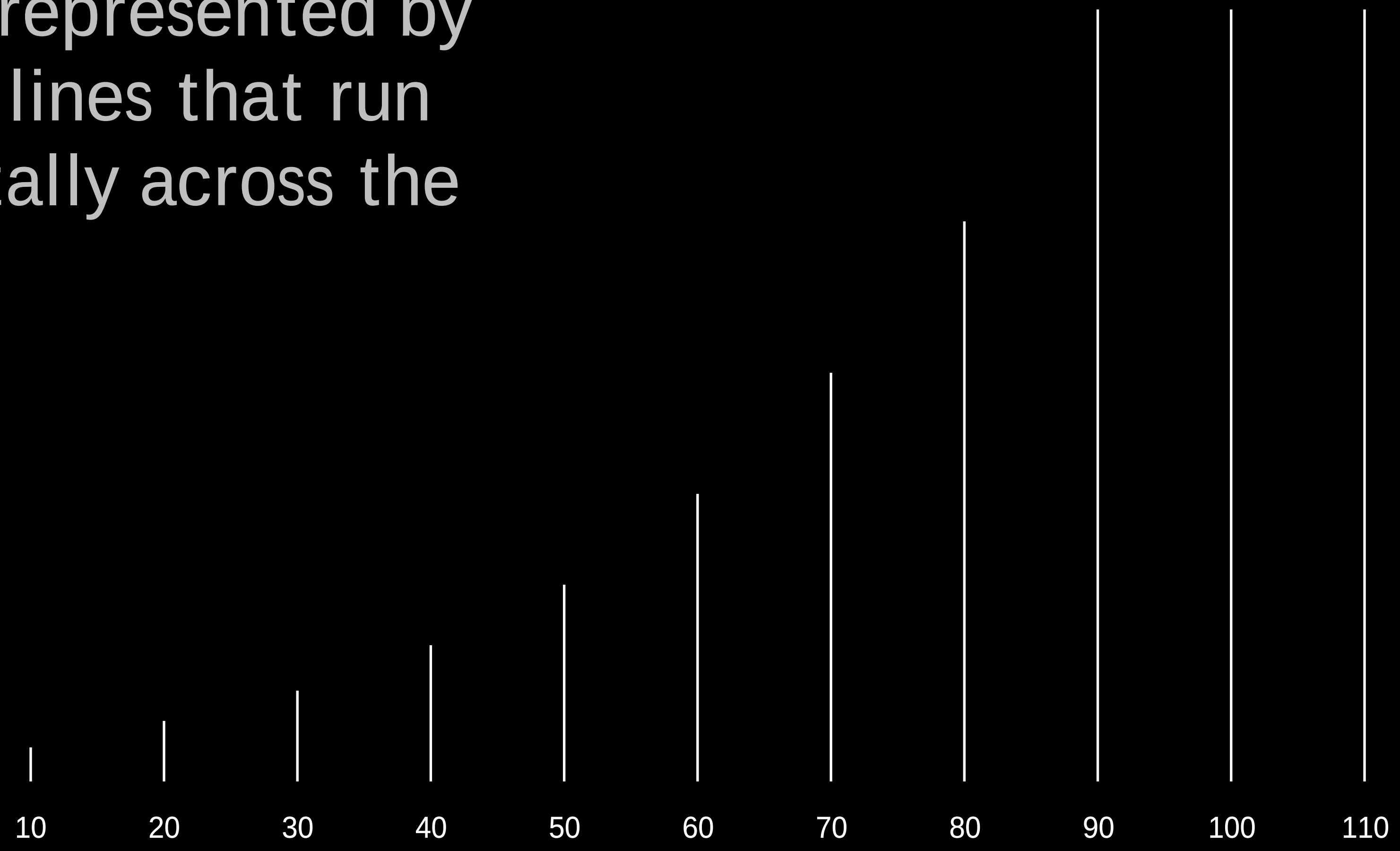
Psychrometric Chart

The dry bulb temperature scale is represented by vertical lines that run horizontally across the chart.



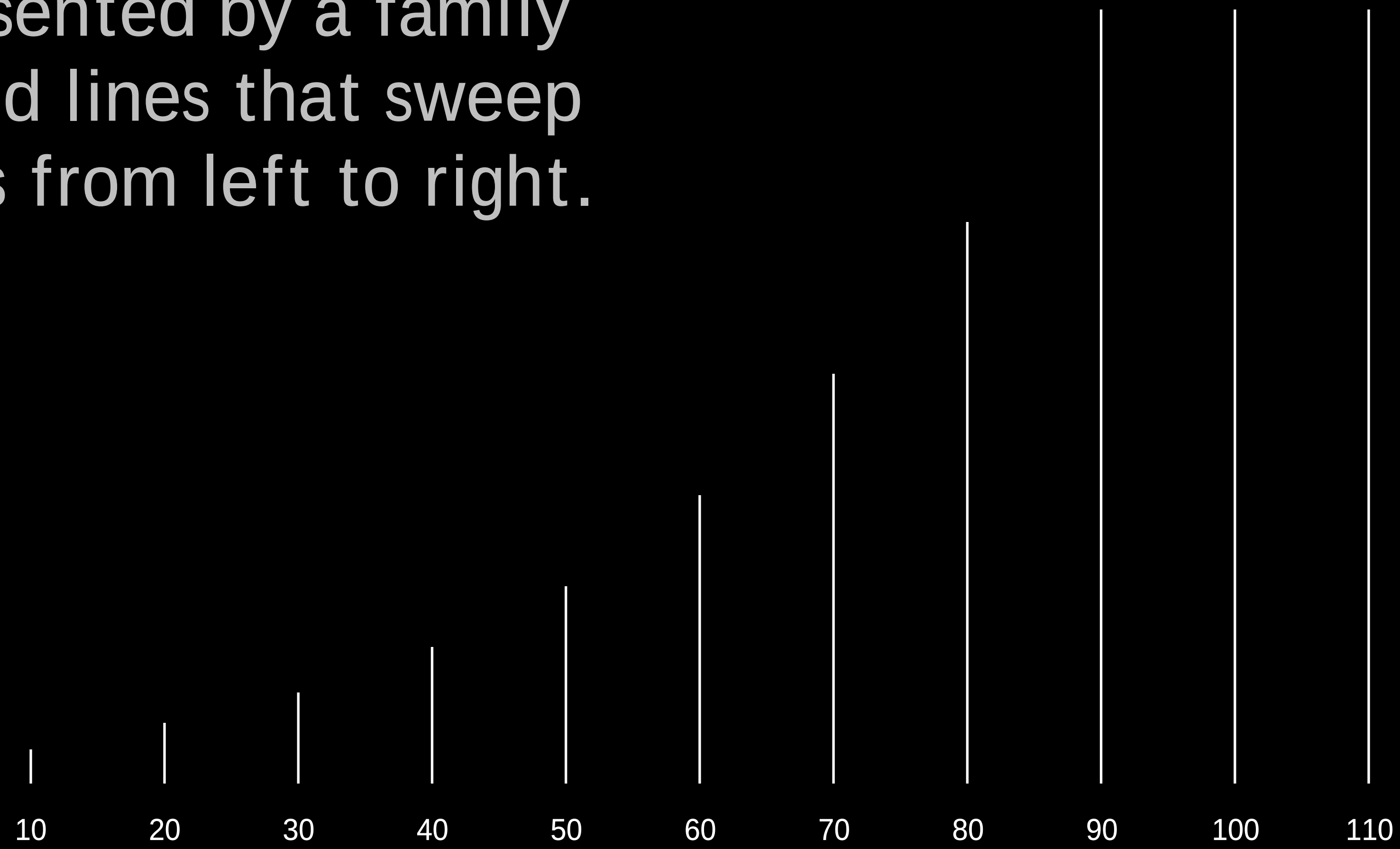
Psychrometric Chart

The dry bulb temperature scale is represented by vertical lines that run horizontally across the chart.



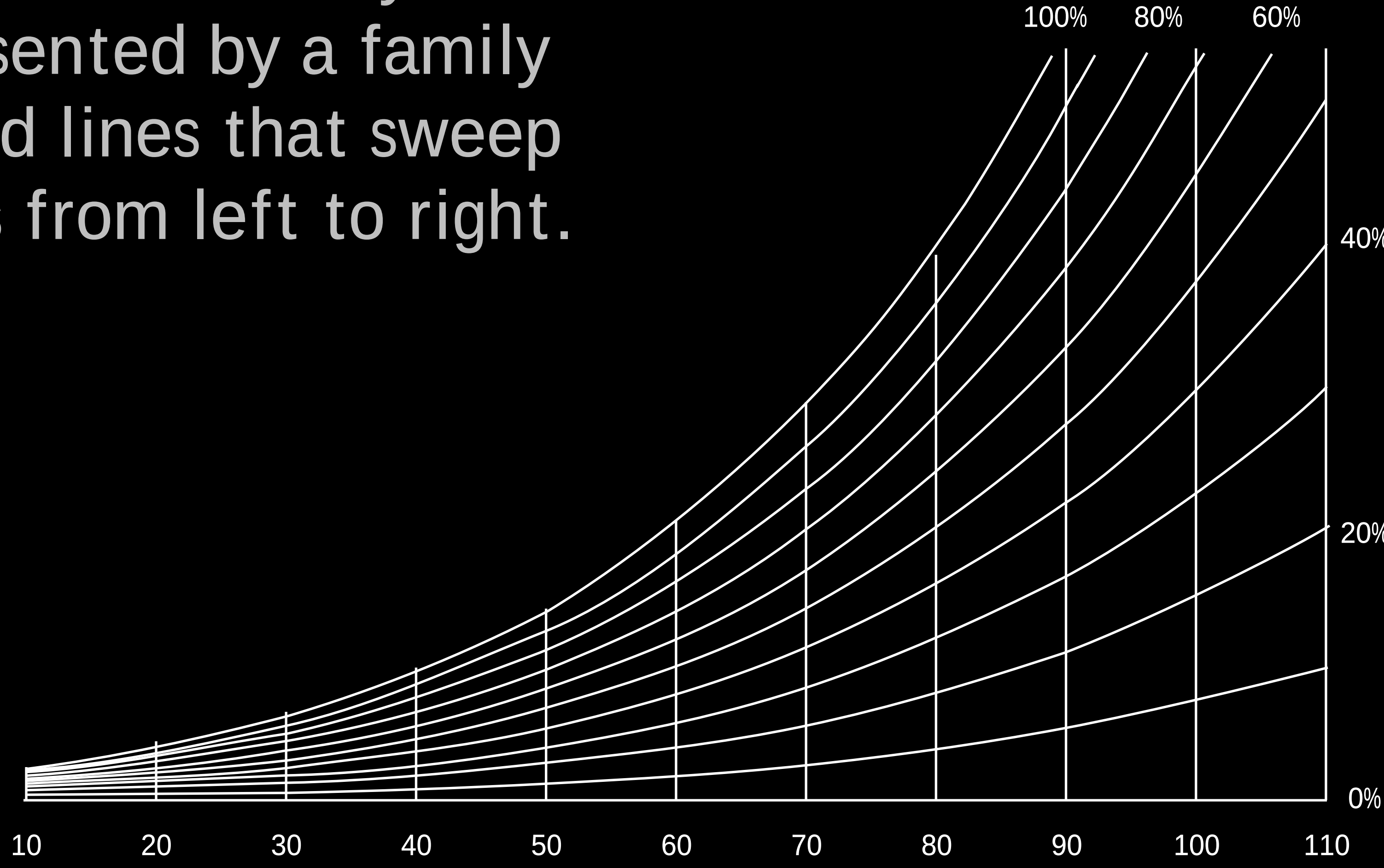
Psychrometric Chart

The relative humidity scale is represented by a family of curved lines that sweep upwards from left to right.



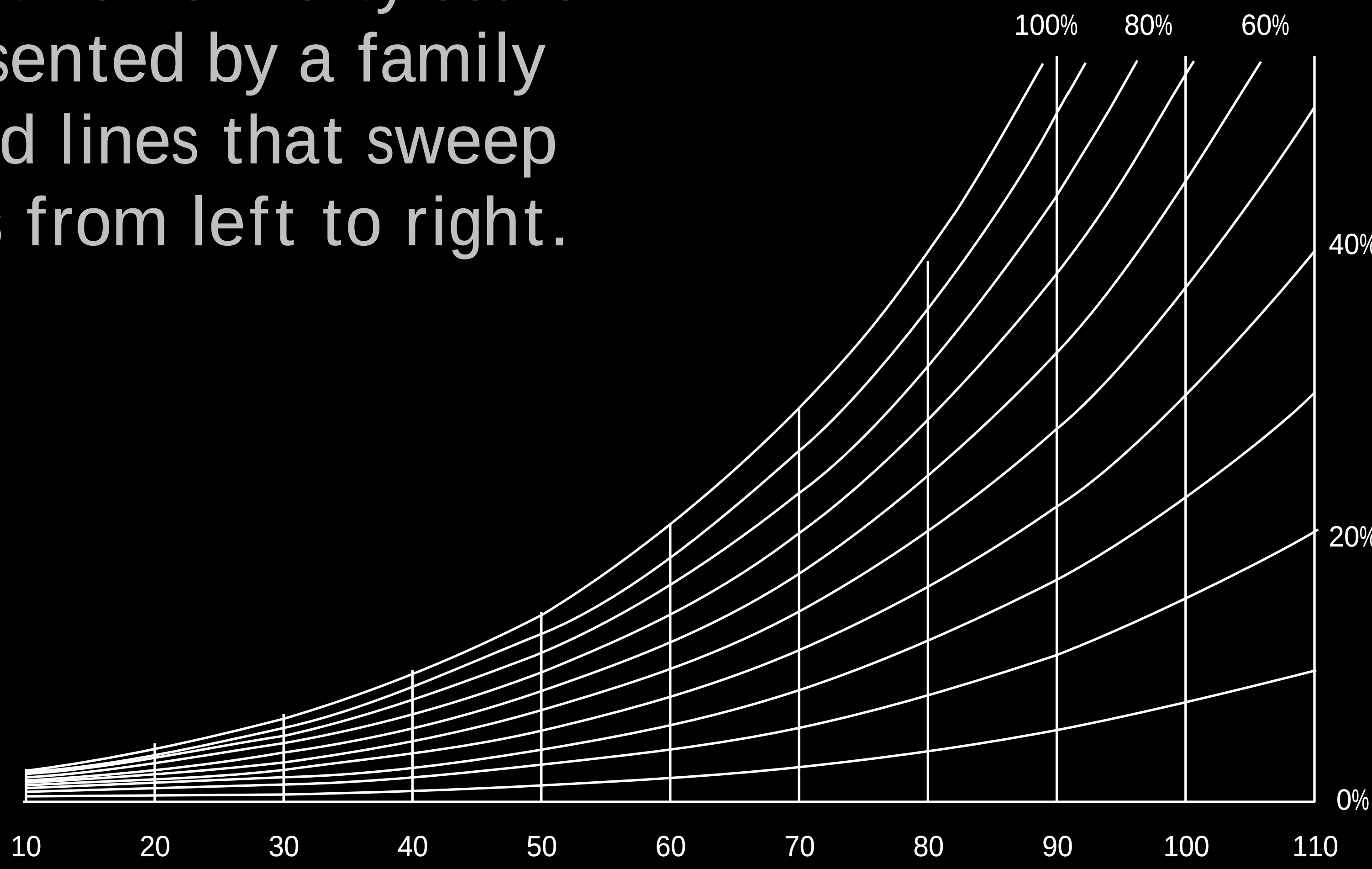
Psychrometric Chart

The relative humidity scale is represented by a family of curved lines that sweep upwards from left to right.



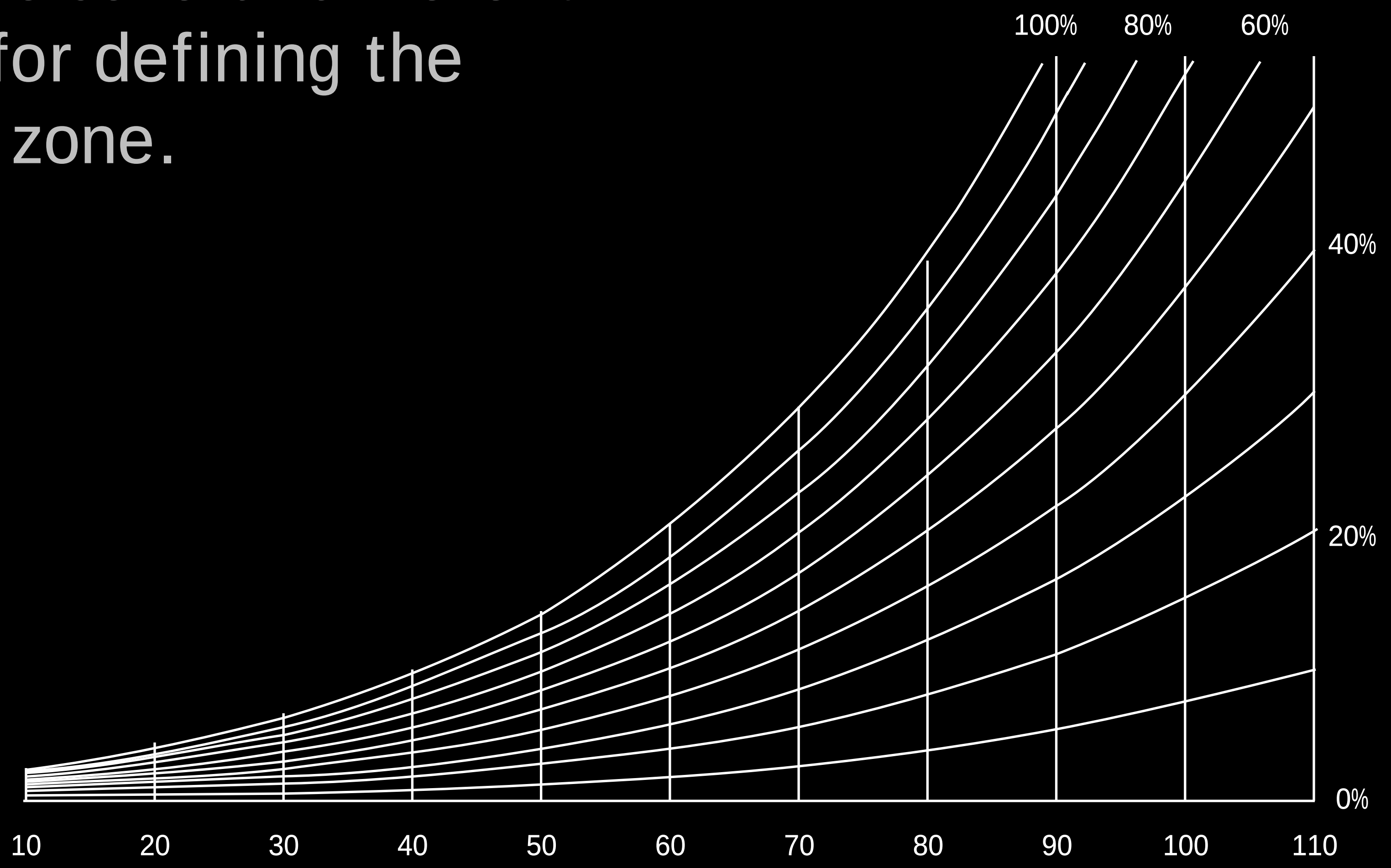
Psychrometric Chart

The relative humidity scale is represented by a family of curved lines that sweep upwards from left to right.



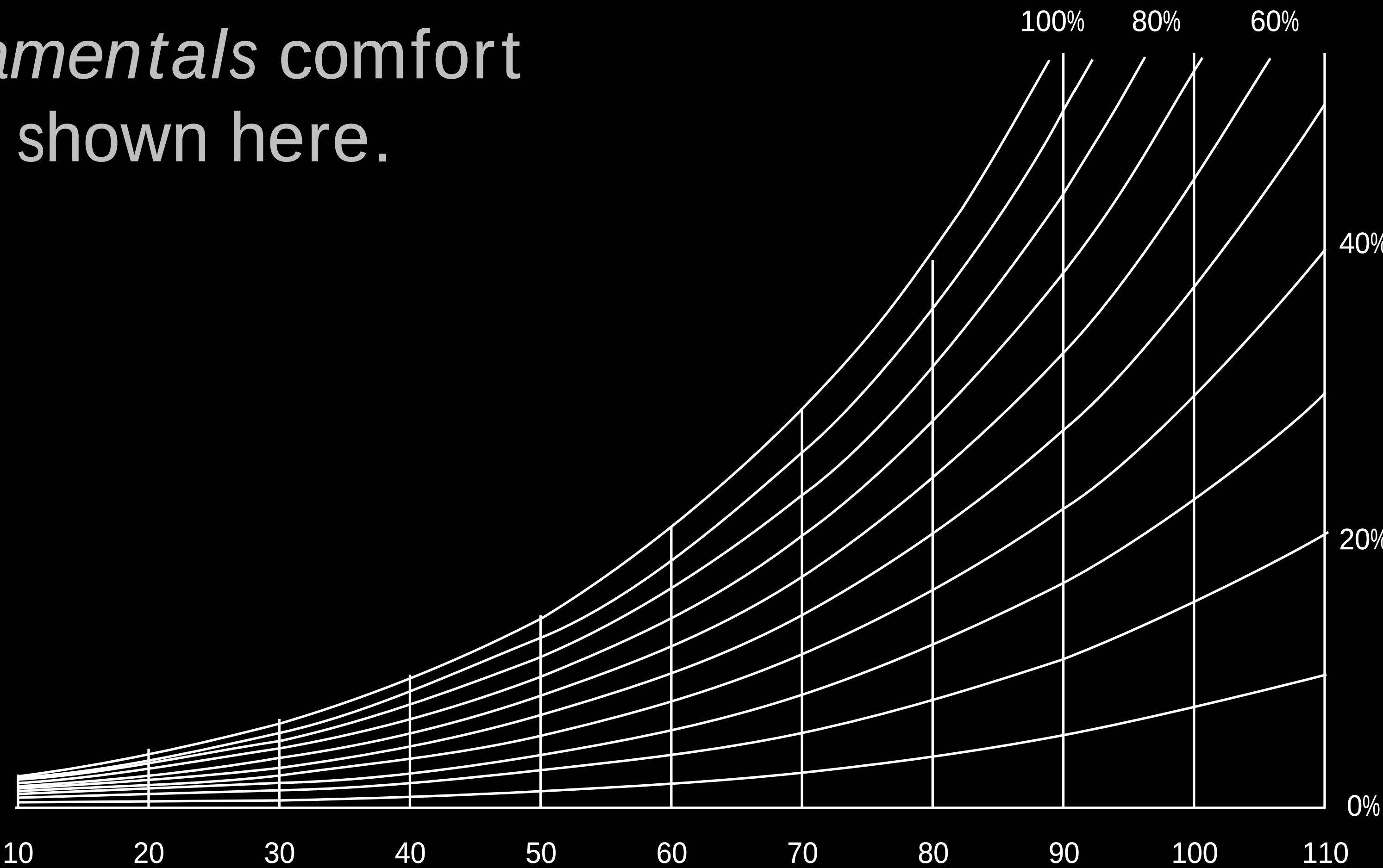
Psychrometric Chart

There are several different models for defining the comfort zone.



Psychrometric Chart

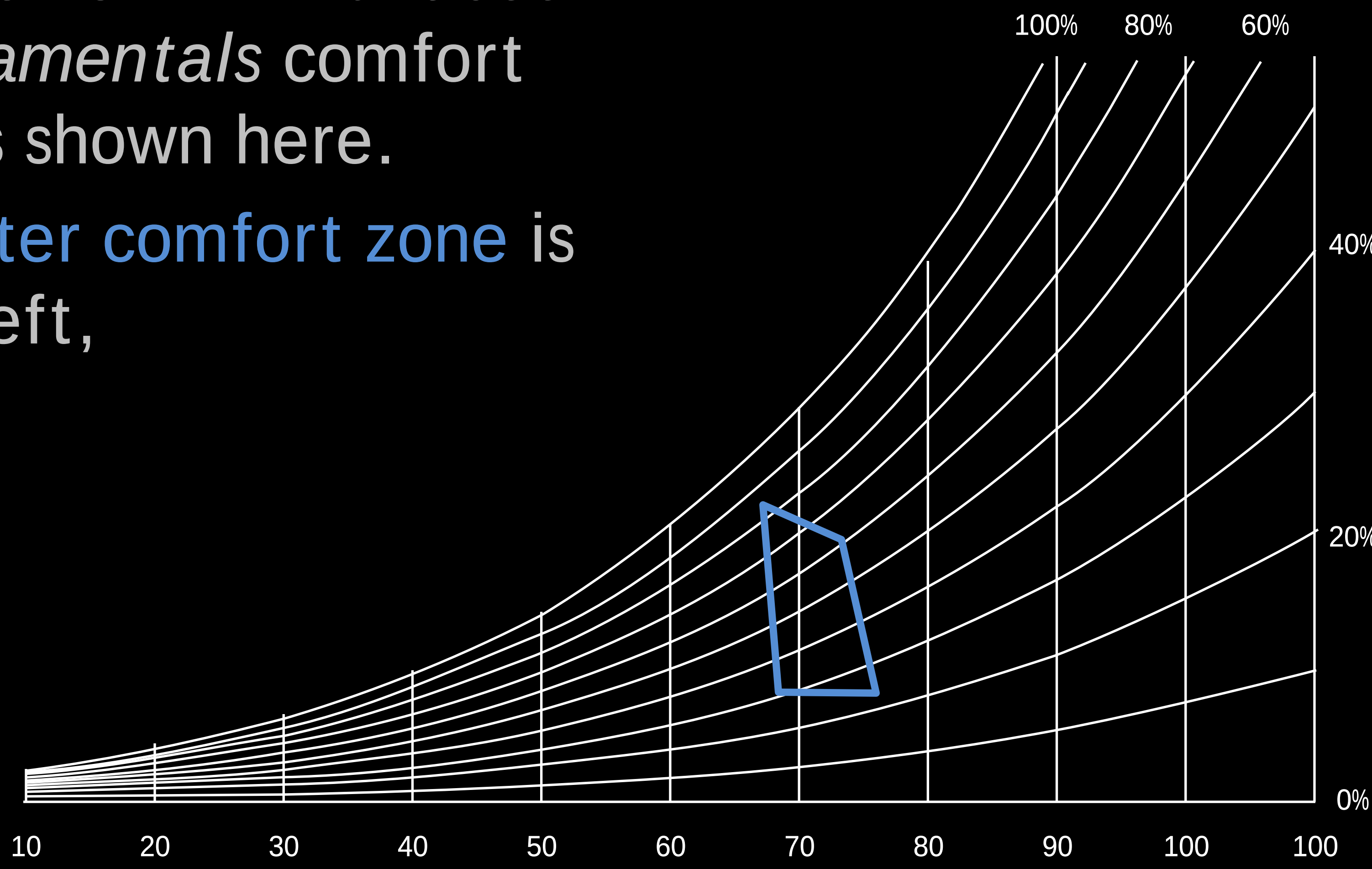
The *2005 ASHRAE Handbook of Fundamentals* comfort model is shown here.



Psychrometric Chart

The *2005 ASHRAE Handbook of Fundamentals* comfort model is shown here.

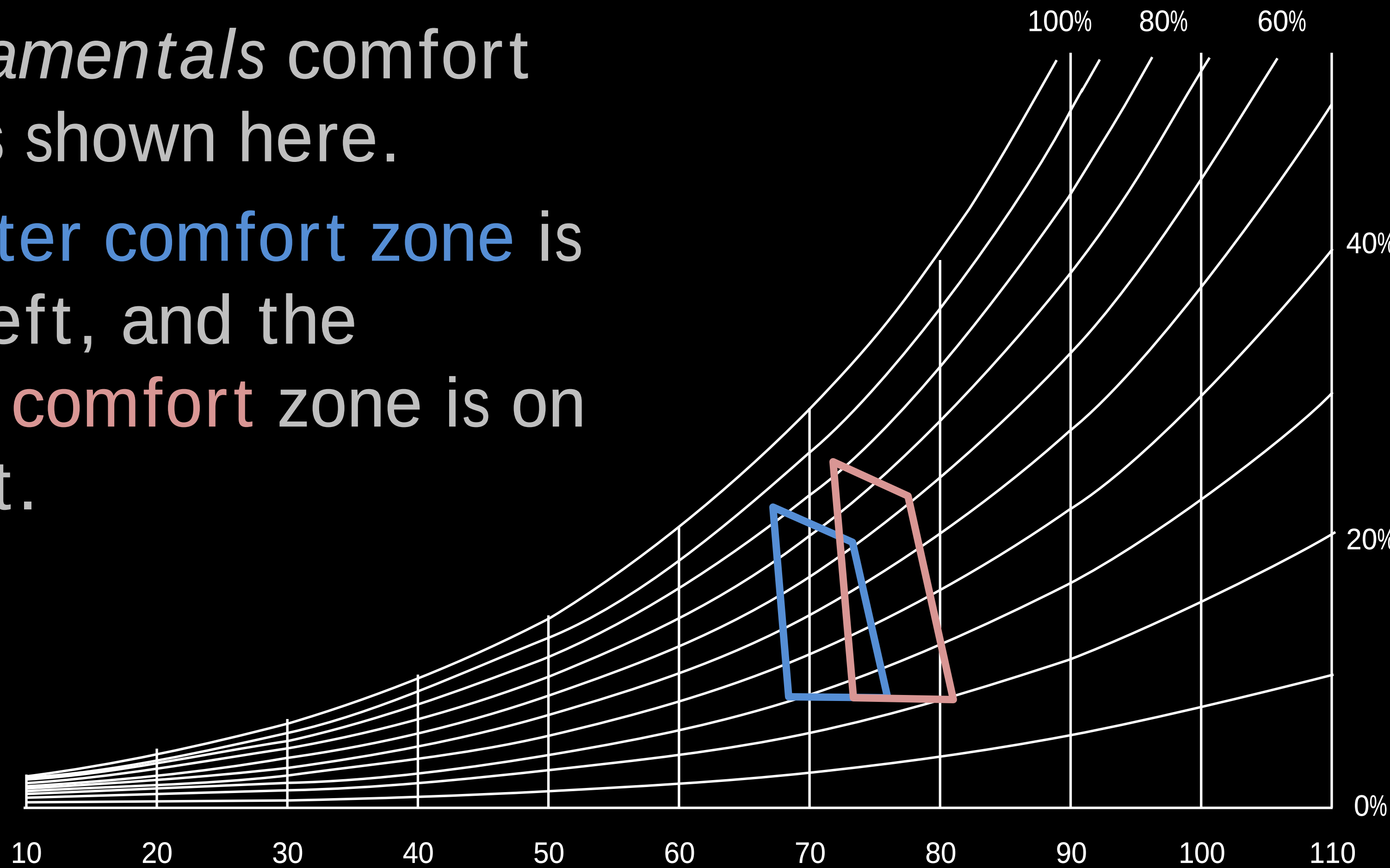
The winter comfort zone is on the left,



Psychrometric Chart

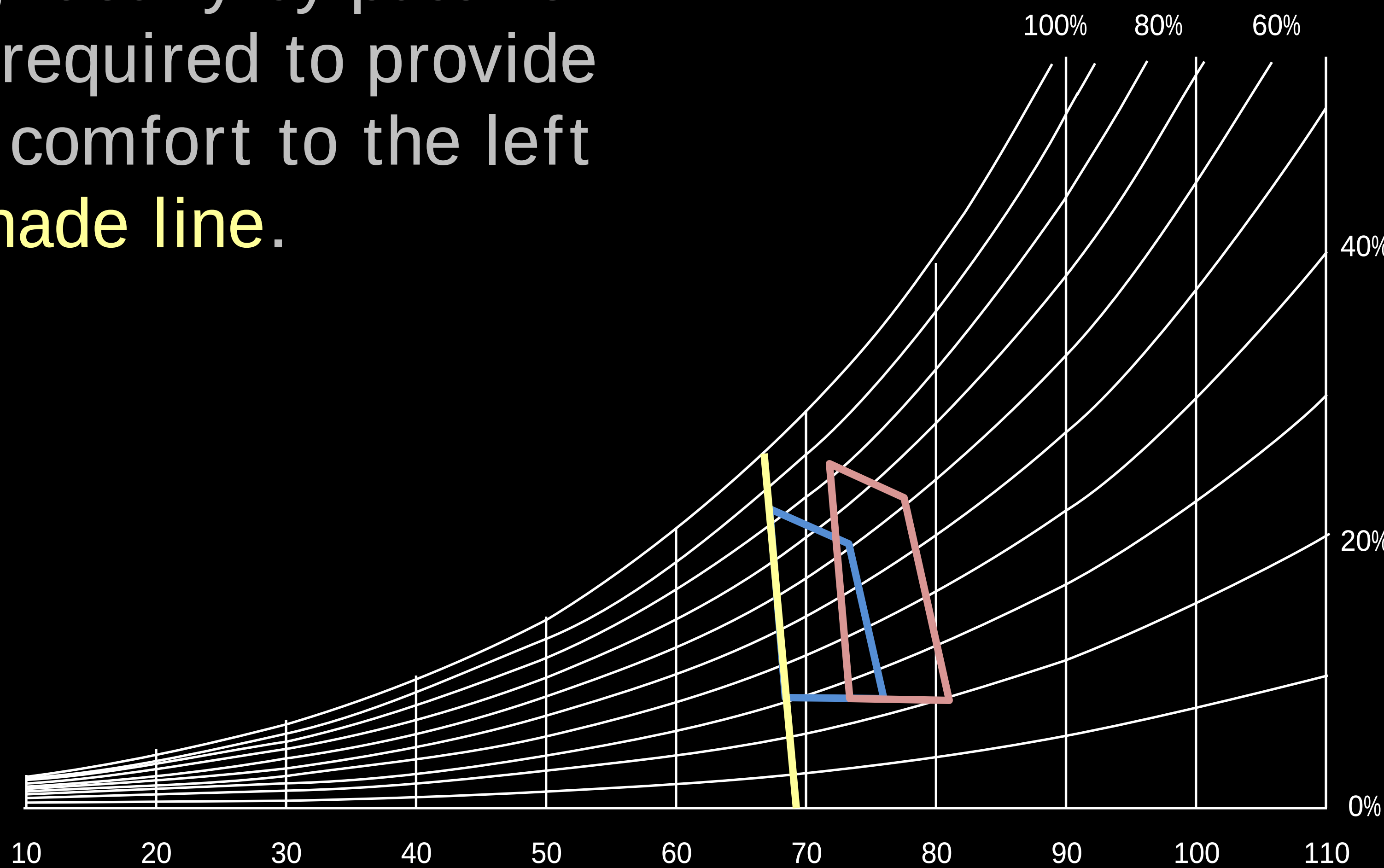
The *2005 ASHRAE Handbook of Fundamentals* comfort model is shown here.

The winter comfort zone is on the left, and the summer comfort zone is on the right.



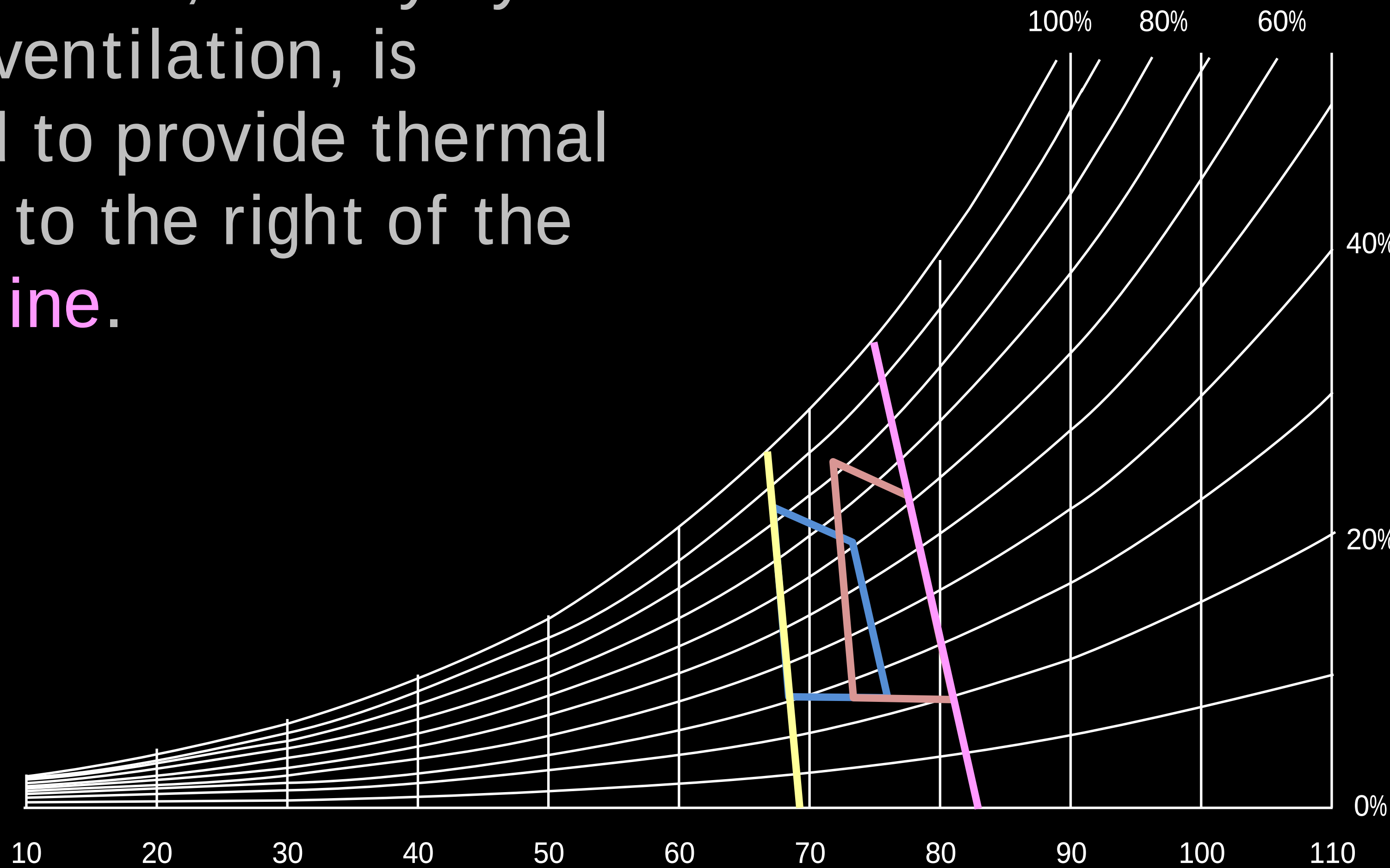
Psychrometric Chart

Heating, ideally by passive solar, is required to provide thermal comfort to the left of the shade line.



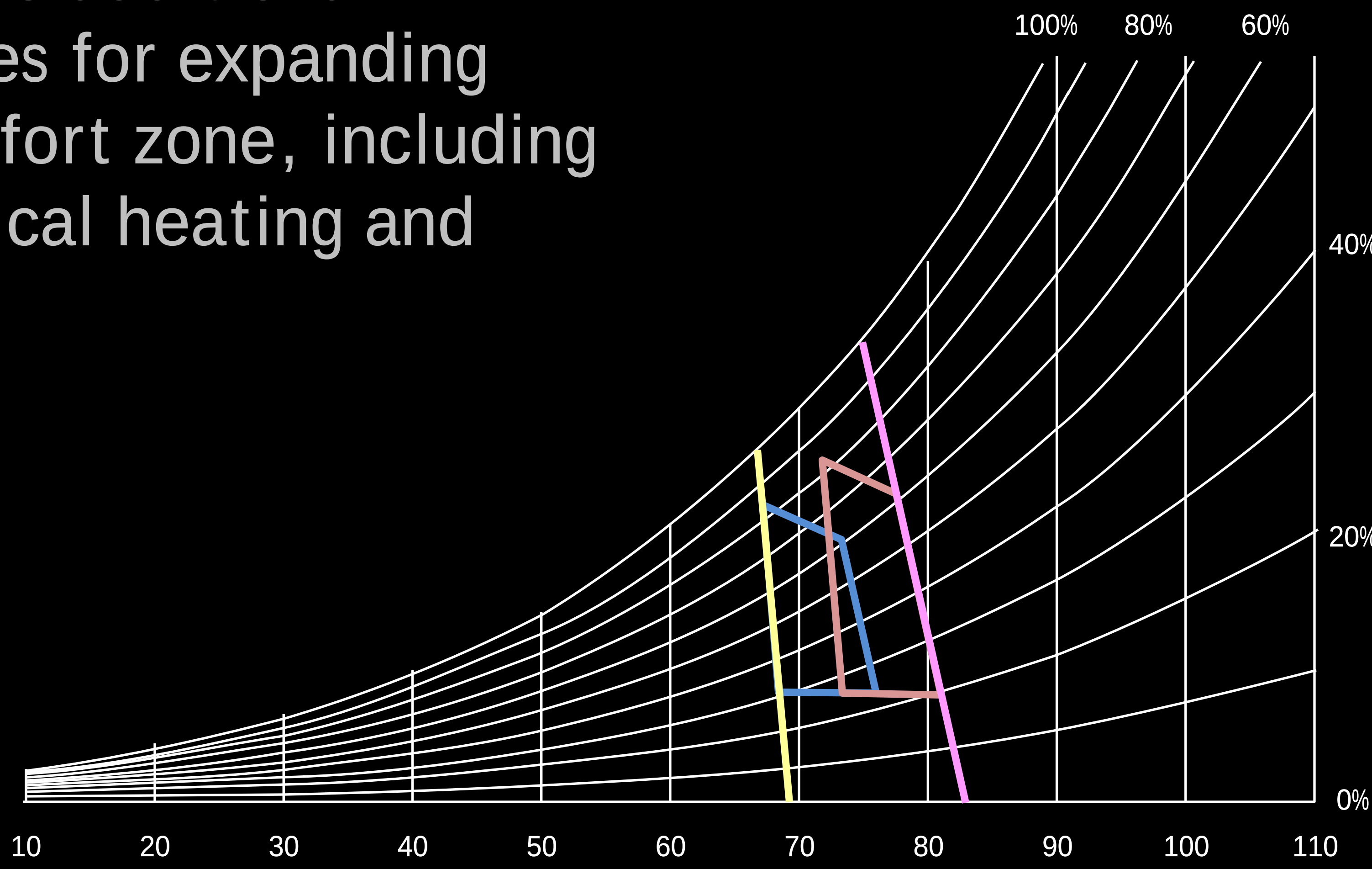
Psychrometric Chart

Air movement, ideally by natural ventilation, is required to provide thermal comfort to the right of the still air line.



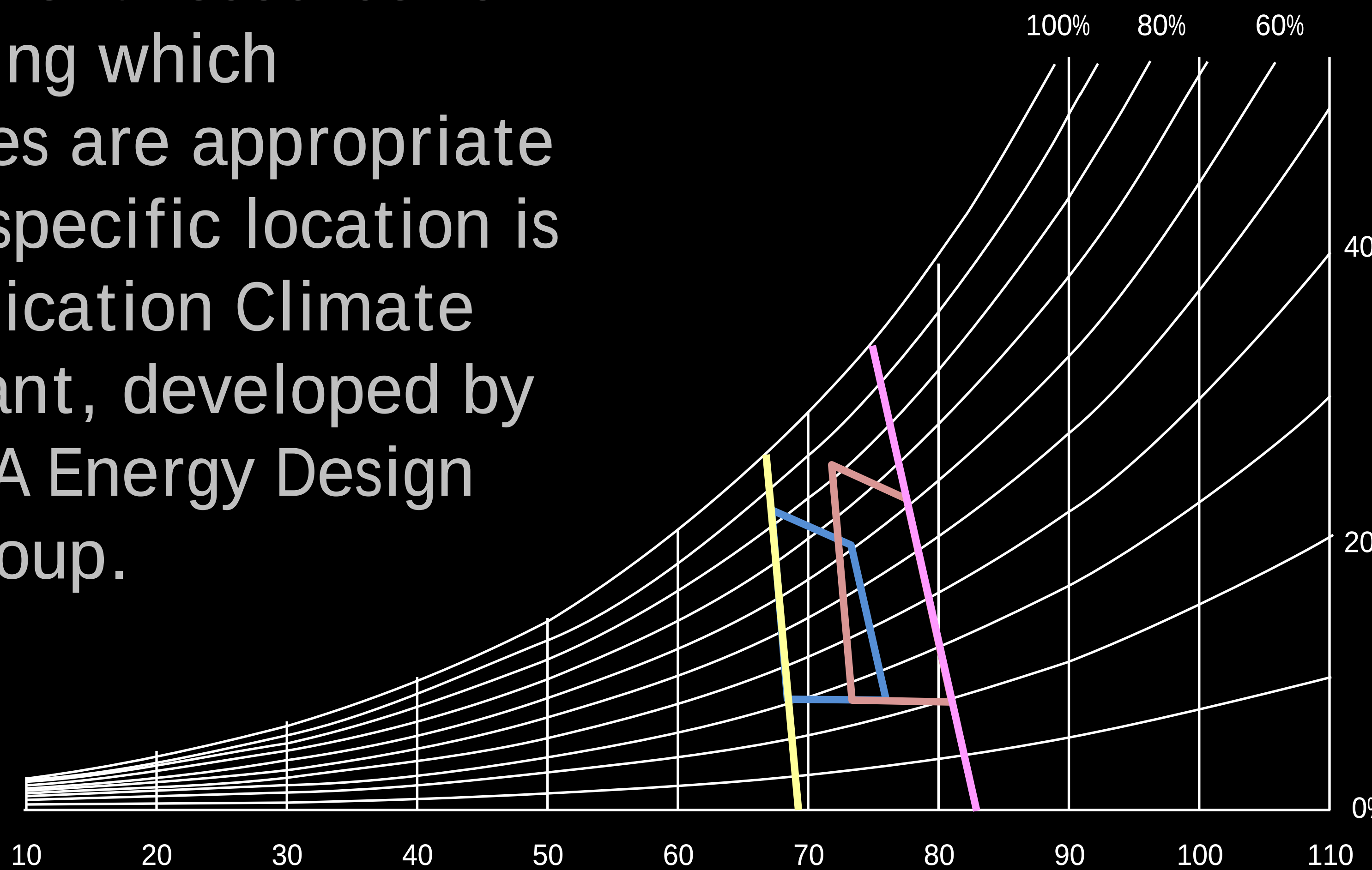
Psychrometric Chart

There are additional strategies for expanding the comfort zone, including mechanical heating and cooling.

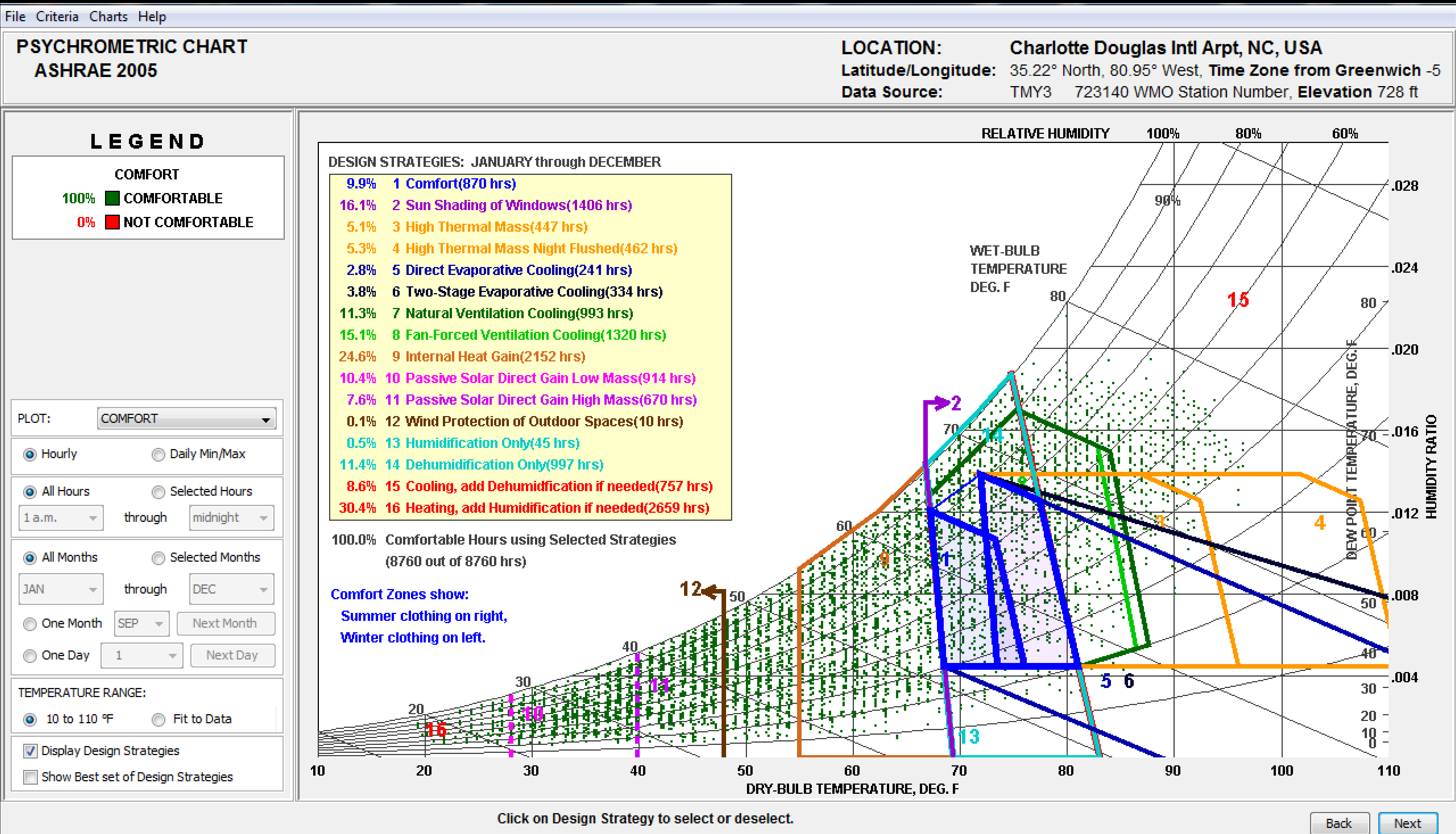


Psychrometric Chart

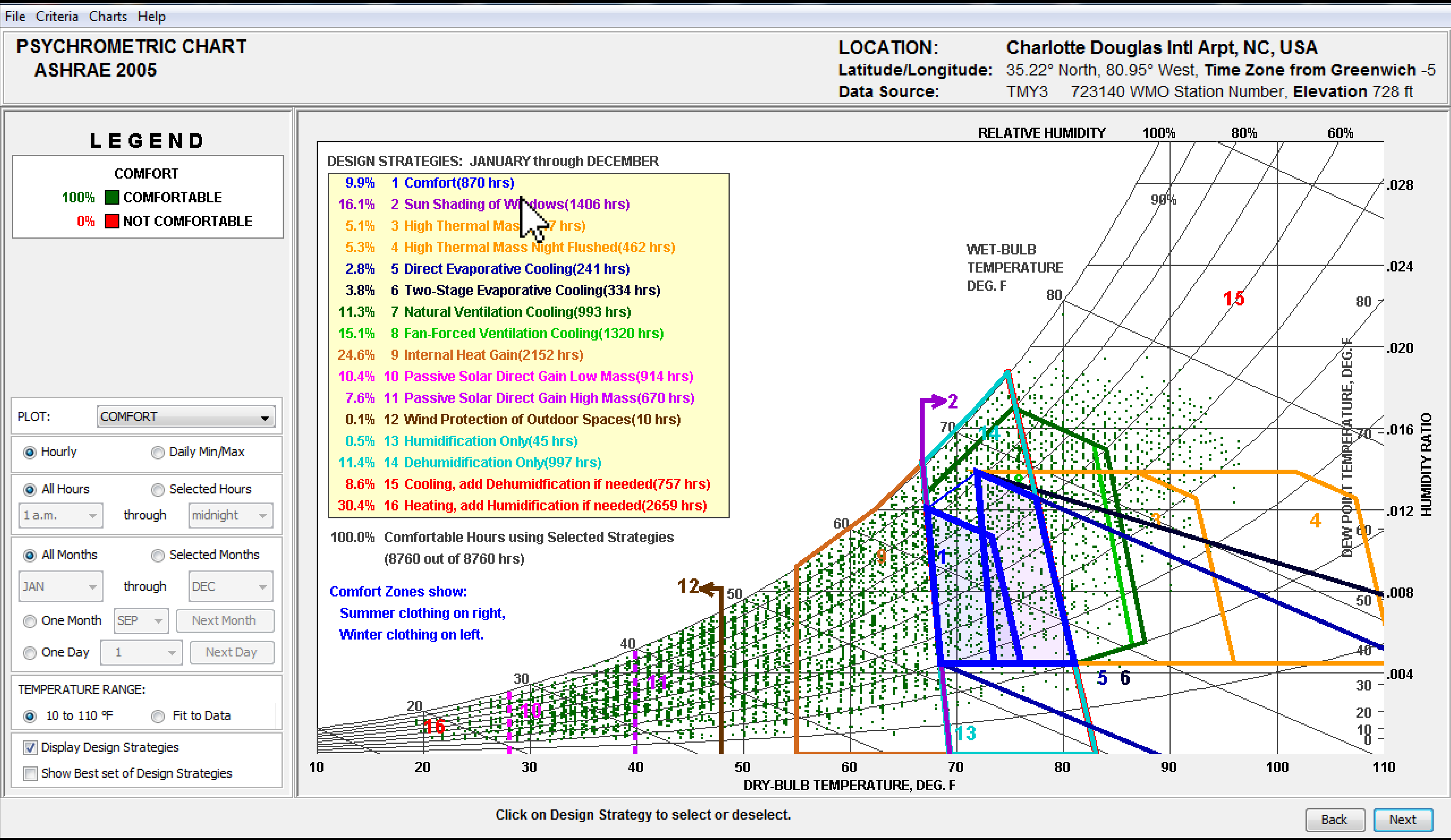
An excellent resource for identifying which strategies are appropriate for any specific location is the application Climate Consultant, developed by the UCLA Energy Design Tools Group.



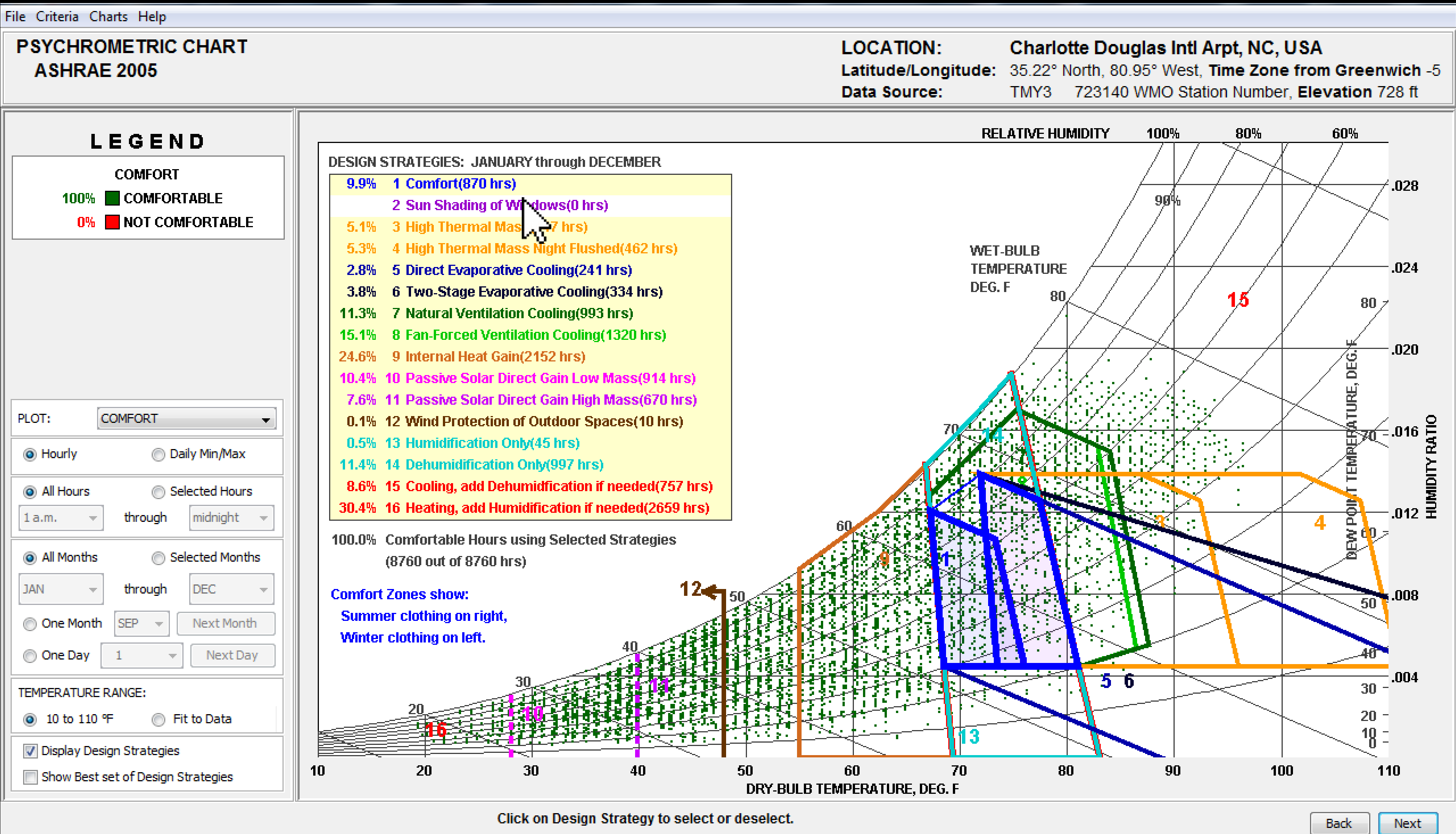
Psychrometric Chart



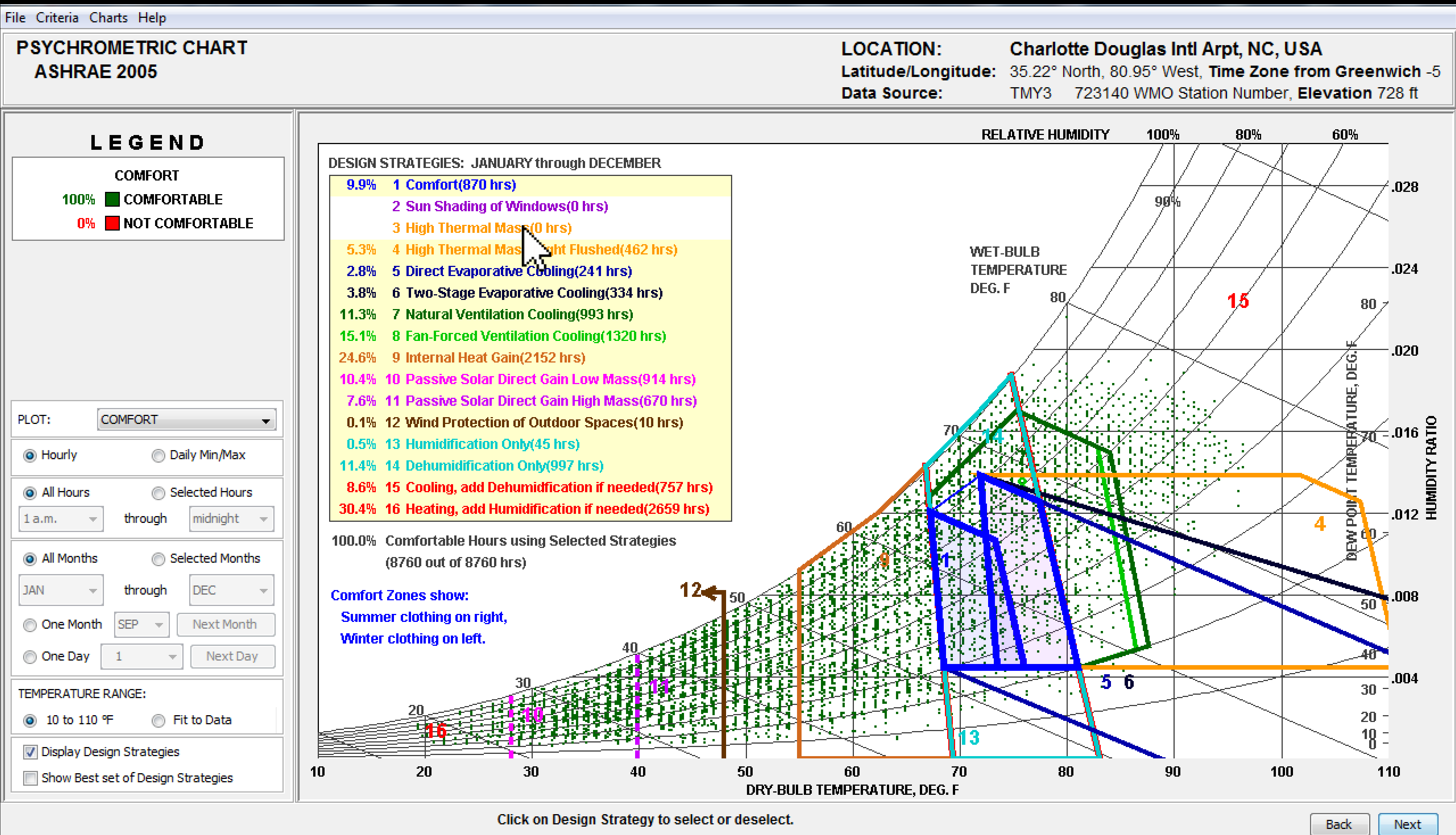
Design Strategies



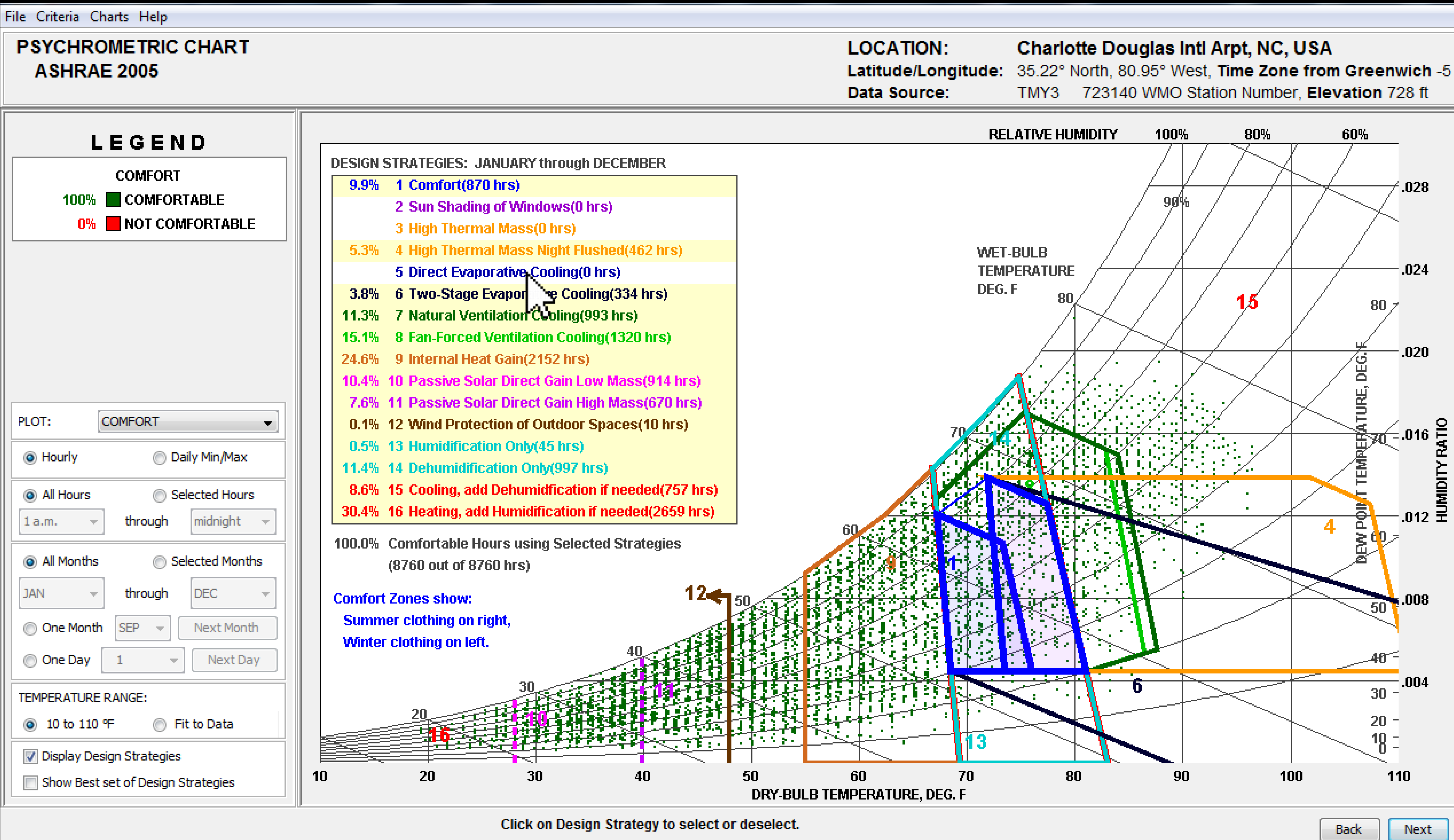
Design Strategies



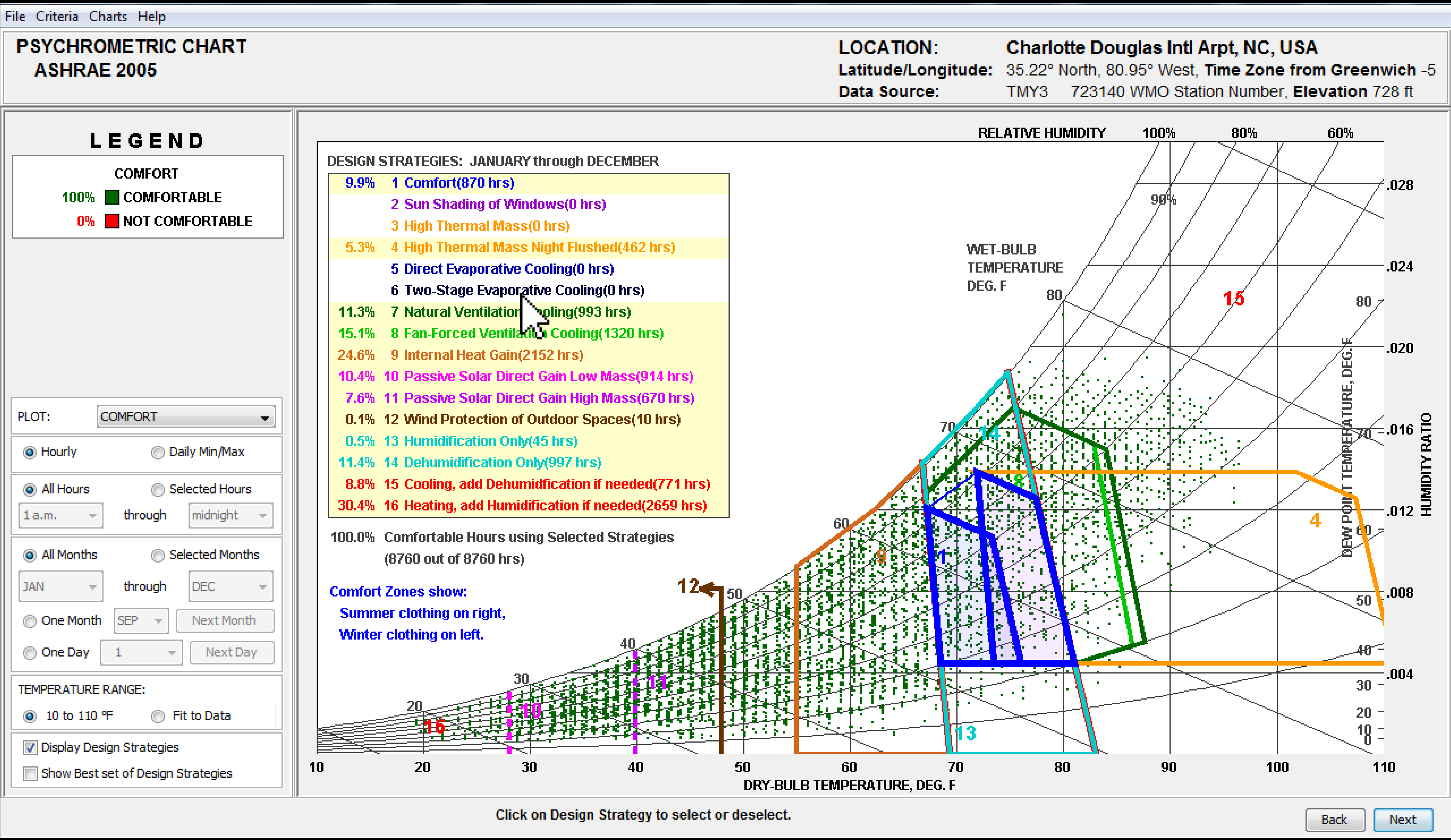
Design Strategies



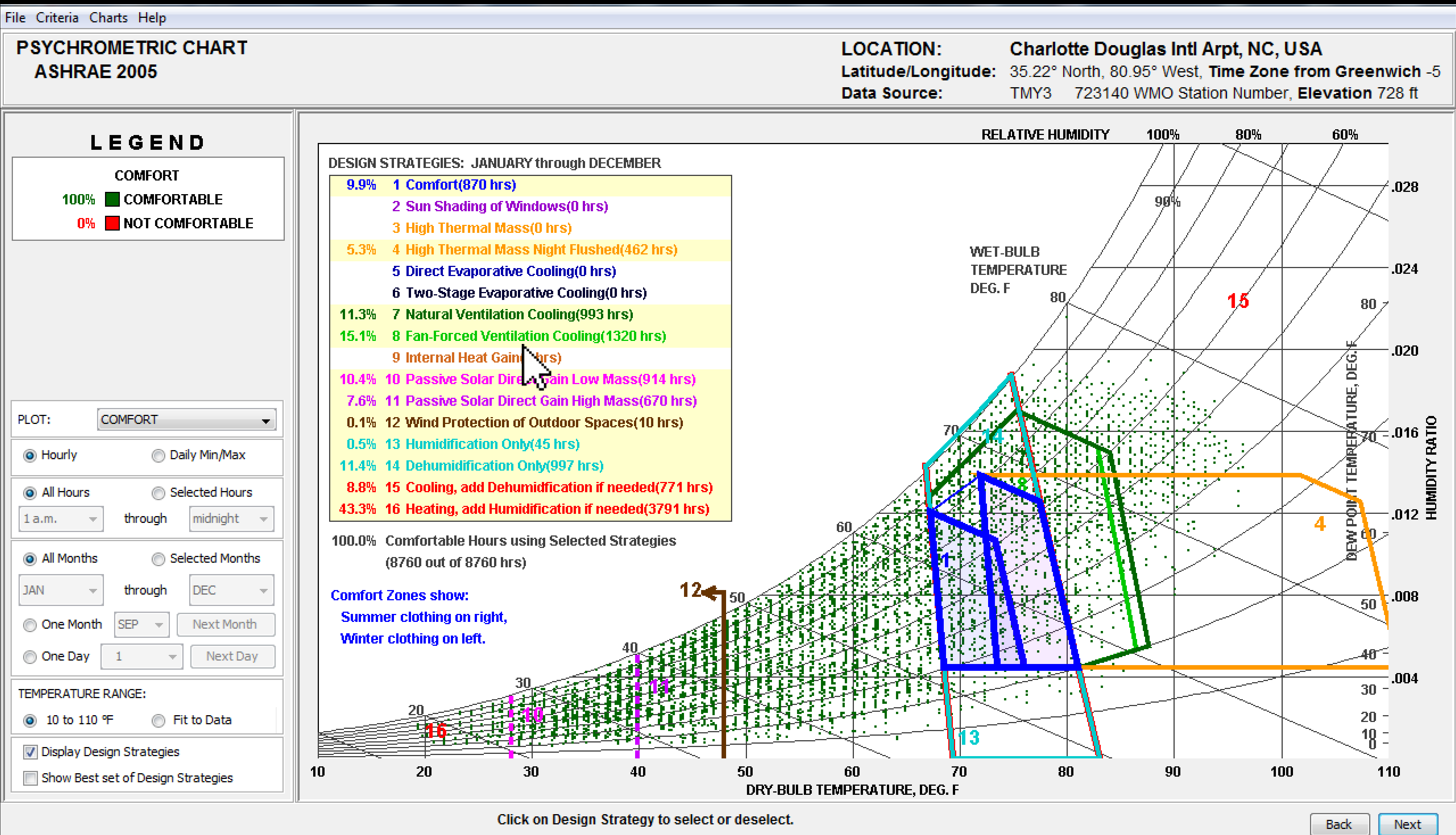
Design Strategies



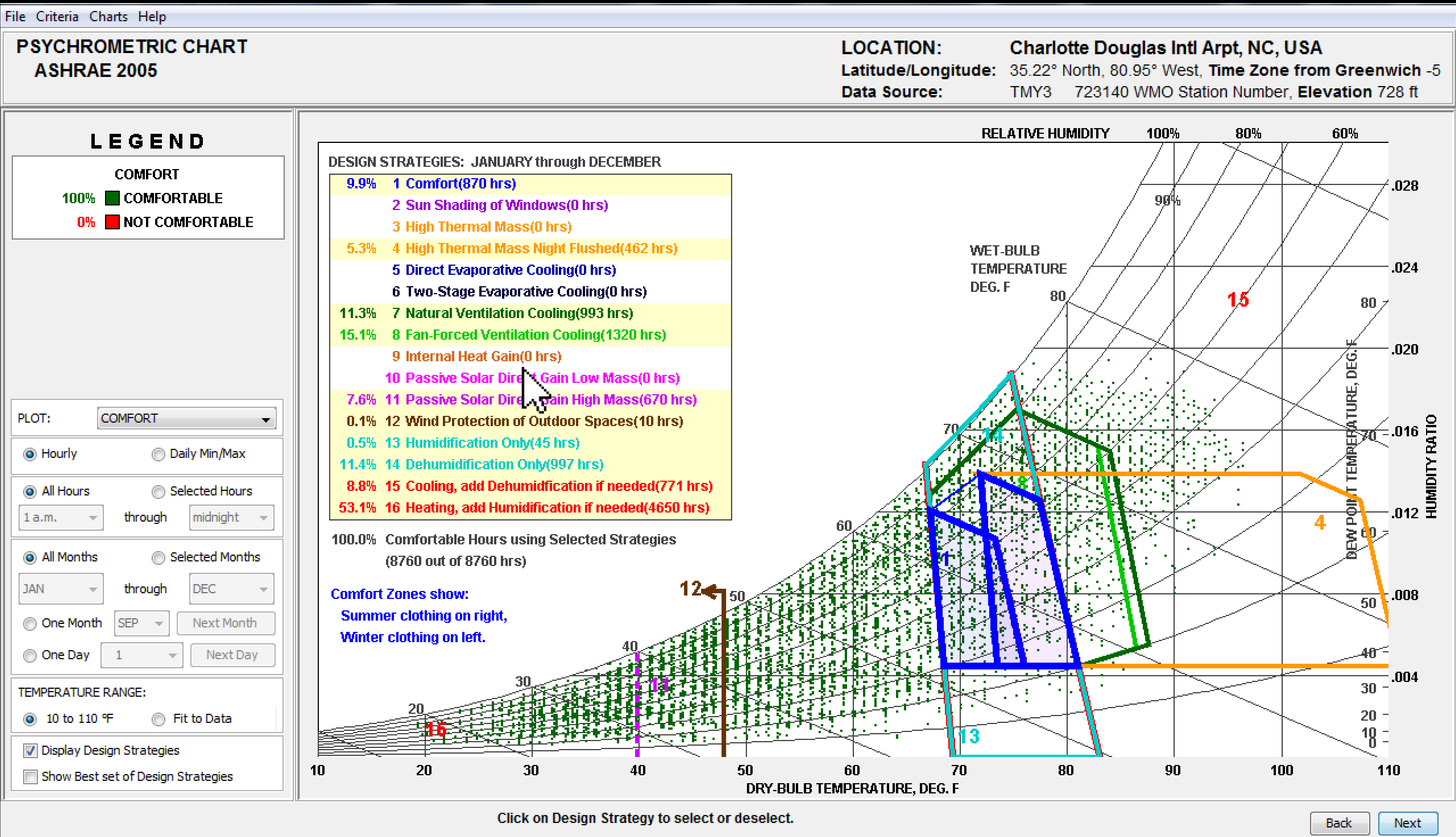
Design Strategies



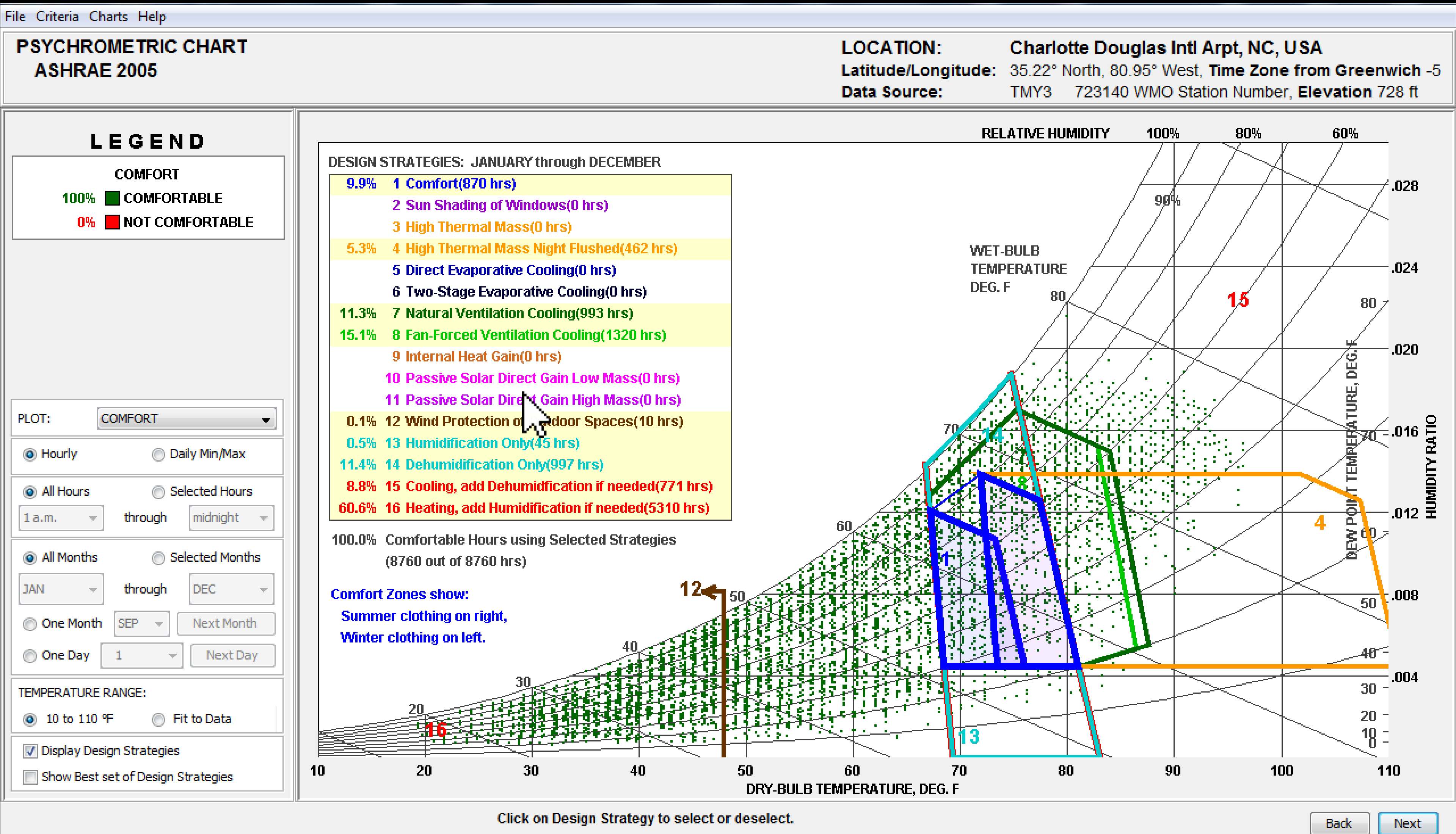
Design Strategies



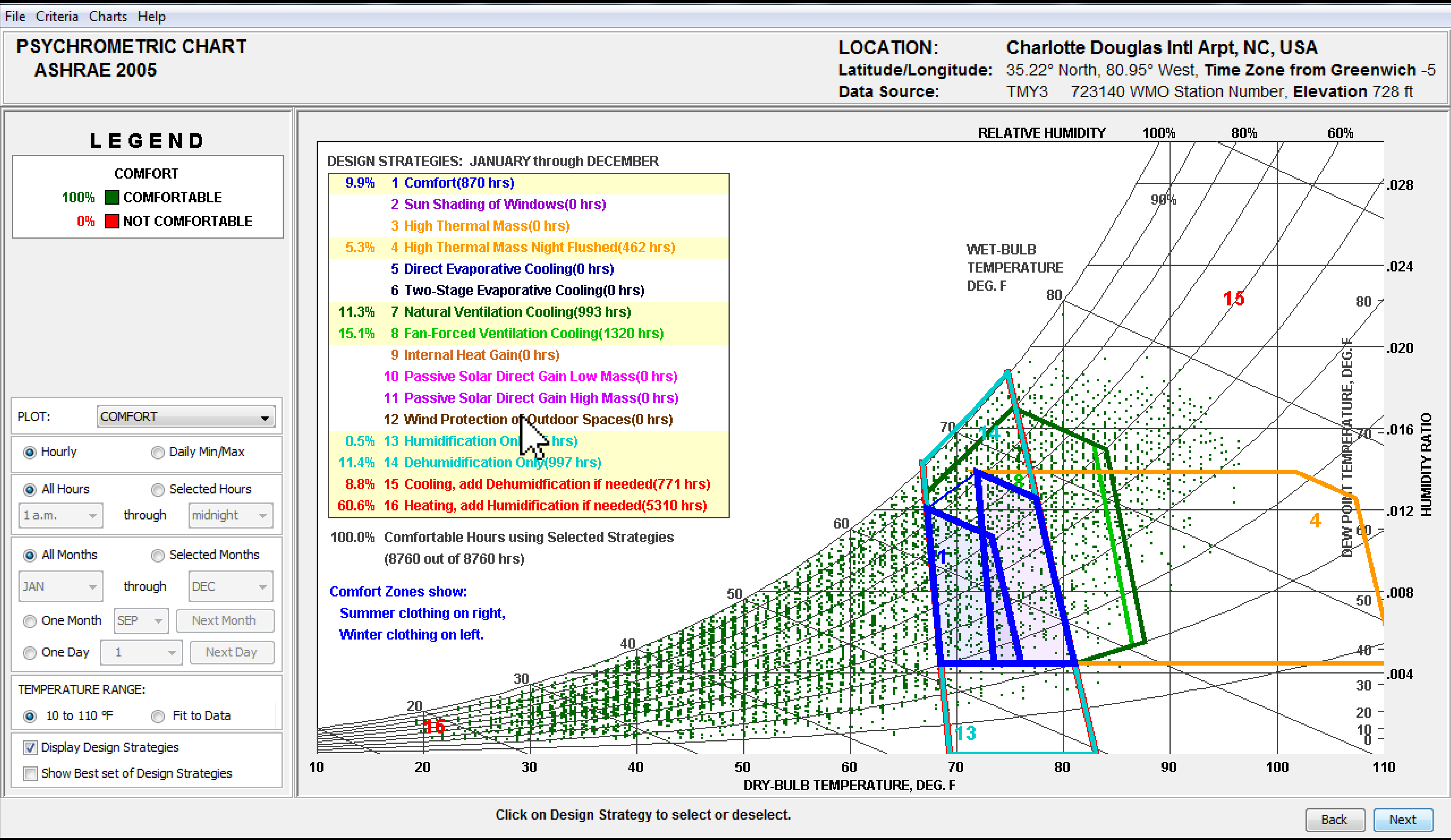
Design Strategies



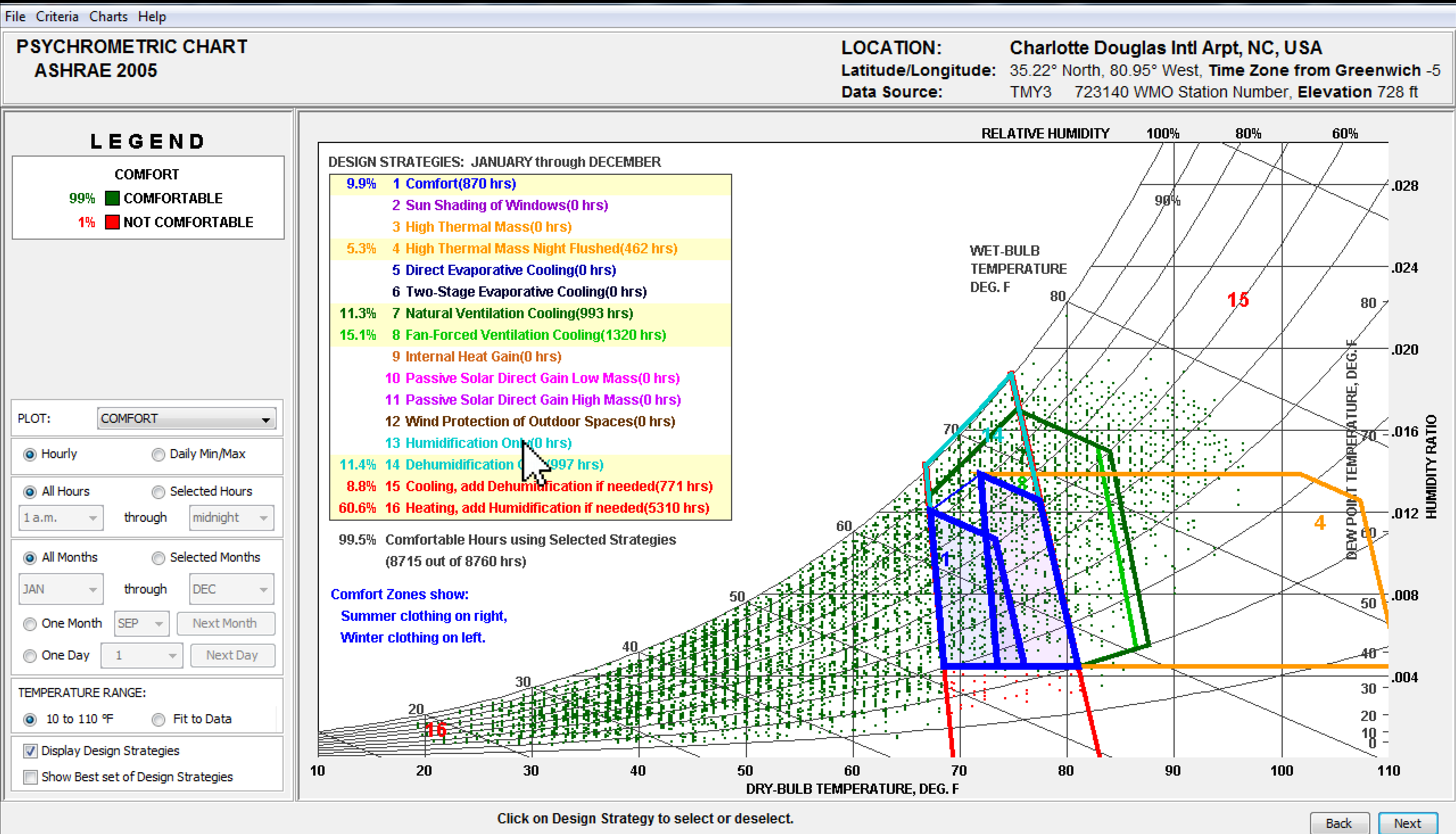
Design Strategies



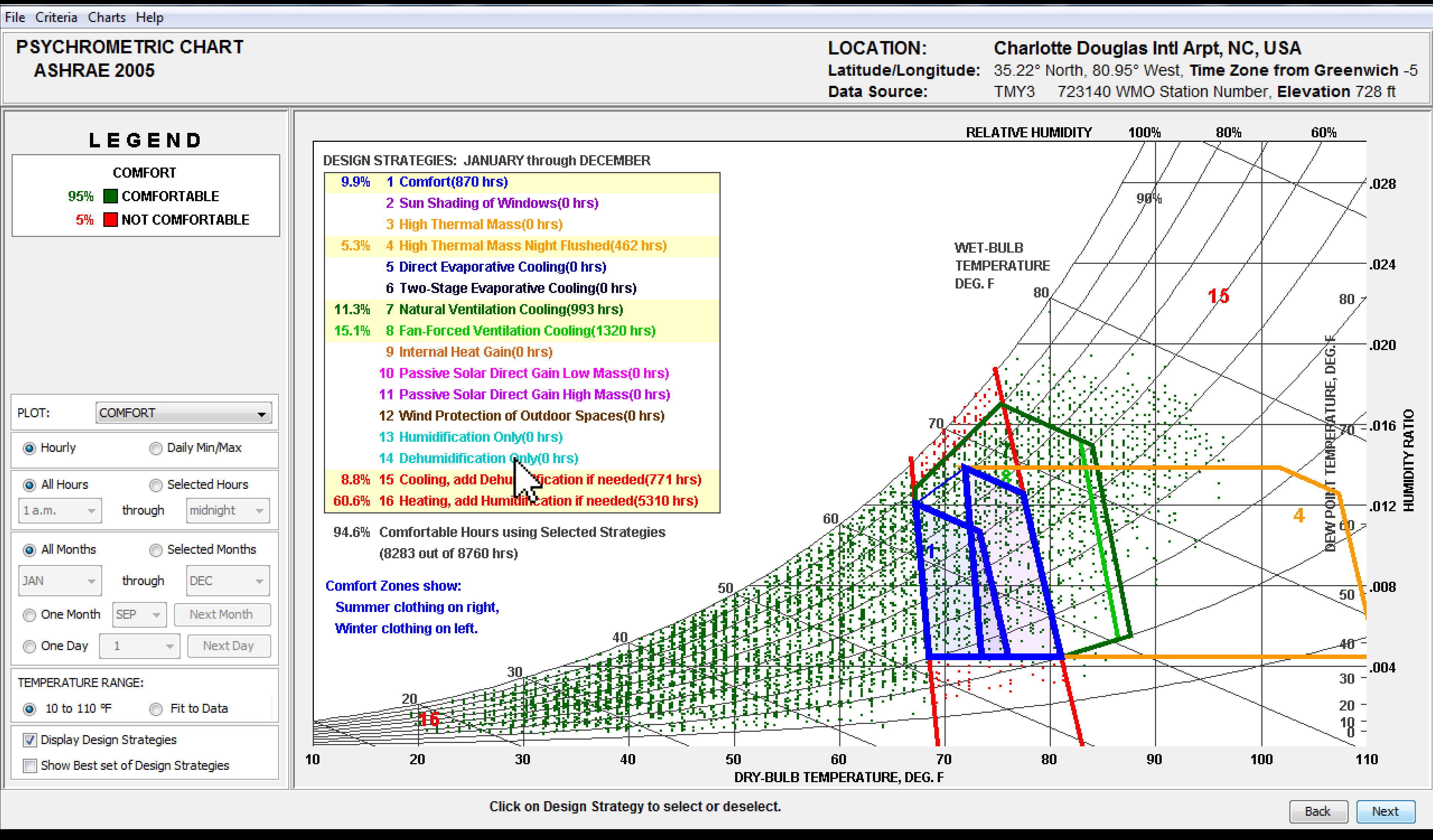
Design Strategies



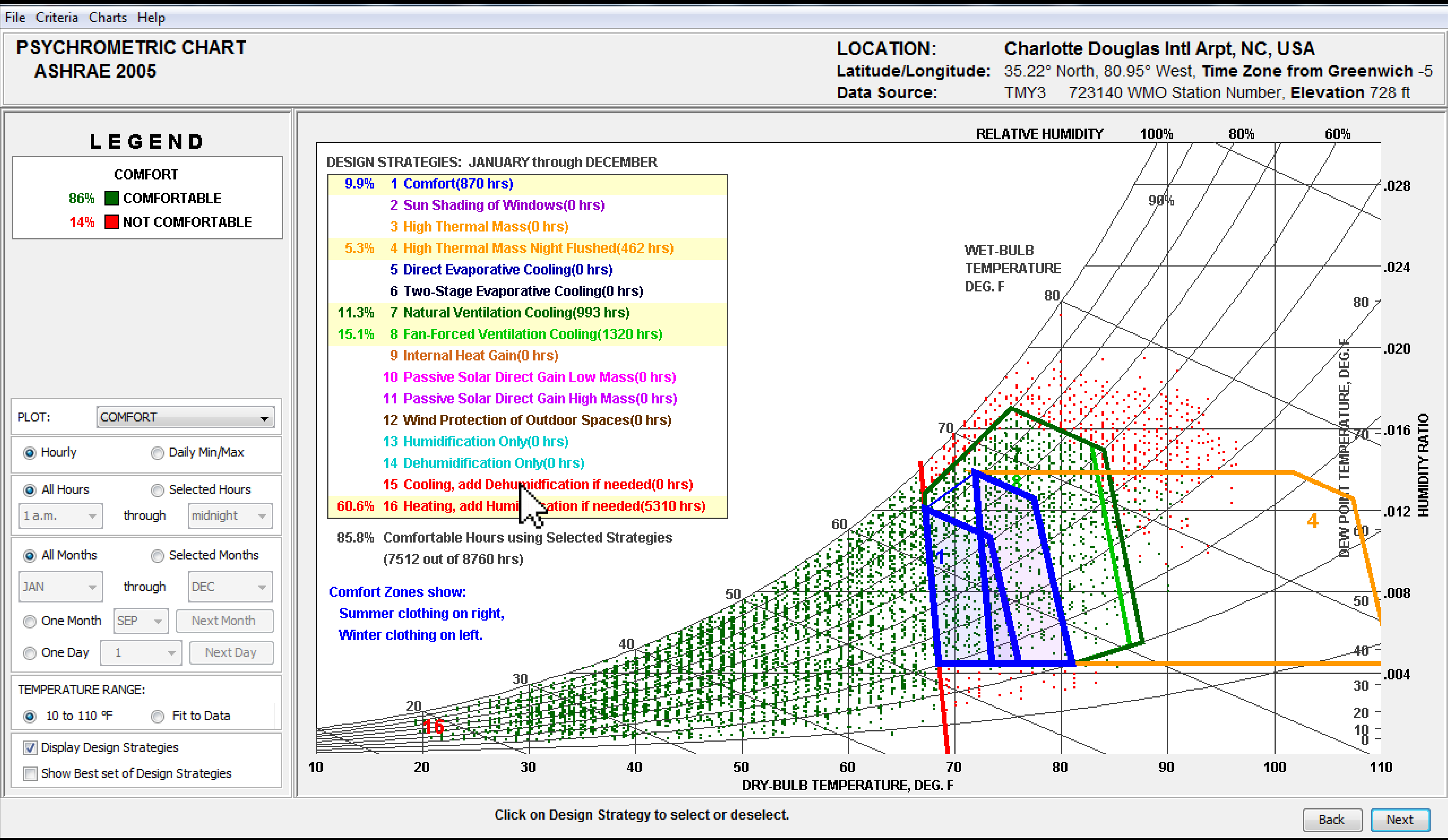
Design Strategies



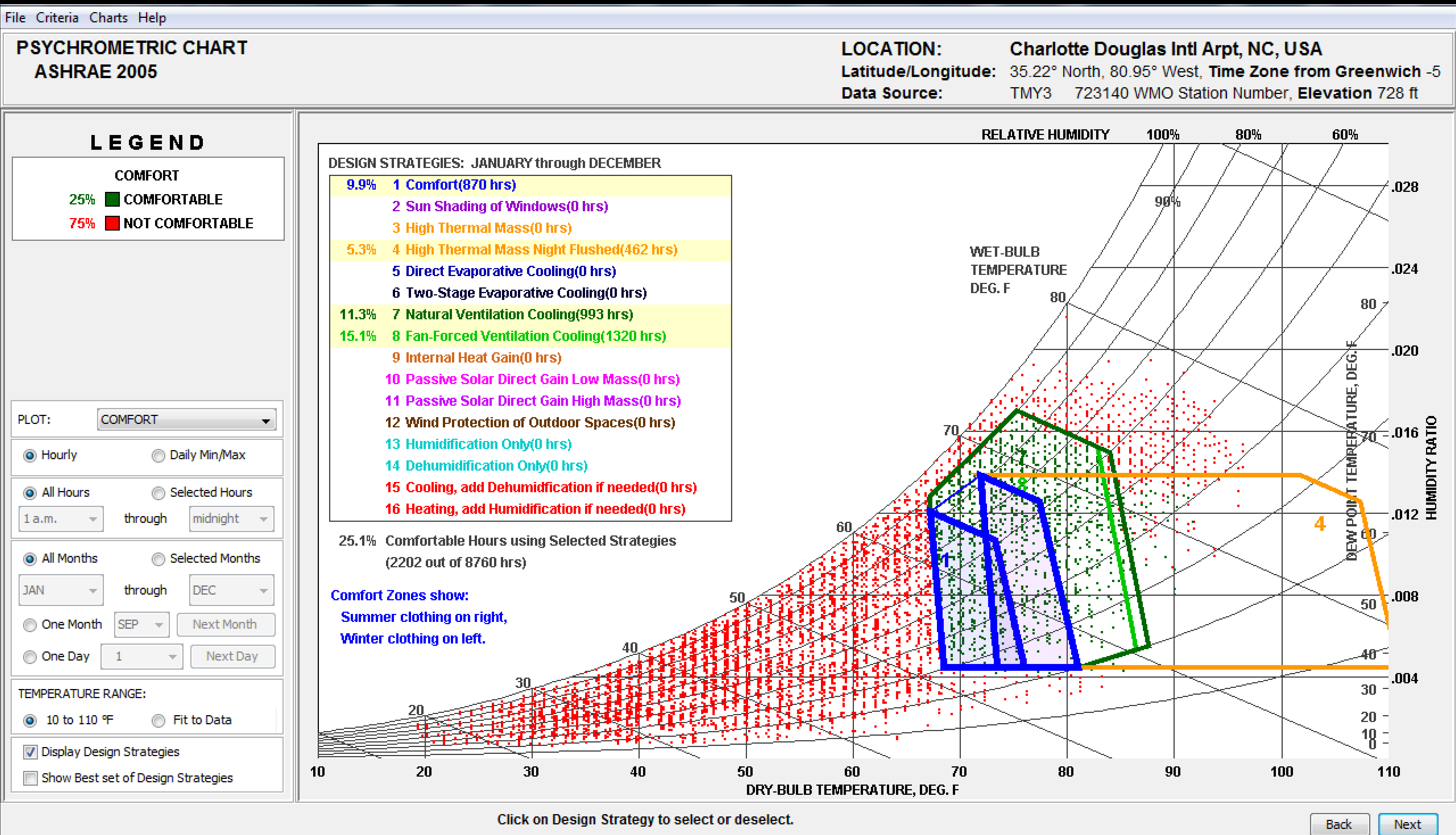
Design Strategies



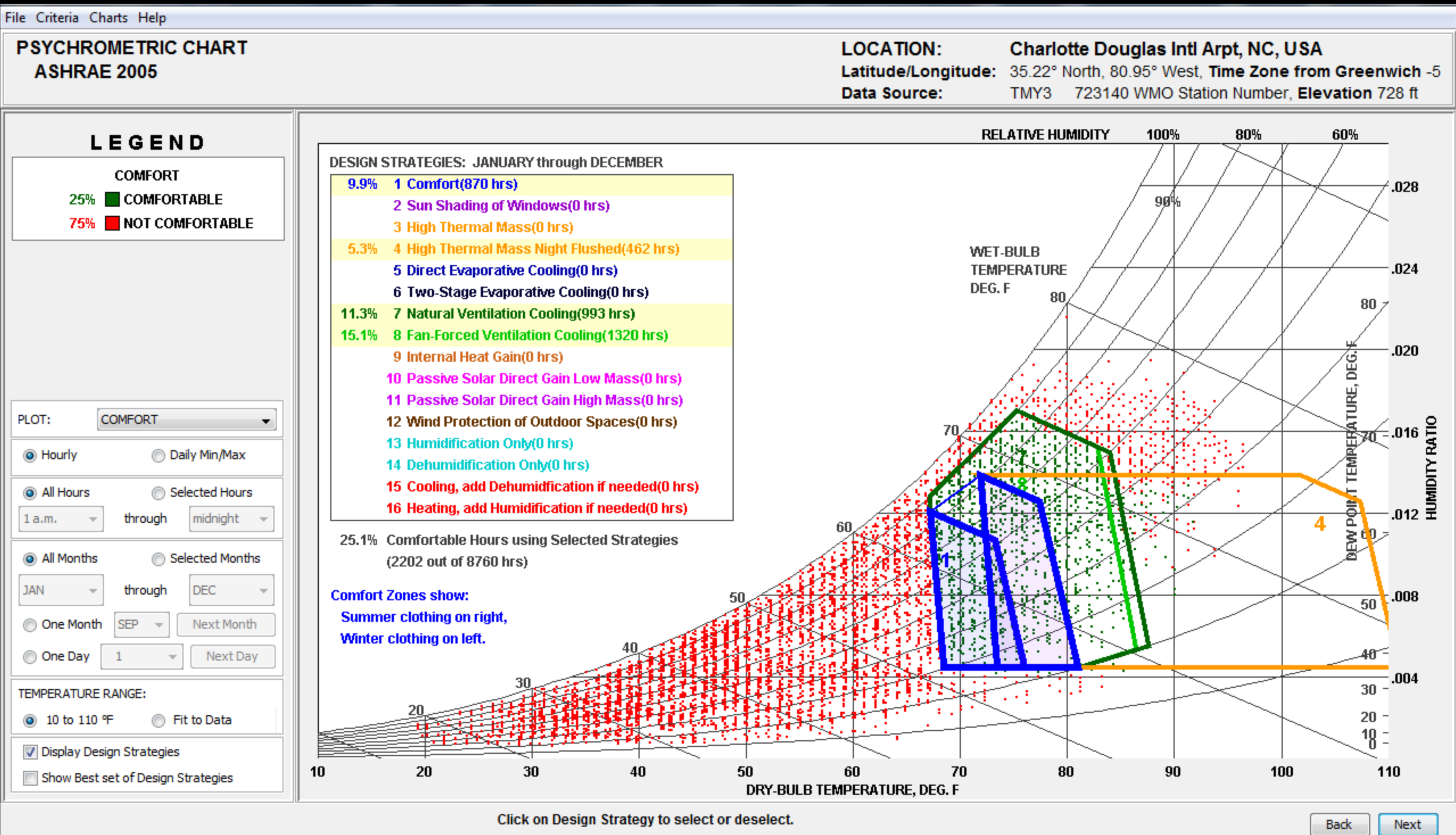
Design Strategies



Design Strategies



Design Strategies



tegies

File C

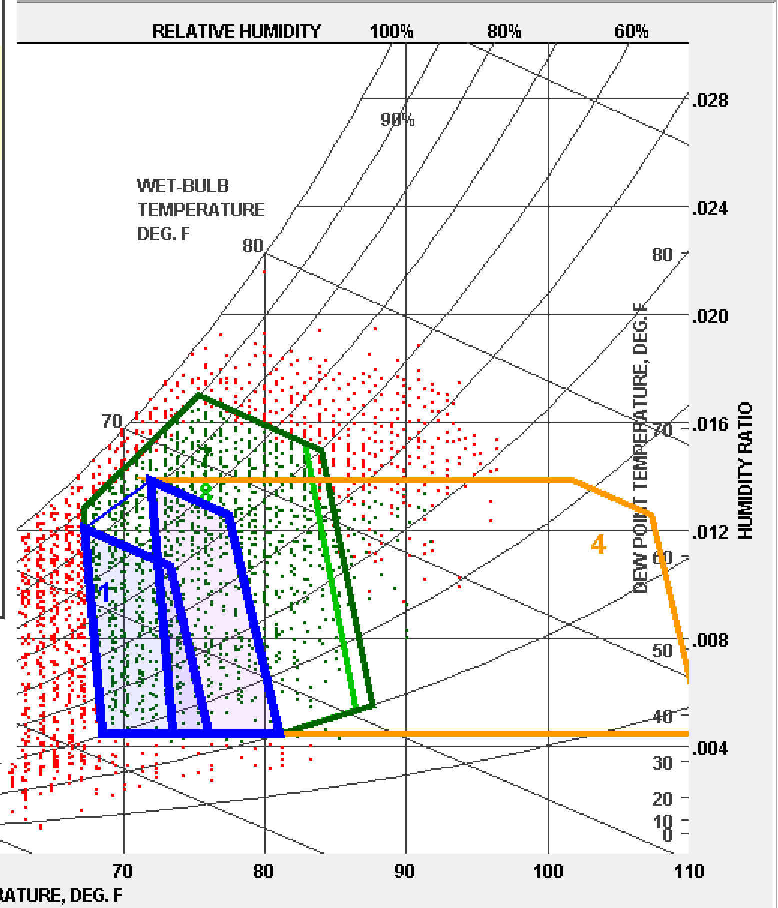
PS
A

ATION: Charlotte Douglas Intl Arpt, NC, USA
ude/Longitude: 35.22° North, 80.95° West, **Time Zone from Greenwich** -5
Source: TMY3 723140 WMO Station Number, **Elevation** 728 ft

DESIGN STRATEGIES: JANUARY through DECEMBER

9.9%	1 Comfort(870 hrs)
	2 Sun Shading of Windows(0 hrs)
	3 High Thermal Mass(0 hrs)
5.3%	4 High Thermal Mass Night Flushed(462 hrs)
	5 Direct Evaporative Cooling(0 hrs)
	6 Two-Stage Evaporative Cooling(0 hrs)
11.3%	7 Natural Ventilation Cooling(993 hrs)
15.1%	8 Fan-Forced Ventilation Cooling(1320 hrs)
	9 Internal Heat Gain(0 hrs)
	10 Passive Solar Direct Gain Low Mass(0 hrs)
	11 Passive Solar Direct Gain High Mass(0 hrs)
	12 Wind Protection of Outdoor Spaces(0 hrs)
	13 Humidification Only(0 hrs)
	14 Dehumidification Only(0 hrs)
	15 Cooling, add Dehumidfication if needed(0 hrs)
	16 Heating, add Humidification if needed(0 hrs)

25.1% Comfortable Hours using Selected Strategies
(2202 out of 8760 hrs)



PLOT

1 a.

JAN

TEMPERATURE RANGE:
10 to 110 °F   Fit to Data

Display Design Strategies
Show Best set of Design Strategies

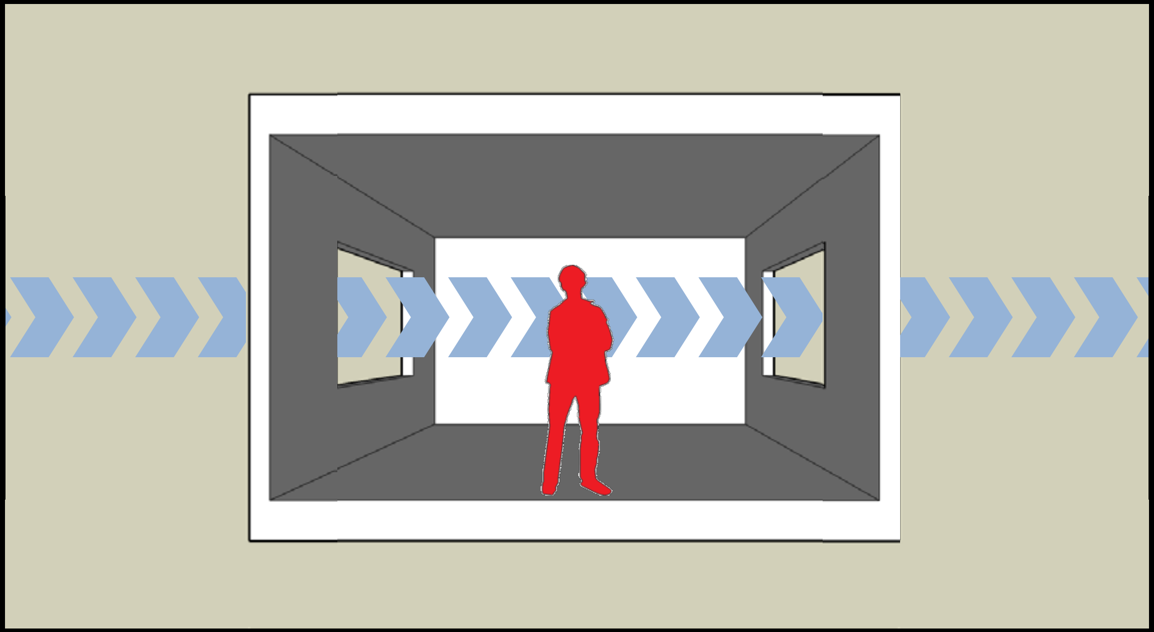
10 20 30 40 50 60 70 80 90 100 110
DRY-BULB TEMPERATURE, DEG. F

Click on Design Strategy to select or deselect.

Back   Next

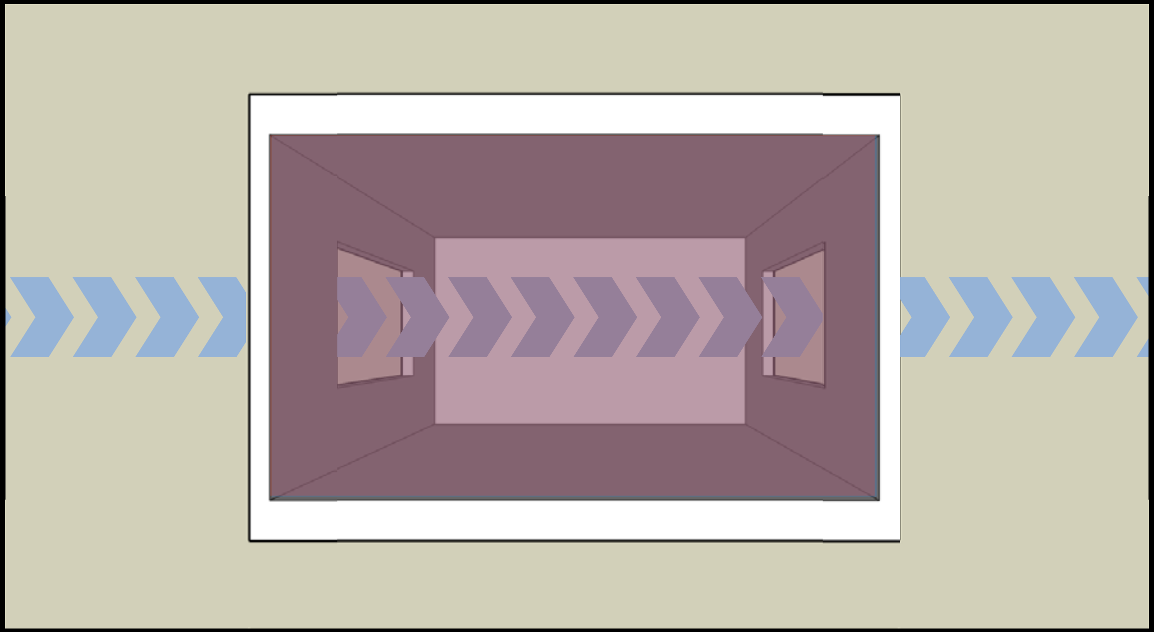
Natural Ventilation Cooling

Natural ventilation cooling is used to cool the occupants



Natural Ventilation Cooling

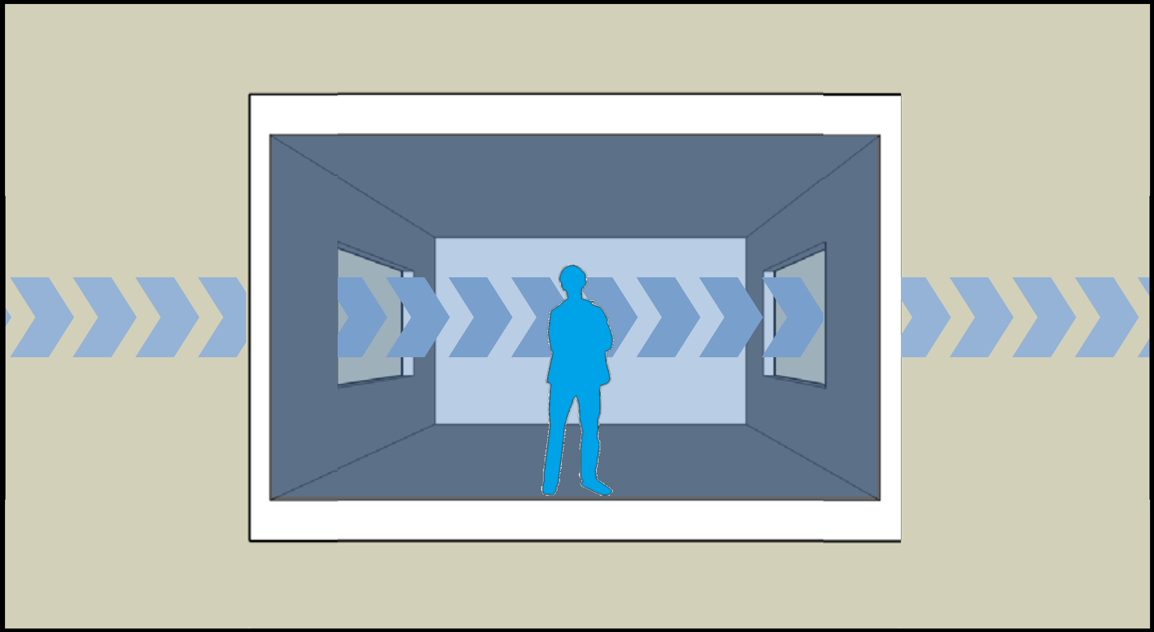
Natural ventilation cooling is used to cool the occupants and/or the building.



Natural Ventilation Cooling

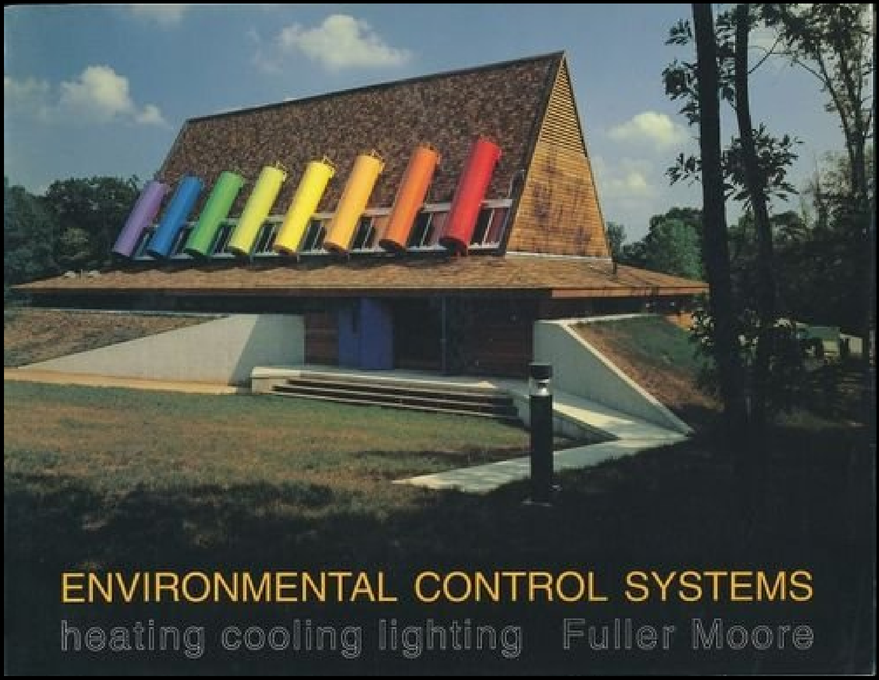
Natural ventilation cooling is used to cool the occupants and/or the building.

Cooling the building requires a higher ventilation rate so it governs the sizing of openings.



Wind Induced Cooling

An excellent resource for determining the required opening sizes for wind induced cooling is, *Environmental Control Systems: heating, cooling, lighting* by Fuller Moore.



The bad news is it is out of print. The good news is it was widely used in teaching so there are plenty of used copies available.

Wind Induced Cooling

"Chapter 15 – Passive Cooling: Ventilation" and "Appendix F: Worksheets" provide an easy to follow, step-by-step process for sizing openings.

Wind Induced Cooling

With a few changes, we will quickly run through the process for a house in Charlotte, NC.

The intent is not to teach the process but to demonstrate how it works and the amount of ventilation required to provide thermal comfort.

Wind Induced Cooling

1. Building conditioned floor area = 1,600 ft^2

Wind Induced Cooling

1. Building conditioned floor area = 1,600 ft^2
2. Average ceiling height = 9 ft

Wind Induced Cooling

1. Building conditioned floor area = 1,600 ft^2
2. Average ceiling height = 9 ft
3. House volume = (step 1) x (step 2) = 14,400 ft^3

Wind Induced Cooling

1.	Building conditioned floor area =	1,600	ft^2
2.	Average ceiling height =	9	ft
3.	House volume = (step 1) x (step 2) =	14,400	ft^3
4.	Design air change rate / hour (recommended value is 30) =	30	ACH

Wind Induced Cooling

1.	Building conditioned floor area =	1,600	ft^2
2.	Average ceiling height =	9	ft
3.	House volume = (step 1) x (step 2) =	14,400	ft^3
4.	Design air change rate / hour (recommended value is 30) =	30	ACH

"Experiments have demonstrated that a constant airflow of 15 air changes per hour (ACH) in a residence of typical construction (frame, slab-on-grade) will maintain the average interior air temperature within 3 °F of ambient, with a peak of 5 °F above ambient in late afternoon."

Wind Induced Cooling

1. Building conditioned floor area =	1,600	ft^2
2. Average ceiling height =	9	ft
3. House volume = (step 1) x (step 2) =	14,400	ft^3
4. Design air change rate / hour (recommended value is 30) =	30	ACH

"Raising the ventilation rate to 30 ACH brings the average house temperature within 1.25 °F of ambient (Chandra et al., 1986)."

[Moore, 191]

Wind Induced Cooling

1.	Building conditioned floor area =	1,600	ft^2
2.	Average ceiling height =	9	ft
3.	House volume = (step 1) x (step 2) =	14,400	ft^3
4.	Design air change rate / hour (recommended value is 30) =	30	ACH
5.	Required air flow rate, cfm = (step 3) x (step 4) / 60 =	7,200	cfm

Wind Induced Cooling

1.	Building conditioned floor area =	1,600	ft^2
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5.	Required air flow rate, cfm = (step 3) x (step 4) / 60 =	7,200	cfm

Looking back at the ventilation rate to maintain indoor air quality, the required amount is 46 cfm. Providing thermal comfort requires more than 150 times more air.

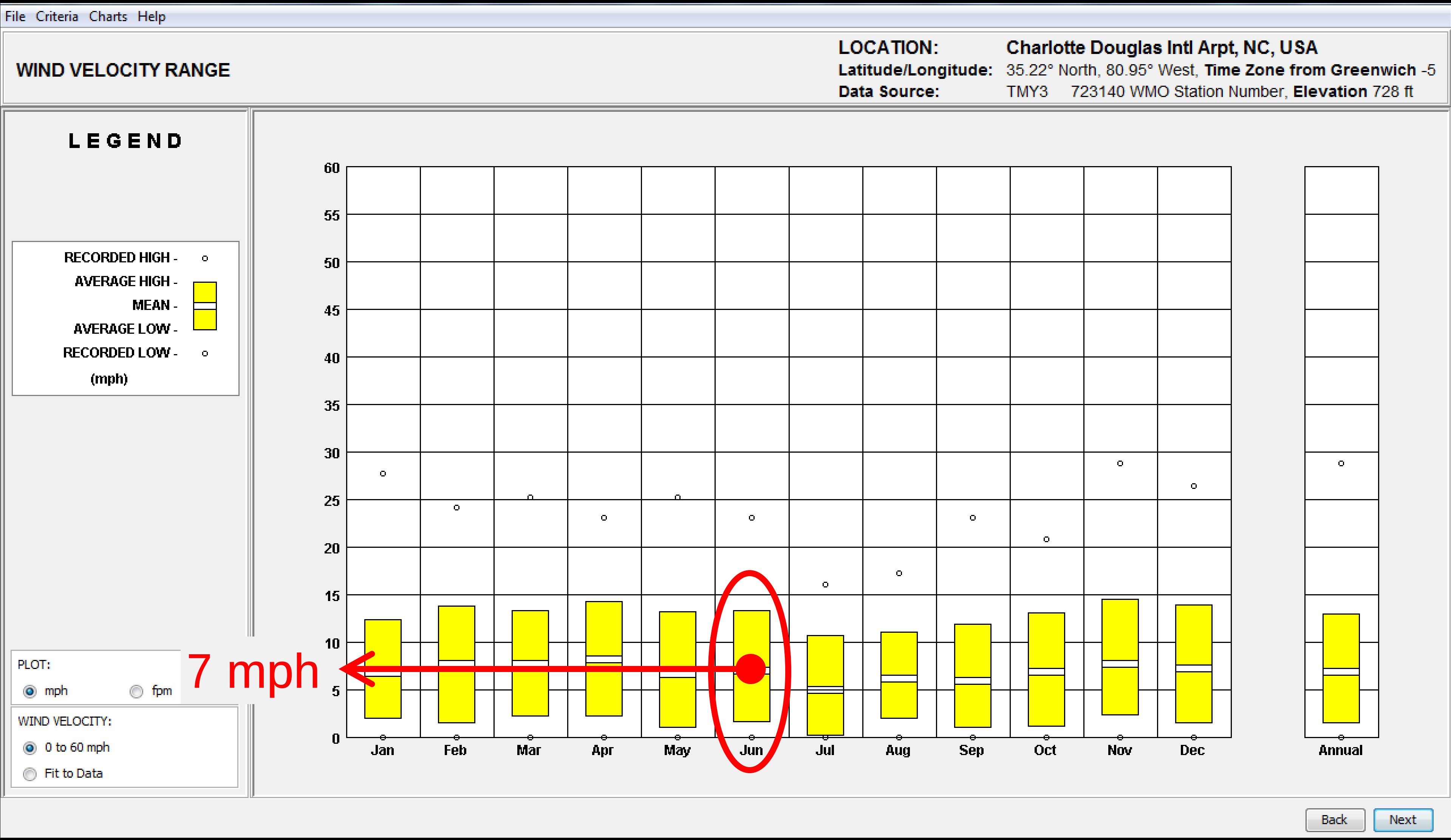
Wind Induced Cooling

1.	Building conditioned floor area =	1,600	ft^2
2.	Average ceiling height =	9	ft
3.	House volume = (step 1) x (step 2) =	14,400	ft^3
4.	Design air change rate / hour (recommended value is 30) =	30	ACH
5.	Required air flow rate, cfm = (step 3) x (step 4) / 60 =	7,200	cfm
6.	Design month (recommended: May for Florida and Gulf Coast; June elsewhere)	June	

Wind Induced Cooling

7. Using Climate Consultant, determine mph wind speed for design month

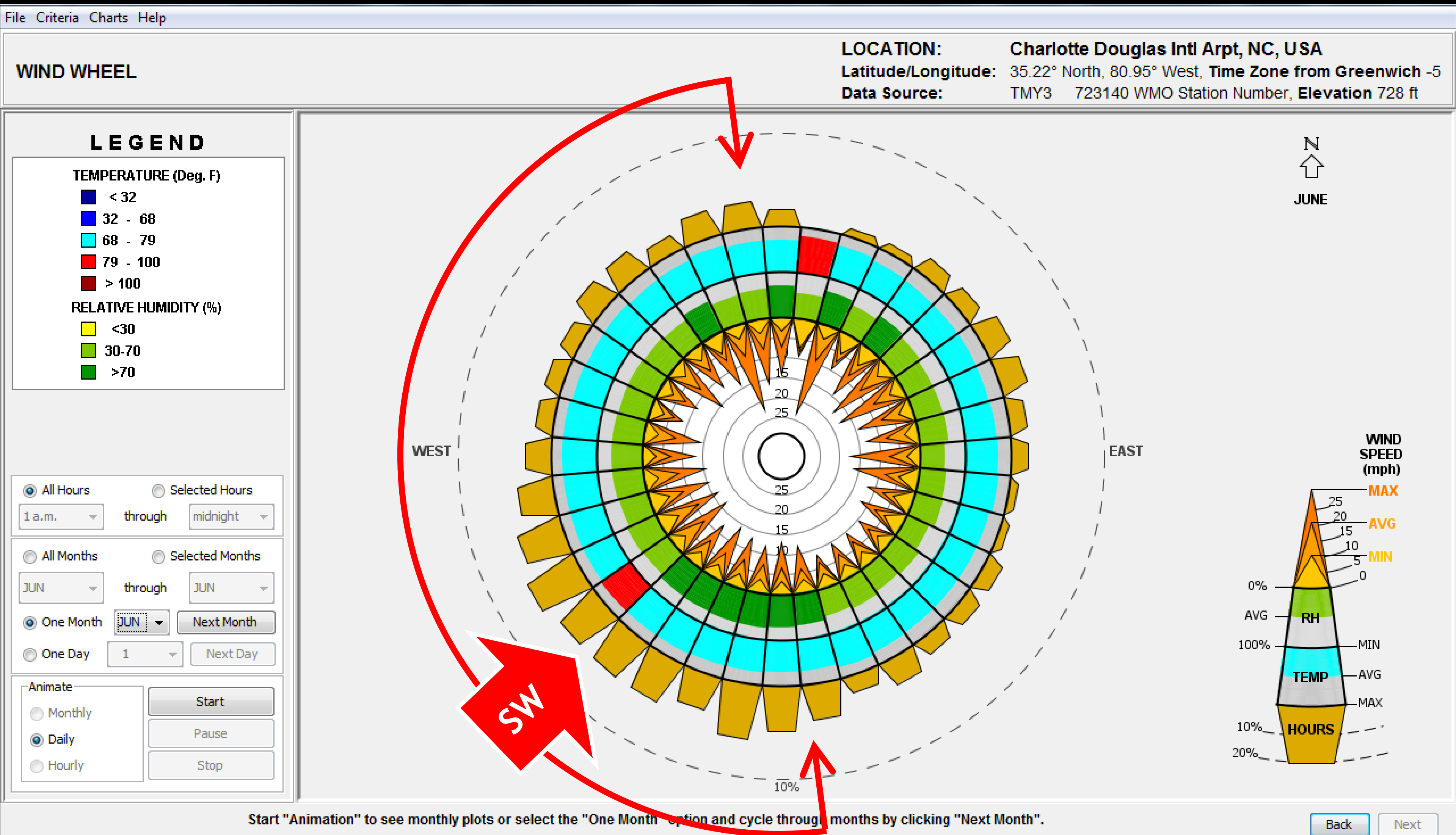
Wind Induced Cooling



Wind Induced Cooling

7. Using Climate Consultant, determine wind speed for design month — 7 mph
8. Using Climate Consultant, determine wind direction for design month

Wind Induced Cooling



Wind Induced Cooling

7. Using Climate Consultant, determine wind speed for design month — 7 mph
8. Using Climate Consultant, determine wind direction for design month — SW

Wind Induced Cooling

7. Using Climate Consultant, determine wind speed for design month — 7 mph
8. Using Climate Consultant, determine wind direction for design month — SW
9. From wind direction, determine the incidence angle on the *windward* wall having the largest area of window (0° = perpendicular to wall) — ± 20 °

Wind Induced Cooling

7. Using Climate Consultant, determine wind speed for design month	7	mph
8. Using Climate Consultant, determine wind direction for design month	SW	
9. From wind direction, determine the incidence angle on the *windward* wall having the largest area of window (0° = perpendicular to wall)	± 20	°

With the intent of designing a climate appropriate house, the windward wall having the largest window area will be oriented within 20 degrees of being perpendicular to the wind direction.

Wind Induced Cooling

10. Determine inlet-to-site 10-meter windspeed ratio (Table 15.1 in Moore, or from various internet sites) = 0.35

Wind Induced Cooling

10.	Determine inlet-to-site 10-meter windspeed ratio (Table 15.1 in Moore, or from various internet sites) =	0.35

For wind incidence angles between 0°and 40° the windspeed ratio (WSR) is 0.35.

Wind Induced Cooling

10.	Determine inlet-to-site 10-meter windspeed ratio (Table 15.1 in Moore, or from various internet sites) =	0.35
11.	Determine windspeed correction factors:	
a.	For house location and ventilation strategy, determine terrain correction factor (Table 15.2 in Moore, or from various internet sites) =	0.47

Wind Induced Cooling

10.	Determine inlet-to-site 10-meter windspeed ratio (Table 15.1 in Moore, or from various internet sites) =	0.35
11.	Determine windspeed correction factors:	
a.	For house location and ventilation strategy, determine terrain correction factor (Table 15.2 in Moore, or from various internet sites) =	0.47

For 24-hour ventilation on an urban site, the terrain correction factor (TCF) is 0.47.

Wind Induced Cooling

b. For neighboring buildings, assume neighborhood convection factor = 0.77; no surrounding building = 1.0 0.77

Wind Induced Cooling

b.	For neighboring buildings, assume neighborhood convection factor = 0.77; no surrounding building = 1.0	0.77
c.	Second floor window (or for house of stilts), correction factor = 1.15; all others, correction factor = 1.0	1.0

Wind Induced Cooling

b.	For neighboring buildings, assume neighborhood convection factor = 0.77; no surrounding building = 1.0	0.77
c.	Second floor window (or for house of stilts), correction factor = 1.15; all others, correction factor = 1.0	1.0
12.	Calculate windspeed correction factor (step 11a) x (step 11b) x (step 11c) =	0.36

Wind Induced Cooling

b.	For neighboring buildings, assume neighborhood convection factor = 0.77; no surrounding building = 1.0	0.77	
c.	Second floor window (or for house of stilts), correction factor = 1.15; all others, correction factor = 1.0	1.0	
12.	Calculate windspeed correction factor (step 11a) x (step 11b) x (step 11c) =	0.36	
13.	Calculate site windspeed in ft/min (step 7) x (step 12) x 88 =	223	ft/min

Wind Induced Cooling

b.	For neighboring buildings, assume neighborhood convection factor = 0.77; no surrounding building = 1.0	0.77	
c.	Second floor window (or for house of stilts), correction factor = 1.15; all others, correction factor = 1.0	1.0	
12.	Calculate windspeed correction factor (step 11a) x (step 11b) x (step 11c) =	0.36	
13.	Calculate site windspeed in ft/min (step 7) x (step 12) x 88 =	223	ft/min
14.	Calculate window inlet airspeed (step 13) x (step 10) =	78	ft/min

Wind Induced Cooling

15. Calculate net aperture inlet area (step 5) / (step 14) = 92 ft^2

Wind Induced Cooling

15. Calculate net aperture inlet area (step 5) / (step 14) = 92 ft^2

16. Determine total effective inlet + outlet area (screened) 3.33 x (step 15) = 307 ft^2

Wind Induced Cooling

15. Calculate net aperture inlet area (step 5) / (step 14) = 92 ft^2

16. Determine total effective inlet + outlet area (screened) 3.33 x (step 15) = 307 ft^2

17. Determine total effective area as a percentage of floor area (step 16) / (step 1) x 100 = 19.2 %

Wind Induced Cooling

15. Calculate net aperture inlet area (step 5) / (step 14) = 92 ft^2
16. Determine total effective inlet + outlet area (screened) 3.33 x (step 15) = 307 ft^2
17. Determine total effective area as a percentage of floor area (step 16) / (step 1) x 100 = 19.2 %

This percentage is roughly four times what is required by most building codes for operable windows; and, it demonstrates the form giving nature of natural ventilation.

Wind Induced Cooling

While wind induced cooling is architecturally form giving, it is stack effect cooling that tends to have a greater influence on architectural form.

Brick Kiln House
Maharashtra, India
Spasm Design Architects
[www.spasmindia.com]

Stack Effect Cooling

Determining the opening sizes for stack effect cooling is a more involved process, so it is a topic for another time.

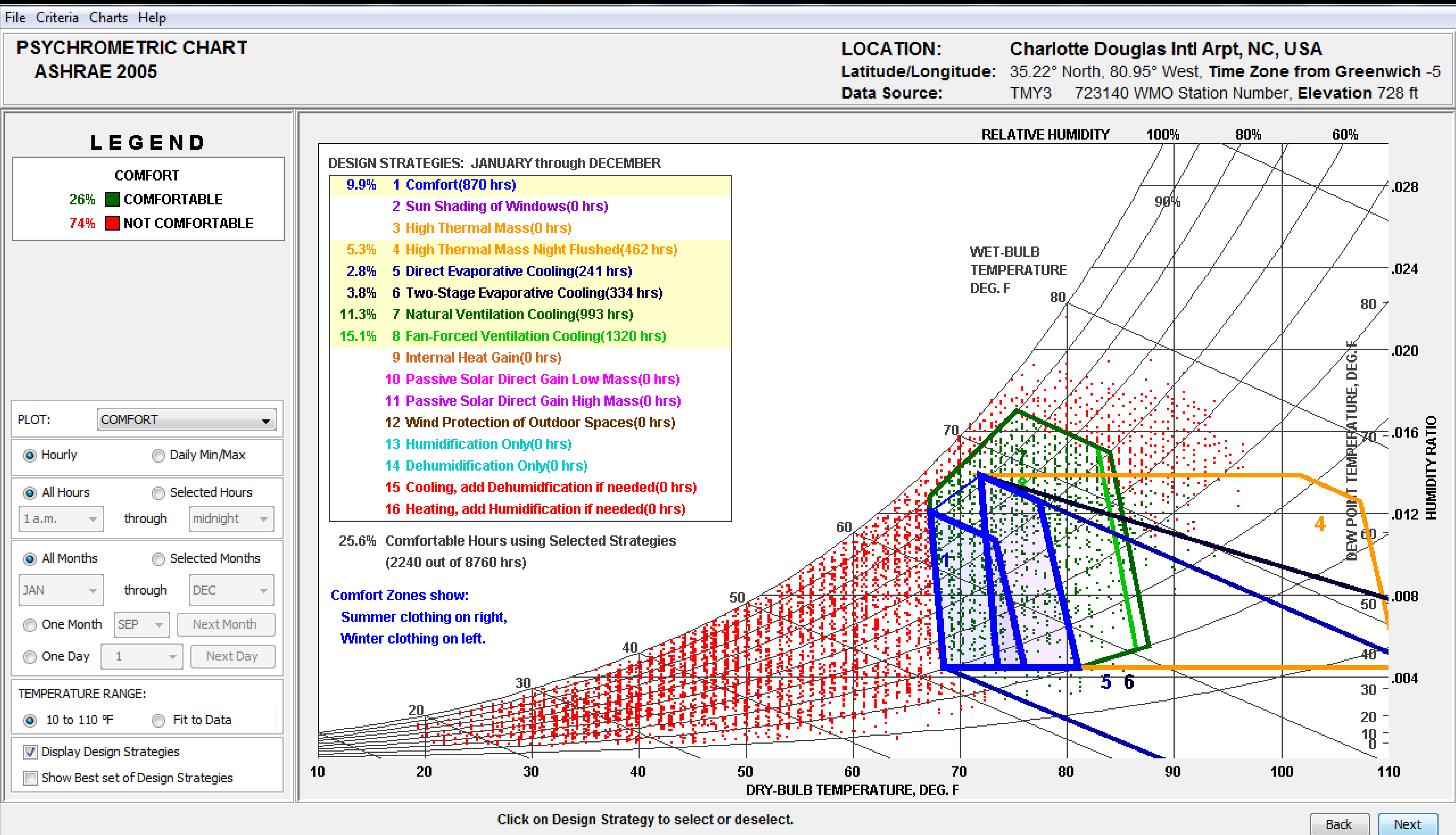
Brick Kiln House
Maharashtra, India
Spasm Design Architects
[www.spasmindia.com]

Stack Effect Cooling

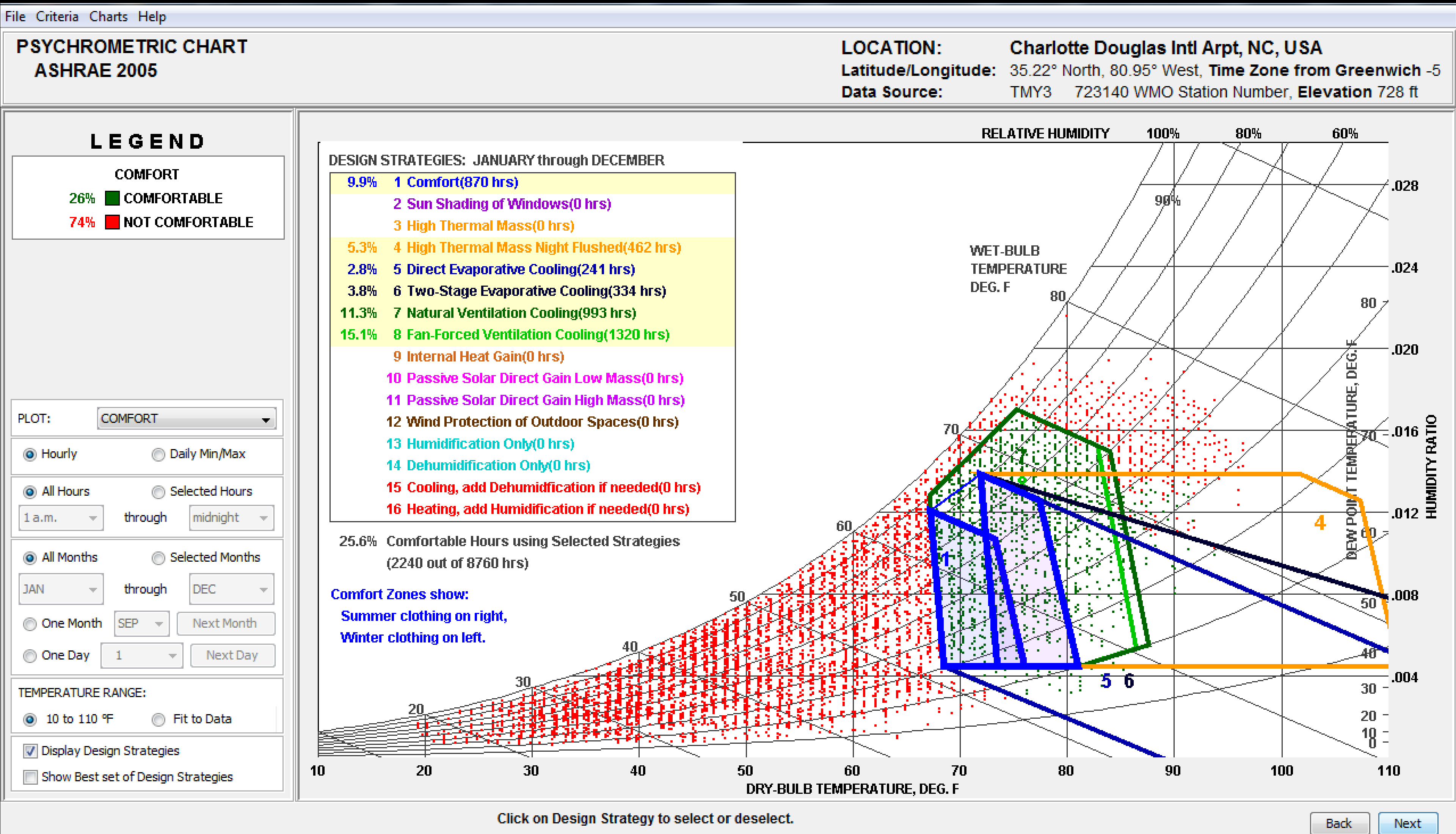
We will move onto forced ventilation by returning to the **design strategies**.

Brick Kiln House
Maharashtra, India
Spasm Design Architects
[www.spasmindia.com]

Design Strategies



Design Strategies



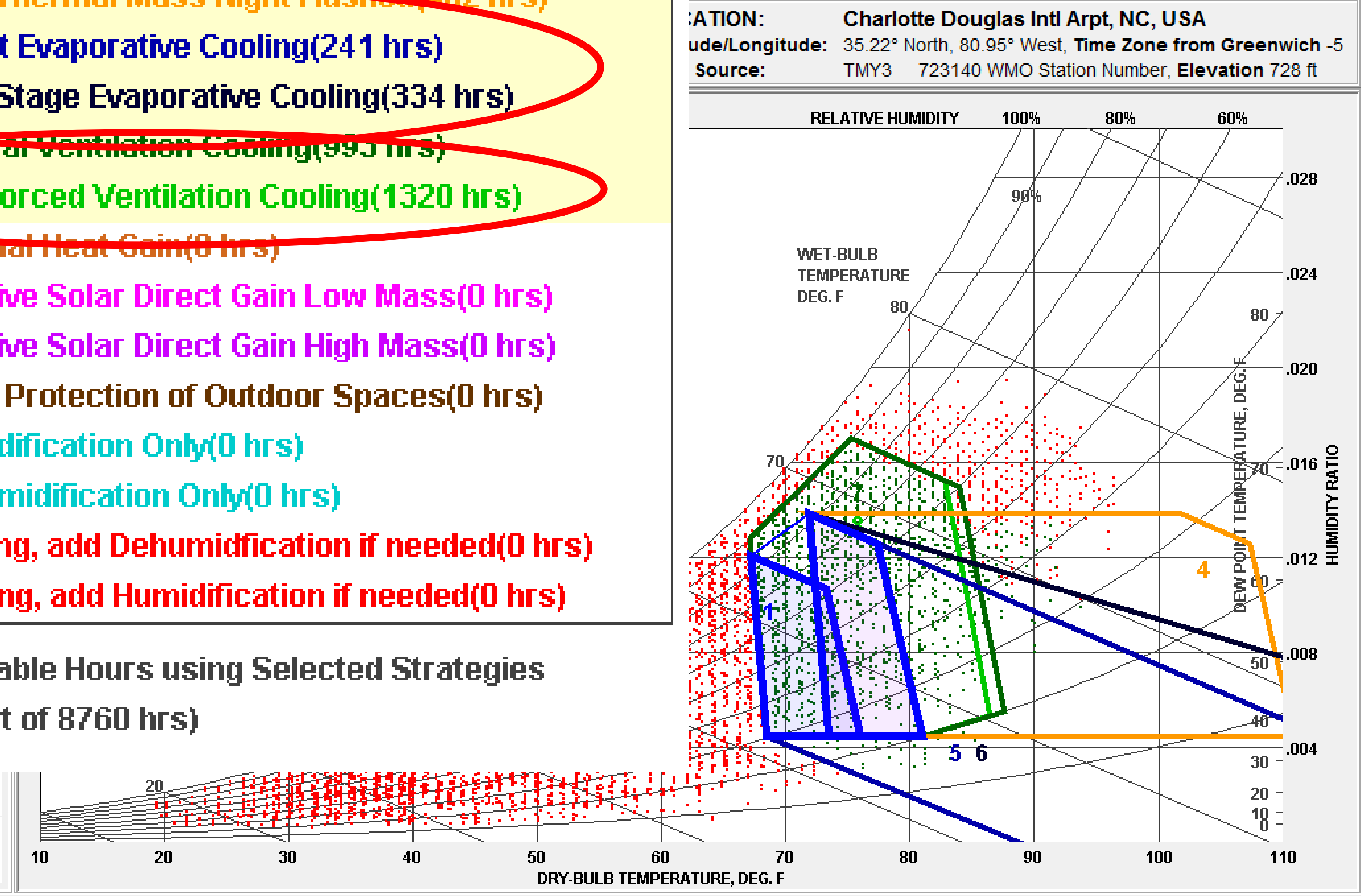
tegies

DESIGN STRATEGIES: JANUARY through DECEMBER

9.9%	1 Comfort(870 hrs)
	2 Sun Shading of Windows(0 hrs)
	3 High Thermal Mass(0 hrs)
5.3%	4 High Thermal Mass Night Flushed(462 hrs)
2.8%	5 Direct Evaporative Cooling(241 hrs)
3.8%	6 Two-Stage Evaporative Cooling(334 hrs)
11.3%	7 Natural Ventilation Cooling(995 hrs)
15.1%	8 Fan-Forced Ventilation Cooling(1320 hrs)
	9 Internal Heat Gain(0 hrs)
	10 Passive Solar Direct Gain Low Mass(0 hrs)
	11 Passive Solar Direct Gain High Mass(0 hrs)
	12 Wind Protection of Outdoor Spaces(0 hrs)
	13 Humidification Only(0 hrs)
	14 Dehumidification Only(0 hrs)
	15 Cooling, add Dehumidifcation if needed(0 hrs)
	16 Heating, add Humidification if needed(0 hrs)

25.6% Comfortable Hours using Selected Strategies

(2240 out of 8760 hrs)



Click on Design Strategy to select or deselect.

Back Next

Fan-Forced Ventilation Cooling

As with natural ventilation cooling, fan-forced ventilation cooling is used to cool the occupants and/or the building.

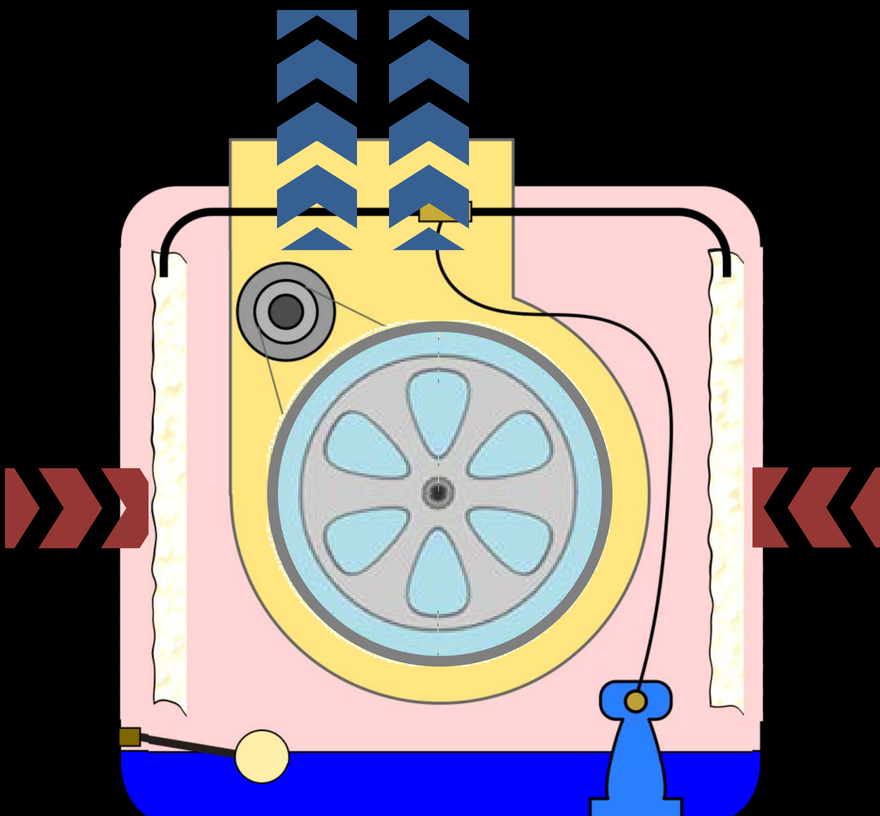
Fan-Forced Ventilation Cooling

As with natural ventilation cooling, fan-forced ventilation cooling is used to cool the occupants and/or the building.

The two primary means for providing fan-forced ventilation cooling are with a direct or two-stage evaporative cooler, or with a whole-house fan.

In Climate Consultant these means are listed as separate strategies because their effectiveness is dependent on different climate conditions.

Evaporative Cooler



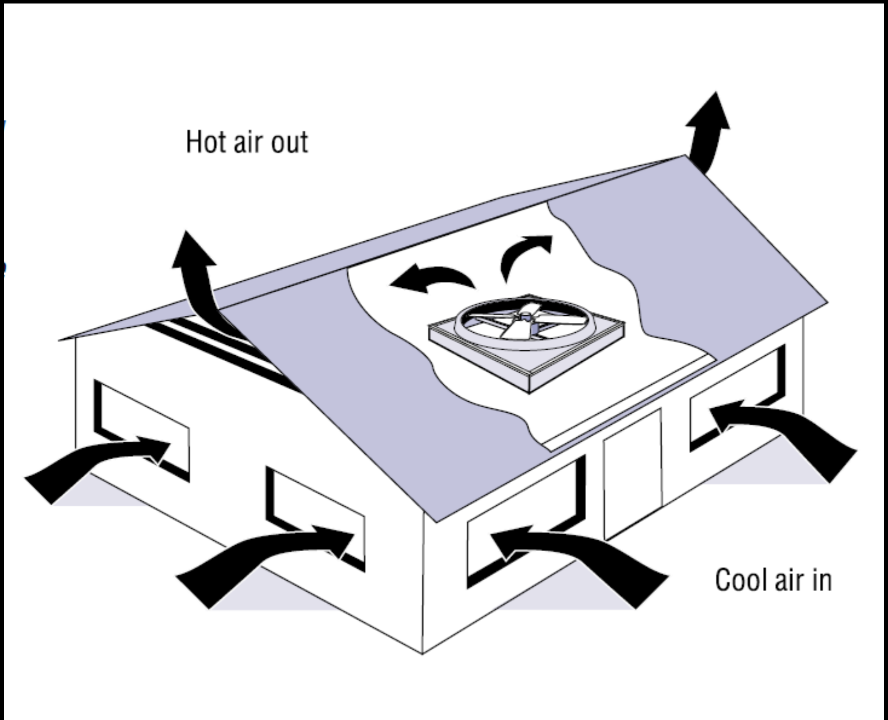
Using evaporation, a direct evaporative cooler lowers the dry bulb temperature of the air by converting sensible heat into latent heat. It is an effective means of fan-forced ventilation in hot-arid regions, such as Tucson, AZ.

In humid regions, such as Chicago, it is not effective.

Direct Evaporative Cooler
[wikipedia.org]

Whole-House Fan

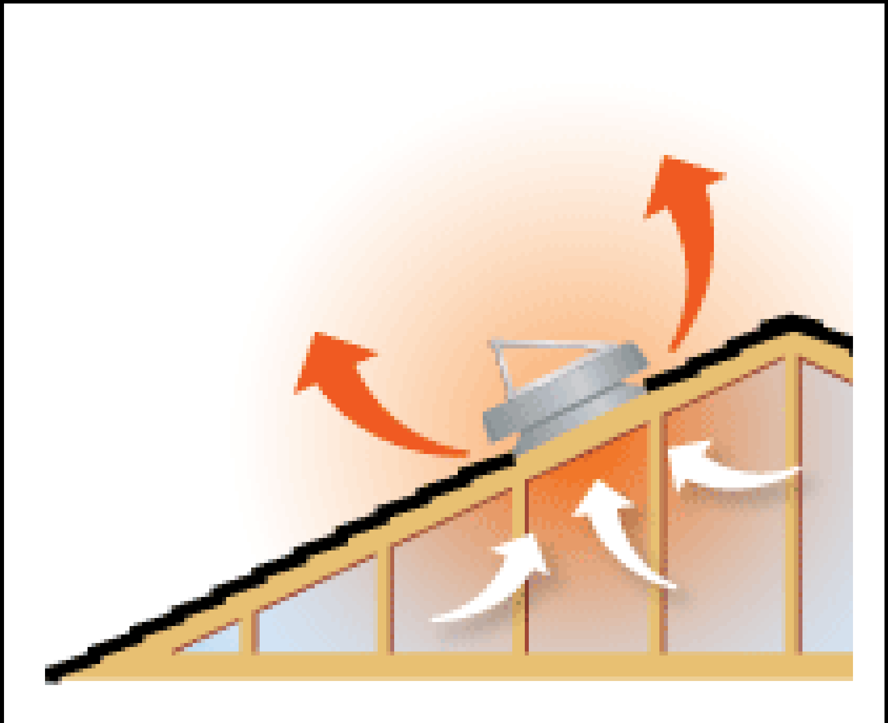
A whole-house fan provides ventilation cooling in the same way wind induced and stack effect ventilation do, by moving a large volume of air though the living spaces of the house.



Whole-House Fan
[DOE Fact Sheet, 4]

Whole-House Fan

An attic fan is not a whole-house fan. It vents the attic to prevent heat build up. It does not provide ventilation to the living spaces within the house.



Solar Attic Fan
[www.solaratticfan.com]

Whole-House Fan

The new generation of whole-house fans are more energy efficient and quieter than their predecessors.

AirScape 1.7 Whole-House Fan
[www.airscapefan.com]

Whole-House Fan

The U.S. Department of Energy provides an easy method for determining the required capacity of a whole-house fan.

Technology Fact Sheet

Buildings for the 21st Century

Buildings that are more energy-efficient, comfortable, and affordable . . . that's the goal of DOE's Office of Building Technology, State and Community Programs (BTS). To accelerate the development and wide application of energy efficiency measures, BTS:

- Conducts R&D on technologies and concepts for energy efficiency, working closely with the building industry and with manufacturers of materials, equipment, and appliances
- Promotes energy/money saving opportunities to both builders and buyers of homes and commercial buildings
- Works with State and local regulatory groups to improve building codes, appliance standards, and guidelines for efficient energy use

WHOLE HOUSE FAN

How to install and use a whole house fan

WHY USE A WHOLE HOUSE FAN?

A whole house fan is a simple and inexpensive method of cooling a house. The fan draws cool outdoor air inside through open windows and exhausts hot indoor air through the attic to the outside. Running a whole house fan whenever outdoor temperatures are lower than indoor temperatures will cool a house.

In summer, the air inside a home is heated during the hot part of the day. During the morning, late evening, and night, the outside air is often cooler and can be used to replace the inside air. Operating the whole house fan at these times will cool interior materials. As daytime temperatures rise, the whole house fan can be turned off. The cool materials (along with ceiling or circulating fans, which create an additional cooling effect) will help keep the interior more comfortable.

WHAT ARE THE BENEFITS?

A whole house fan can be used as the sole means of cooling or to reduce the need for air conditioning. If both methods of cooling are present, seasonal use of the whole house fan (during spring and fall) may yield the optimum combination of comfort and cost.

✓ Initial cost benefit

- Equipment cost for

✓ Economics of operation

- Operating a properly sized 2-ton air conditioner with a seasonal energy efficiency ratio (SEER) of 10 in Atlanta, Georgia, costs over $250 per cooling season (1,250 hours), based on 8.5¢/kWh, or roughly 20¢ per hour of runtime.
- A large 18,000 Btu/h window unit air conditioner with an energy efficiency ratio (EER) of 8.8 costs more than 17¢ to operate for one hour.
- By contrast, a whole house fan has a motor in the $^1/_4$ to $^1/_2$ hp range, uses 120 to 600 watts, and costs around 1¢ to 5¢ per hour of use.

MAXIMIZE YOUR SAVINGS WITH FAN COVERS

During the winter months (and in summer when air conditioning is used), a whole house fan represents a potential energy loss because it is essentially a large, uninsulated hole in the ceiling. Since standard fan louvers do not insulate or seal tightly, a cover should be constructed to airseal and insulate this hole (see diagrams on pages 2 and 3 for construction details). The cover may be installed from the attic side (if attic access is easily available) or

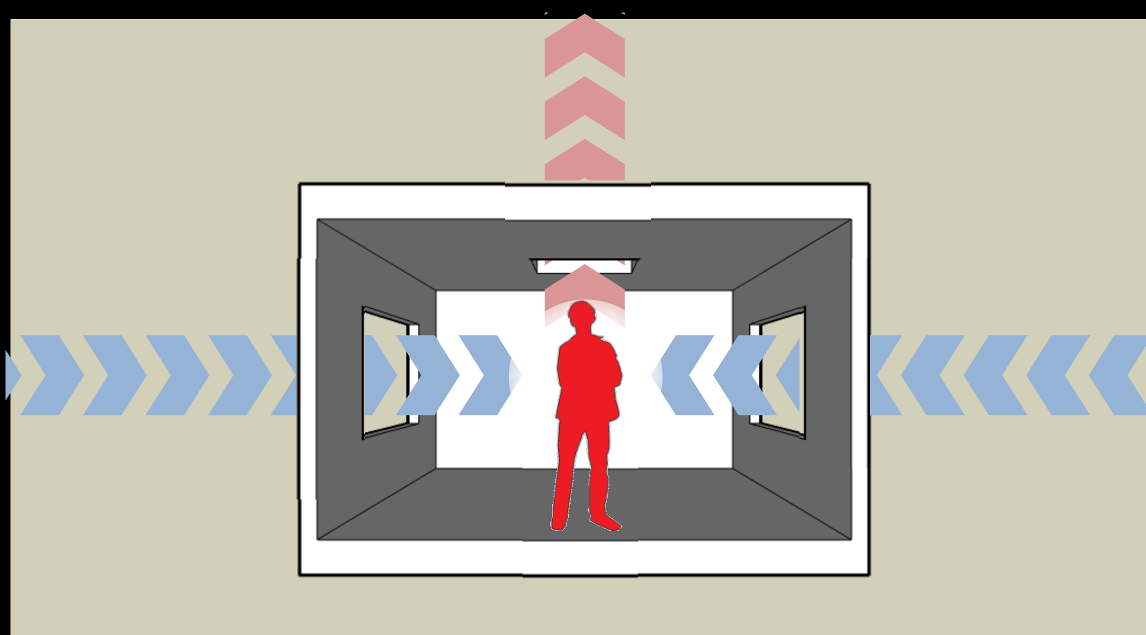
Whole House Fan Technology Fact Sheet
[DOE Fact Sheet, 1]

Whole-House Fan

$$0.5 A_{floor} h_{ceiling} \le Q_{fan} < 1.0 A_{floor} h_{ceiling}$$

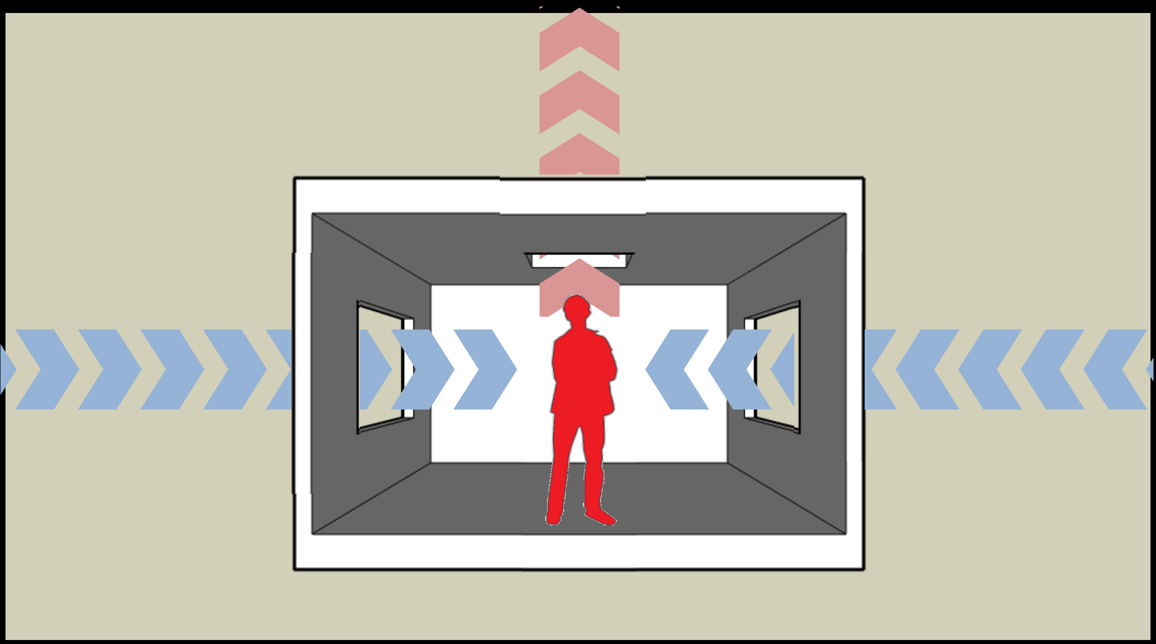
Q_{fan} $0.5 \times 1,$ $7,200 \le Q_{fan} < 14,400$ 600×9 ft²

$h_{ceiling}$ – average height of ceiling, ft



Whole-House Fan

$$7,200 \leq Q_{fan} < 14,400$$



Whole-House Fan

$$7,200 \leq Q_{fan} < 14,400$$

Two 4,410 cfm fans are required to provide fan-forced ventilation.

More Ventilation Methods

Numerous other ventilation methods are widely used in hot-arid and warm-humid regions outside the United States.

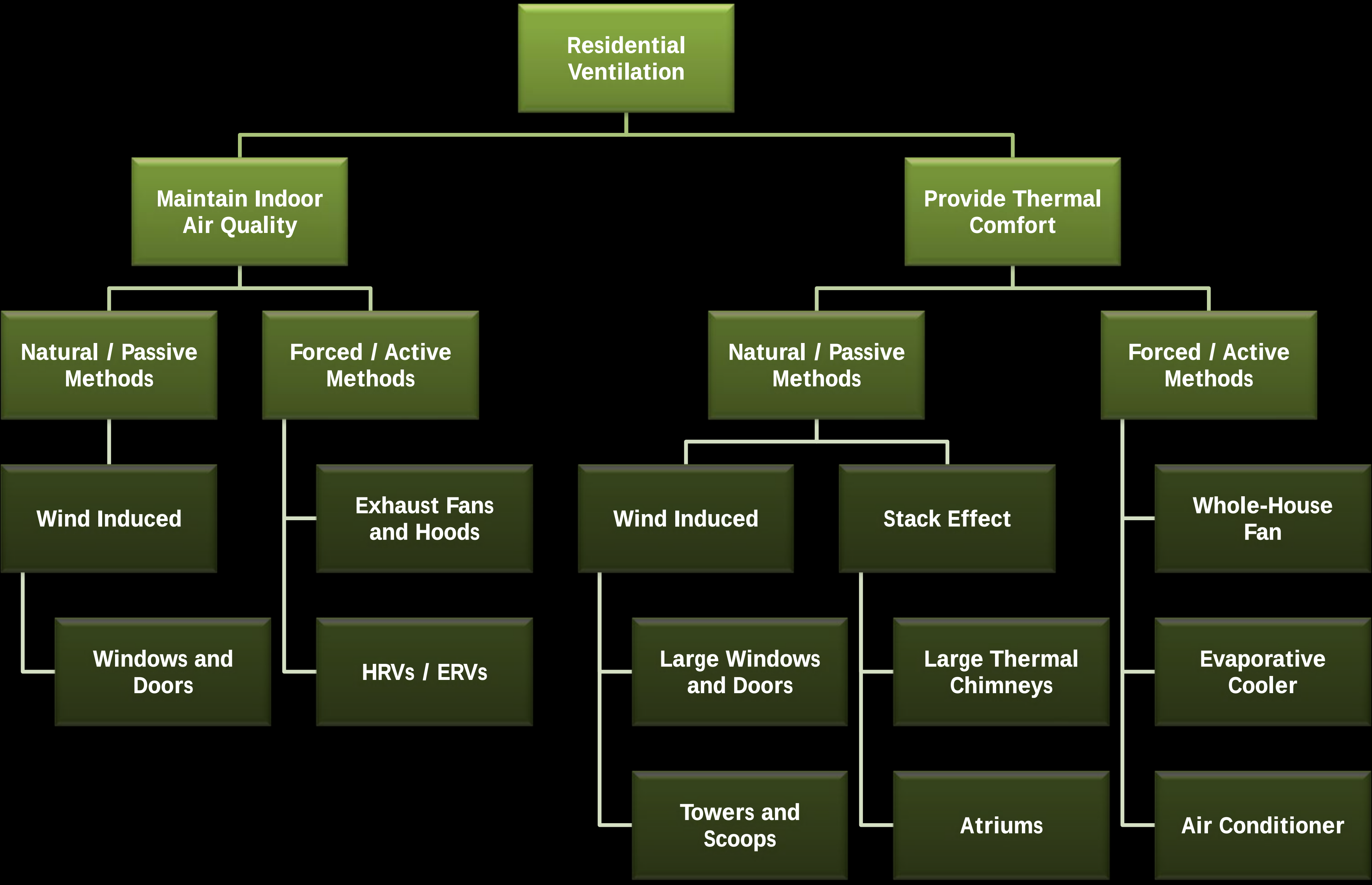
Wind Tower
Doha, Qatar
1935
[www.flickr.com/photos/jungle_boy]

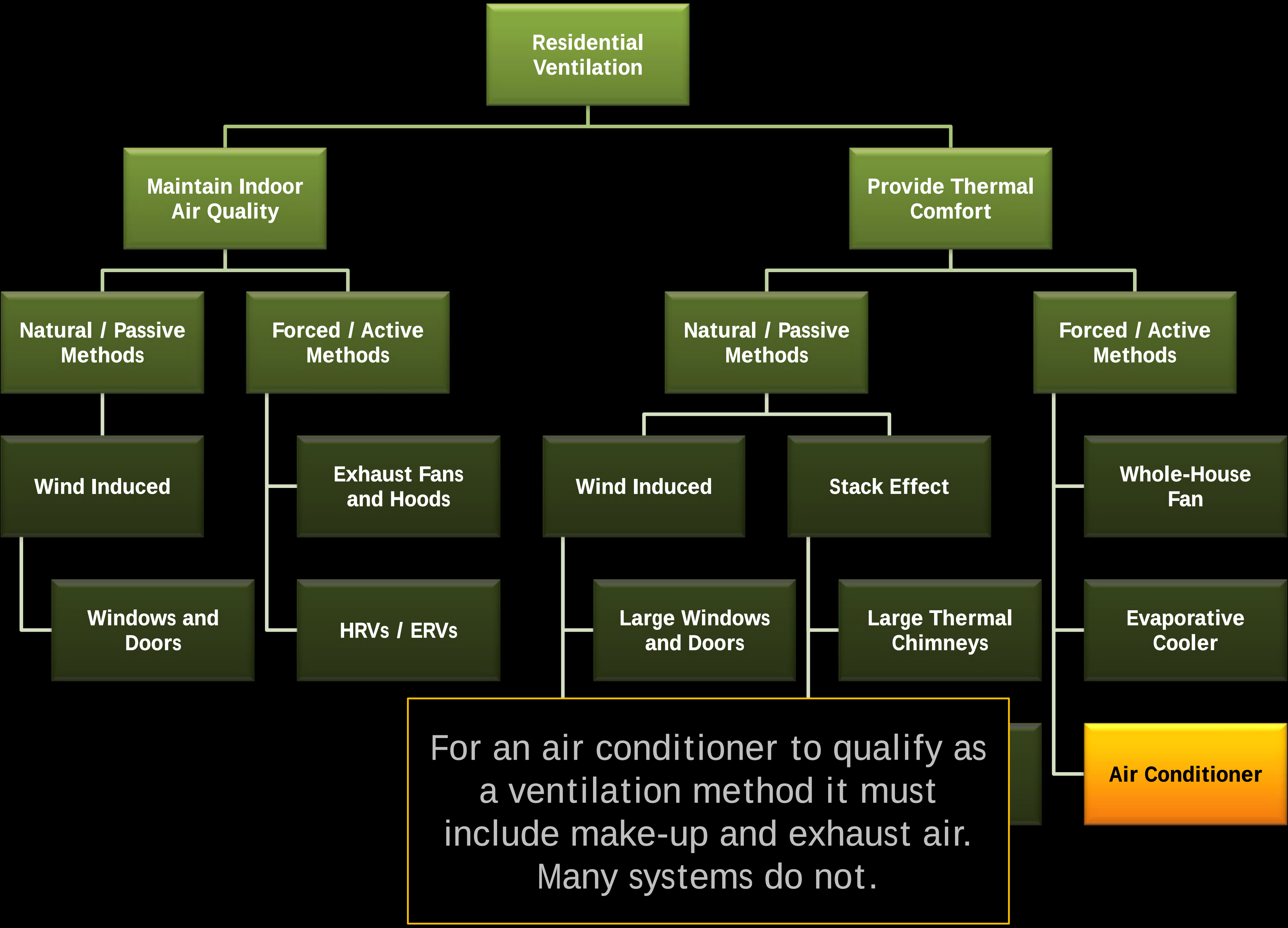
More Ventilation Methods

Wind Tower
Doha, Qatar
1935
[www.flickr.com/photos/jungle_boy]

Many of these methods are well suited to be adapted for housing in the United States.

The following chart provides a sampling of the methods that are currently in use.


Residential Ventilation
Maintain Indoor Air Quality
Provide Thermal Comfort
Natural / Passive Methods
Forced / Active Methods
Wind Induced
Windows and Doors
Exhaust Fans and Hoods
HRVs / ERVs
Natural / Passive Methods
Forced / Active Methods
Wind Induced
Stack Effect
Large Windows and Doors
Towers and Scoops
Large Thermal Chimneys
Atriums
Whole-House Fan
Evaporative Cooler
Air Conditioner


Residential Ventilation
Maintain Indoor Air Quality
Provide Thermal Comfort
Natural / Passive Methods
Forced / Active Methods
Natural / Passive Methods
Forced / Active Methods
Wind Induced
Exhaust Fans and Hoods
Wind Induced
Stack Effect
Whole-House Fan
Windows and Doors
HRVs / ERVs
Large Windows and Doors
Large Thermal Chimneys
Evaporative Cooler
Air Conditioner
For an air conditioner to qualify as a ventilation method it must include make-up and exhaust air. Many systems do not.

Comparing Ventilation Methods

Several different methods of ventilation have been discussed, and three methods were sized for a single-story house in Charlotte with 1,600 ft^2 of conditioned space and 9-foot ceilings. The air flow rates, spatial requirements, and form giving influences of these methods are as follows:

Comparing Ventilation Methods

Type of Ventilation	Q (cfm)	Spatial Requirement and Form Giving Influence
Exhaust and make-up to maintain indoor air quality	46 each	Minimal spatial requirements; weak form giving
Wind induced to provide thermal comfort	≈7,200	Moderate spatial requirements; strong form giving
Fan-forced to provide thermal comfort	≥7,200	Moderate spatial requirements; weak to moderate form giving

Comparing Ventilation Methods

Social benefits are assessed in terms of: 1) personal heath, 2) household financial security, and 3) community development. The criteria are: 1) the absence of triggers for asthma and COPD (chronic obstructive pulmonary disease), 2) energy costs, and 3) long-term viability of the housing, respectively.

Comparing Ventilation Methods

Environmental benefits are assessed at the meso/community scale and the macro/global scale. It is not assessed at the micro/indoor scale. The criterion for assessment is carbon emissions associated with fossil fuel energy usage.

Comparing Ventilation Methods

Type of Ventilation	Social and Environmental Benefits
Make-up / exhaust to maintain indoor air quality	Strong social benefit, weak environmental benefit
Wind induced to provide thermal comfort	Moderate to strong social benefit; strong environmental benefit
Fan-forced to provide thermal comfort	Moderate to strong social benefit; moderate to strong environmental benefit

Comparing Ventilation Methods

Type of Ventilation	Social and Environmental Benefits
Make-up / exhaust to maintain indoor air quality	Strong social benefit, weak environmental benefit
Wind induced to provide thermal comfort	Moderate to strong social benefit; strong environmental benefit
Fan-forced to provide thermal comfort	Moderate to strong social benefit; moderate to strong environmental benefit

One more design tool … **CFD.**

Computational Fluid Dynamics

Computational fluid dynamics (CFD) is a branch of fluid mechanics that is used to model, among other things, air flow through buildings.

Grier Heights House 1
Rendering by Professor John Nelson

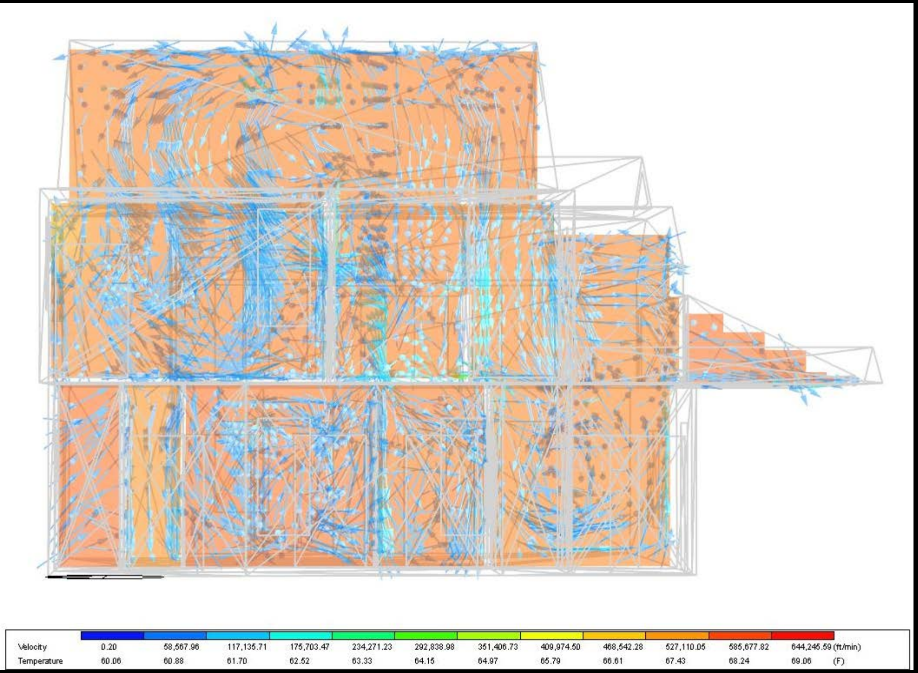
Computational Fluid Dynamics

Computational fluid dynamics (CFD) is a branch of fluid mechanics that is used to model, among other things, air flow through buildings.

Several CFD software applications are available, but their use by small firms for the design of housing may be impractical from a budgetary point of view.

Grier Heights House 1
Rendering by Professor John Nelson

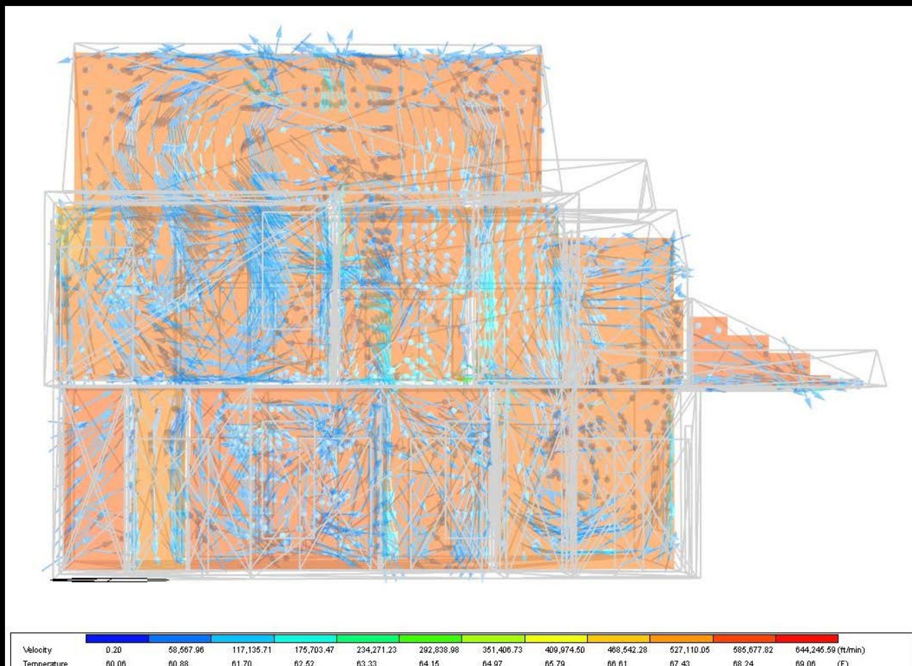
Computational Fluid Dynamics



The key benefit of CFD modeling is it provides the paths, velocities, and dry bulb temperatures of the air moving through the modeled spaces.

Grier Heights House 1
DesignBuilder CFD model by
Michelle MacDonnell

Computational Fluid Dynamics



The key benefit of CFD modeling is it provides the paths, velocities, and dry bulb temperatures of the air moving through the modeled spaces.

CFD software is a good tool for avoiding the pitfalls associated with drawing magic arrows that represent the smart air moving through a building section.

Grier Heights House 1
DesignBuilder CFD model by
Michelle MacDonnell

Research in Ventilation

UNC Charlotte is currently working on a couple of funded research projects involving ventilation in single-family.

Professors Robert Cox and Thomas Gentry in one of the communities being served by the SWIFT Program.

Research in Ventilation

UNC Charlotte is currently working on funded research projects involving ventilation in single-family.

The SWIFT (Streamlined Weatherization Improvements for Tomorrow) Project, which is partially funded by a $2 million WIPP grant from the U.S. Department of Energy, is investigating the use of fan-forced ventilation in low-income, single-family housing to maintain indoor air quality and provide low cost cooling.

Professors Robert Cox and Thomas Gentry in one of the communities being served by the SWIFT Program.

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Discussion

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University of North Carolina Charlotte
Speaker

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Assistant Professor
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University of North Carolina Charlotte
Speaker

Stephen Schreiber, FAIA
University of Massachusetts Amherst
Moderator

Submit a question to the moderator via the Chat box. They will be answered as time allows.

Thank you for joining us!

This concludes the AIA/CES Course #H13001.

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