Energy Efficiency in High Ambient Regions, the Use of Circulating Fans, and Energy Efficiency of Air Conditioners

8 March 2023

Lisa Cherney

Education Manager, AMCA International

Webinar Moderator

- Joined AMCA in February 2019
- Responsible for development of AMCA's education programs; staff liaison for the Education & Training Committee
- Projects include webinars, online education modules, presentations at trade shows, AMCA Speakers Network and many other items.

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Energy Efficiency in High Ambient Regions, the Use of Circulating Fans, and Energy Efficiency of Air Conditioners

Purpose and Learning Objectives

The purpose of this presentation is to explore the use of circulating fans and air conditioners to reduce building energy use, increase thermal comfort, and provide improved comfort during extreme events.

At the end of this presentation, you will be able to:

1. Explain what a Large Diameter Ceiling Fan (LDCF) is and its typical characteristics.
2. Outline how LDCFs contribute to thermal comfort and building energy savings.
3. Lists the ways LDCFs increase resilience to extreme events and climate change.
4. Identify the organizations that are involved in establishing LDCF specifications.
5. Describe the proper specifications and strategies for measuring and reducing HVAC energy consumption in high ambient regions.

Nabil Shahin

International Technical Director
AHRI

- Based in Dubai
- Over 26 years of experience in HVAC, including multiple techno-commercial positions in residential and commercial HVAC industry
- Very familiar with international HVAC regulations & standards in the U.S, Europe, Middle East and Africa
- Master’s degree in Mechanical Engineering from Tennessee State University

Christian Taber

Principal Engineer – Codes and Standards
Big Ass Fans

- Over 23 years experience in the industry
- B.S. in chemical engineering & M.S. in mechanical engineering from Iowa State University; M.S. in biological/biosystems engineering from the University of Kentucky
- ASHRAE certified High-Performance Building Design Professional and Certified Energy Manager
- Chair of AMCA North America Air Movement Advocacy Committee; serving on AMCA committees 230, 214, 211, 208, 11 and others, as well as ASHRAE Standard 90.1

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Energy Efficiency of Air conditioning Equipment in High Ambient Regions

Webinar

Agenda

1 Brief Intro to AHRI
2 Energy Efficiency of HVAC
3 Energy Efficiency Saving Practices
4 HVAC Equipment Standards and Certification

BRIEF INTRO TO AHRI

An expert in HVACR & WH Regulations

AIR-CONDITIONING, HEATING, & REFRIGERATION INSTITUTE

we make life better®

not-for-profit organization

AHRI MENA OFFICE UAE

A global **trade association** that provides added value to its:

1000+ licensees, including **330+** international companies

A recognized & accredited **certification body** that certifies energy efficient products in

40+ certification programs

A 65+ year-old **standards development organization** that ensures performance ratings and testing for HVACR&WH products

165 + standards & guidelines

BRIEF INTRO TO AHRI

Other Core Activities

AHRI Industry Events

The Global event for HVACR Industry

Training & Certification

Technician Training & Certification

Refrigerant Driving License

Regulations

US Federal Regulations

GCC National Regulations

Research

AHRI-led program tests alternative refrigerants for major product categories

www.ahrinet.org/saferefrigerant

BRIEF INTRO TO AHRI

Programs and products

MEMBERS

Strength in Numbers

Representing 90+ % of the Global Industry

Regional MEMBERS

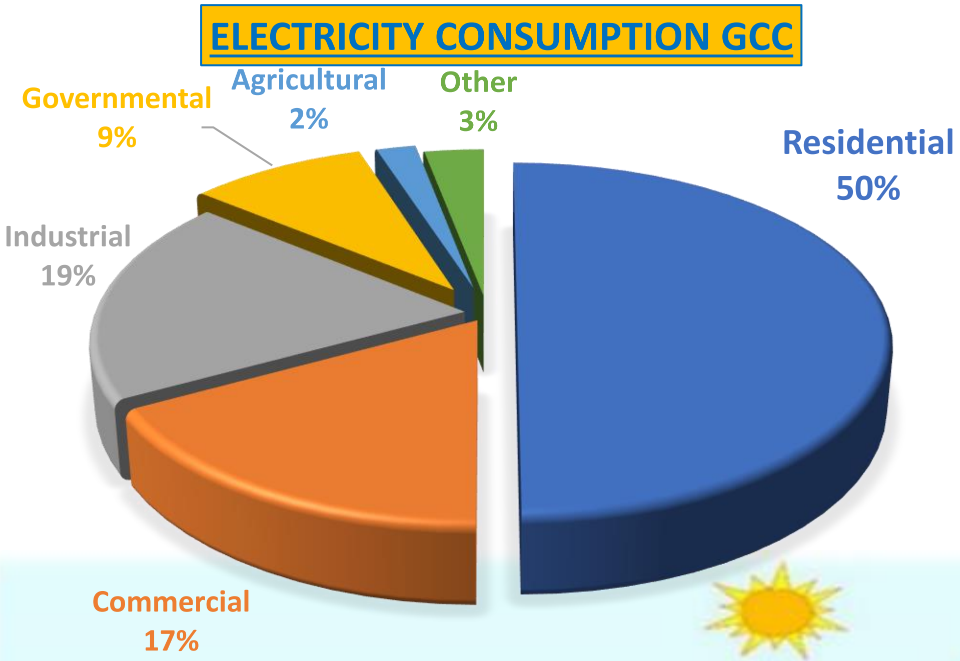
INTERNATIONAL LICENSEES OPERATING IN THE MENA REGION

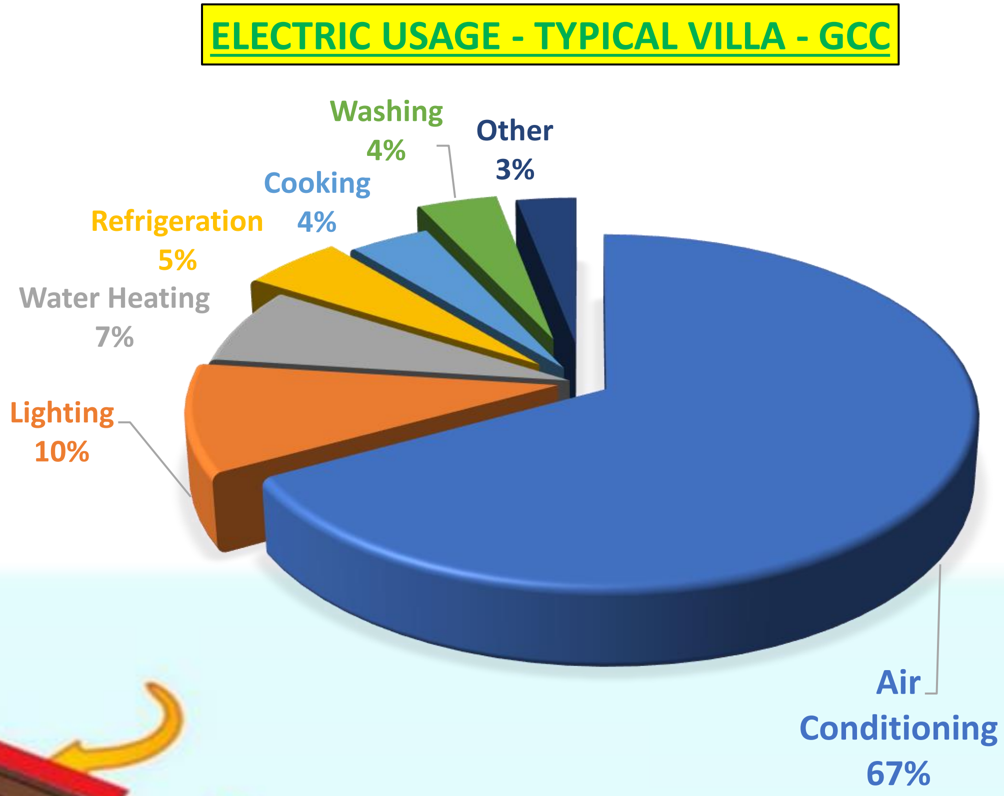
LICENSEES

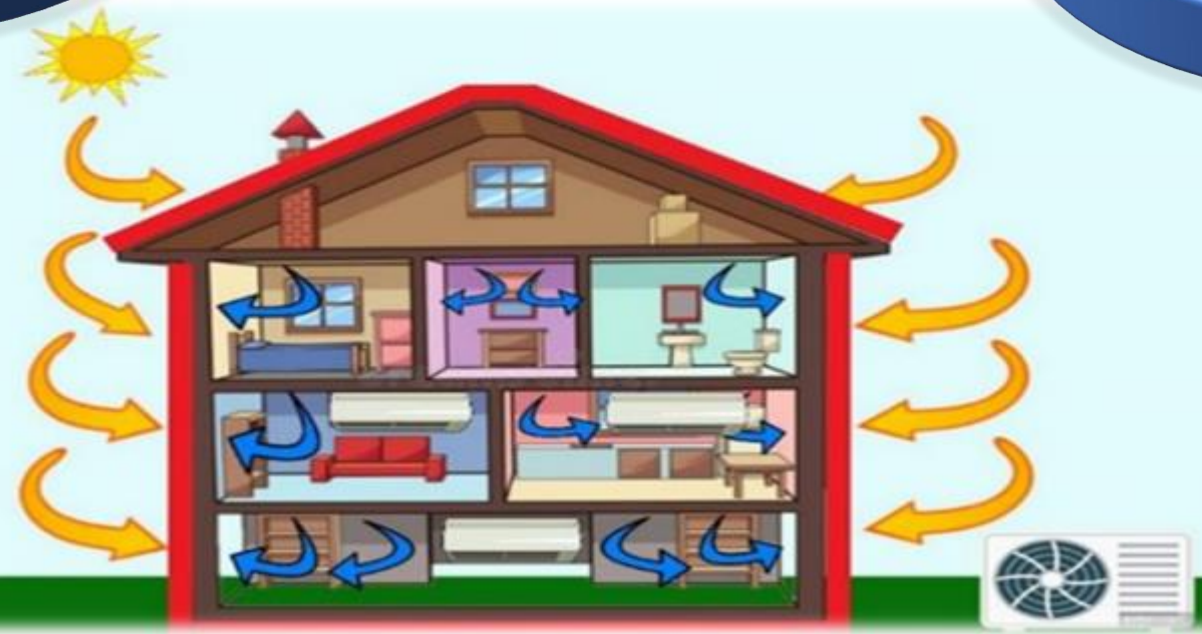
LICENSEES & MEMBERS

2 Energy Efficiency of HVAC

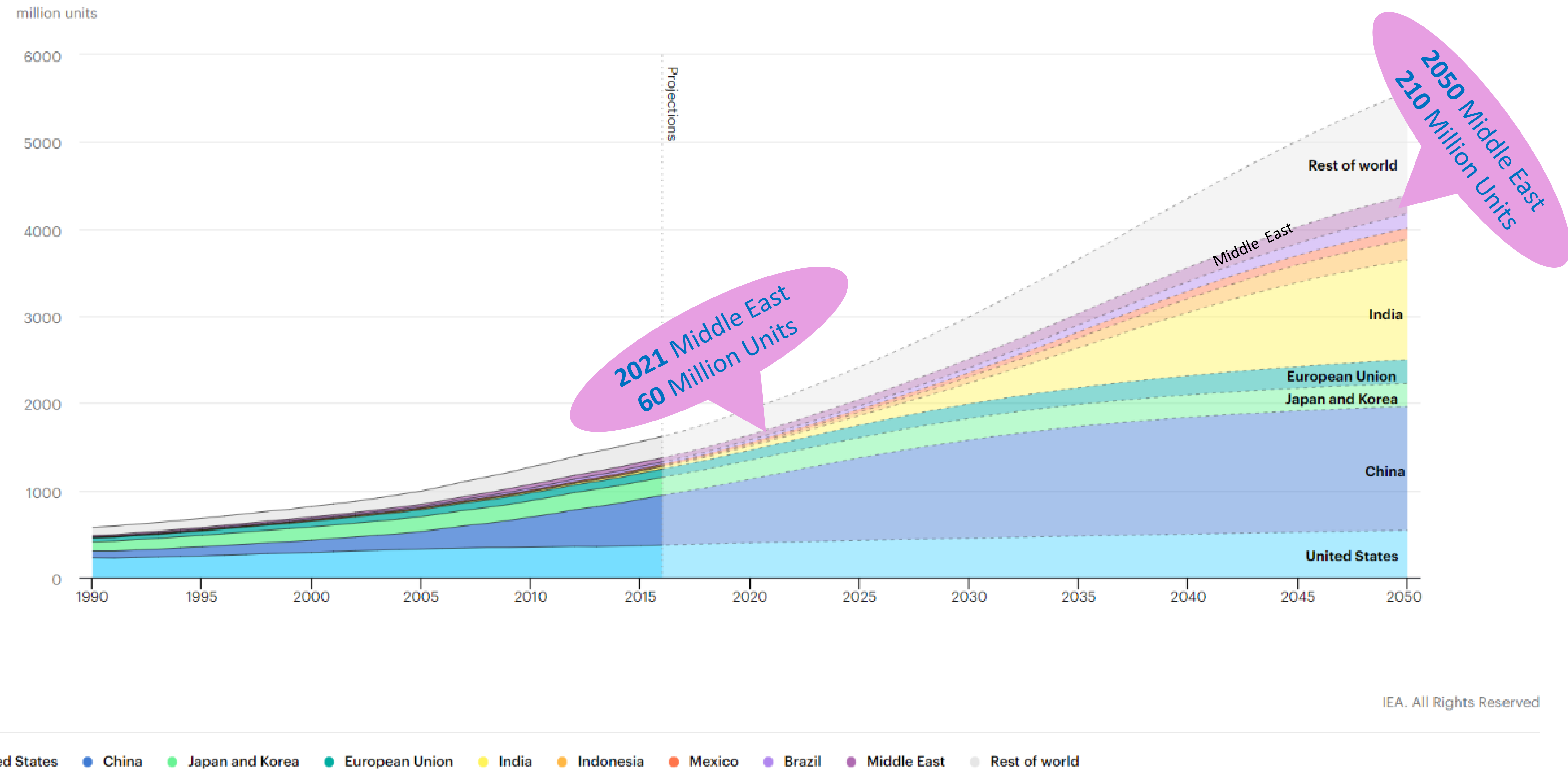
Electric Energy Consumption and HVAC Share



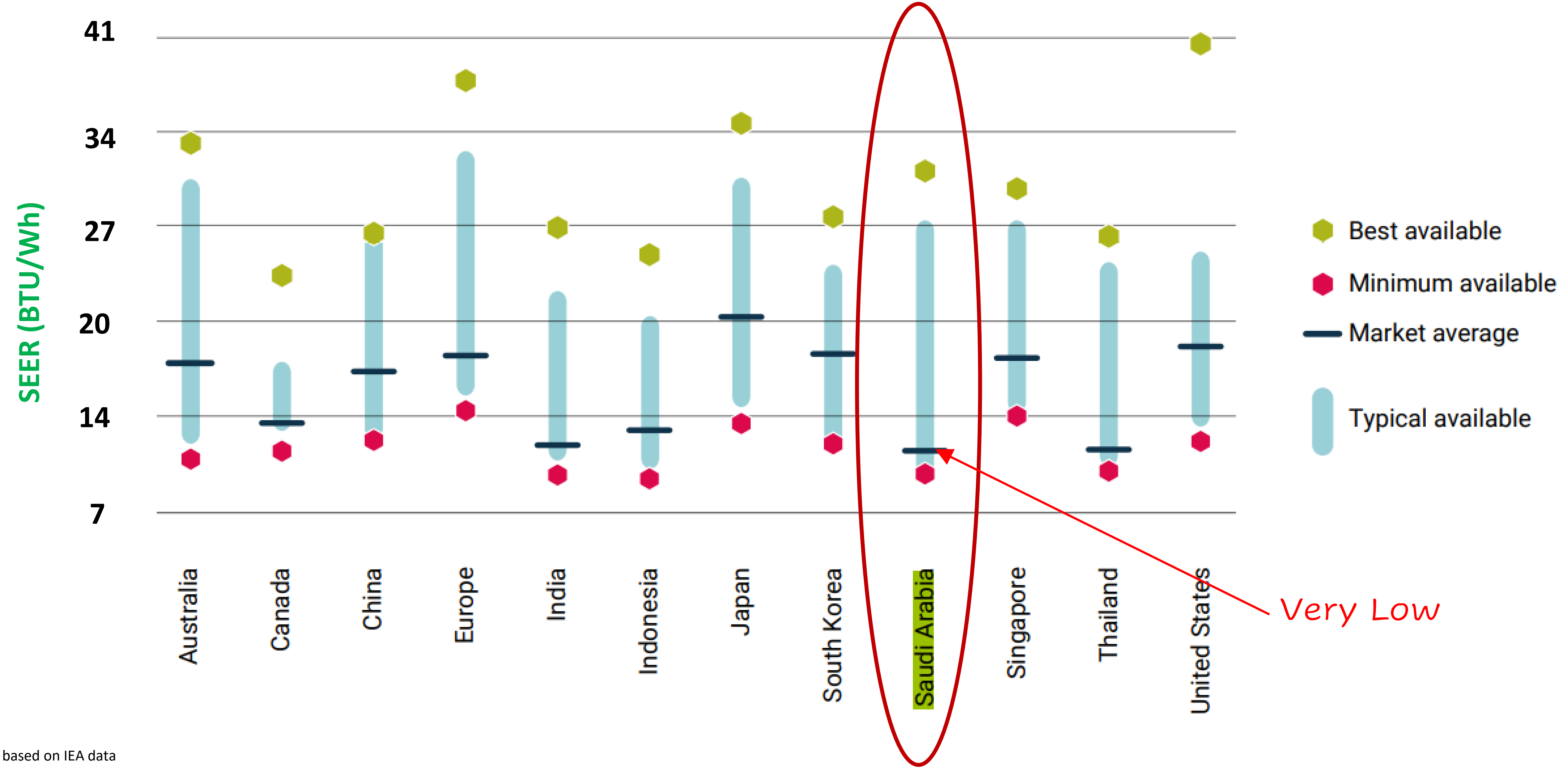




Global Air Conditioner Stock, 1990-2050



Efficiency of available residential ACs



based on IEA data

HOW TO REDUCE ACTUAL ENERGY CONSUMPTION?

SASO

هيئة الإمارات للمواصفات والمقاييس
Emirates Authority For Standardization & Metrology

MINISTRY OF ELECTRICITY & WATER
STATE OF KUWAIT

إستدامة
estidama

QATAR STANDARDS

EWA
هيئة الكهرباء والماء
Electricity & Water Authority
Kingdom of Bahrain

TECHNOLOGY

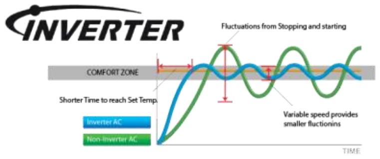
MANUFACTURERS

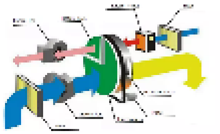
Awareness
Surveillance
Certification

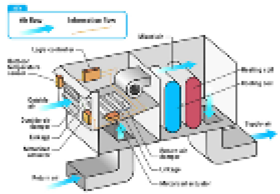
AUTHORITIES

STANDARDS

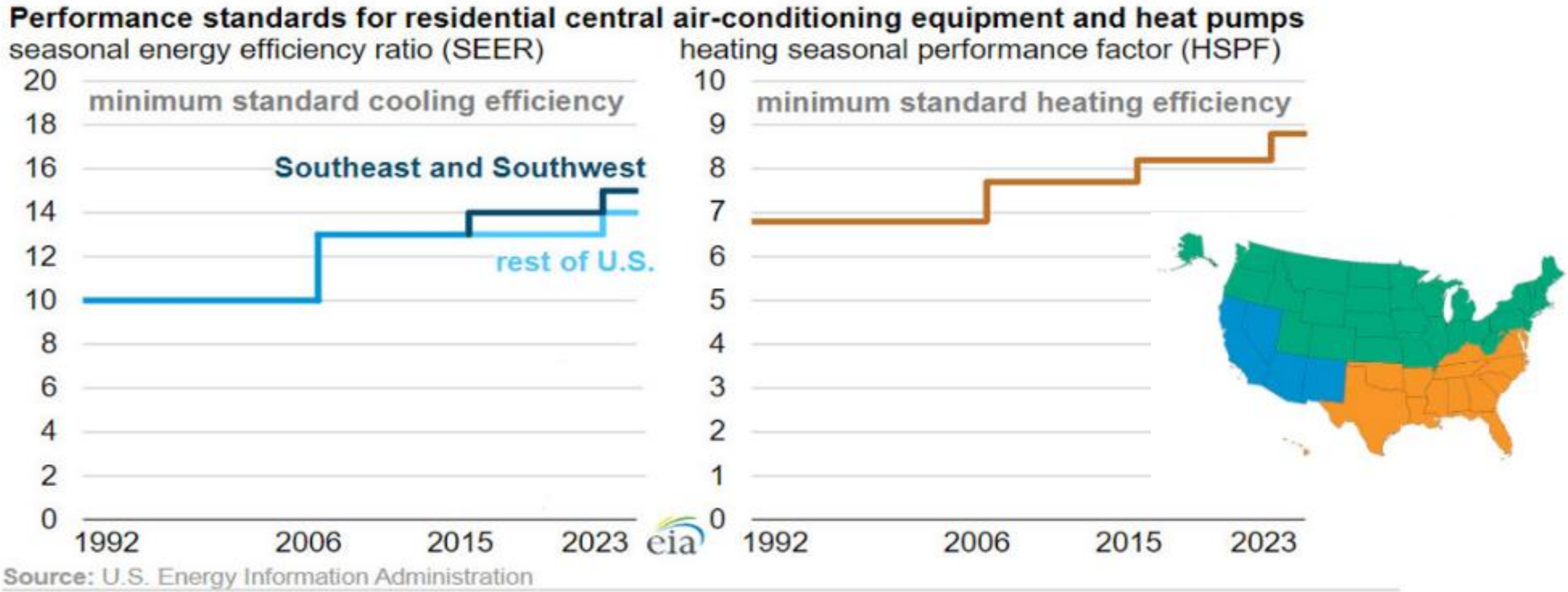
REGULATION







U.S. Department of Energy Minimums For Residential ACs

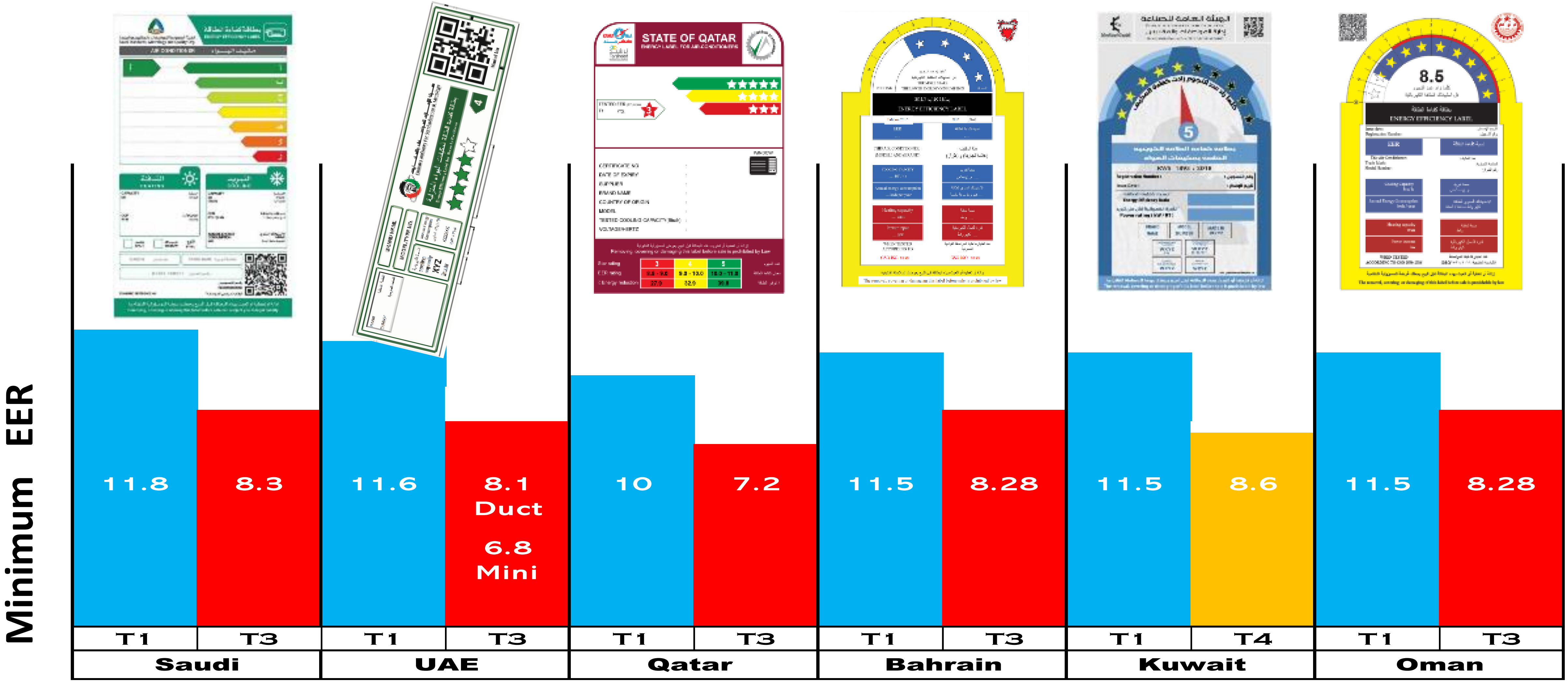


Jan 2023 Min **SEER** 15 Min **EER** 12.2 (BTU/Wh)

Kuwait Equivalent: → Min **SEER** 0.8 Min **EER*** 1 & 1.4 (KW/Ton)

*@ T1 35 °C and T4 48 °C

GCC Energy Efficiency & Labeling Requirements for AC Units

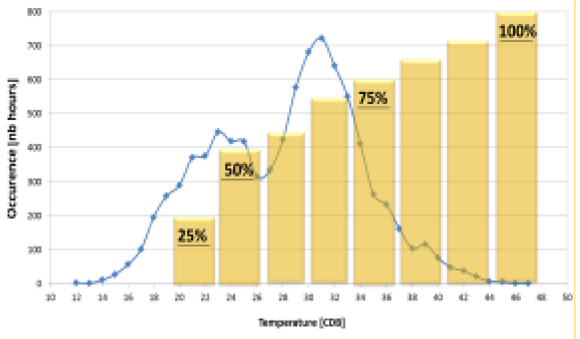


T1 = 35° C T3 = 46 °C T4 = 48 °C

ENERGY CONSUMPTION SIMULATION

ELECTRICITY CONSUMPTION

OPERATION LOAD:
DEPENDS ON OUTDOOR TEMPERATURE



EFFICIENCY
CALCULATION METHOD
Declared Data vs Actual

- EER
- SEER

EQUIPMENT :
DEPENDS ON TECHNOLOGY

- Fixed Speed AC
- Variable Speed AC
- Variable Refrigerant Flow
- Other Technologies

ENERGY EFFICIENCY REPRESENTATATION

WHAT IS EFFICIENCY – WHY IS IT IMPORTANT?

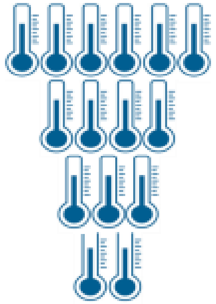
- Energy efficiency equals system performance vs. energy use
- The more efficient, the less energy consumption

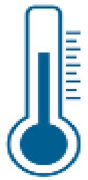
SEER: Seasonal Energy Efficiency Ratio

= Total Cooling Load ÷ Total Power Consumption

EER: Energy Efficiency Ratio

= Cooling Capacity ÷ Power Input





CSPF

IEER

IPLV

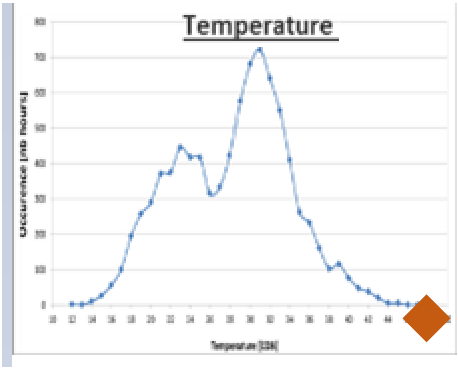
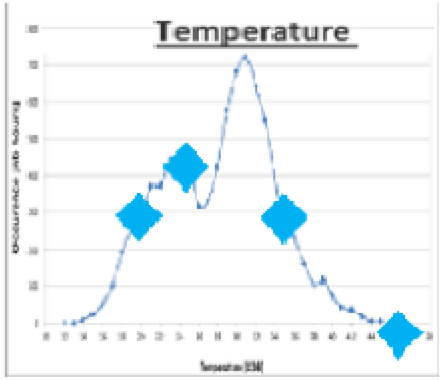
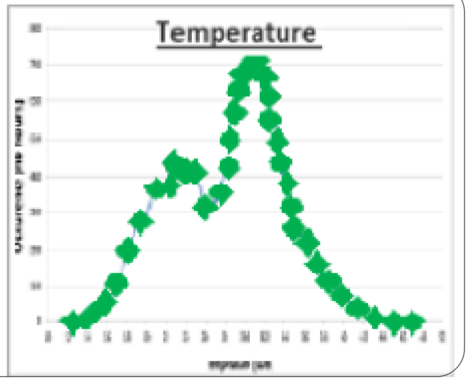
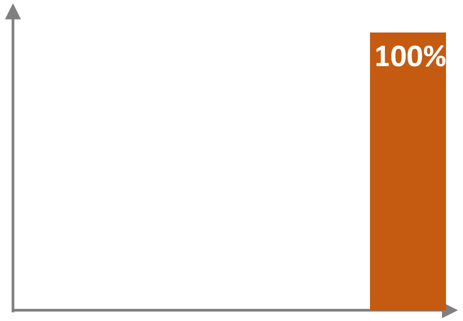
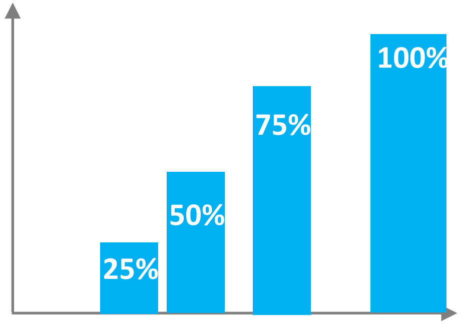
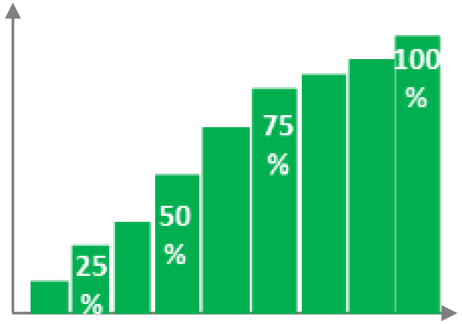
ESEER

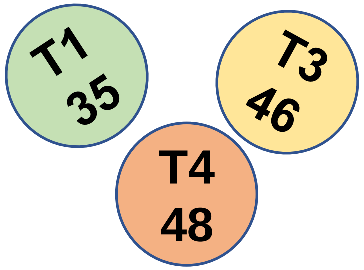
SEER

EER

HOW TO CALCULATE EFFICIENCY

MORE ADVANCED → MORE ADVANCED →

CONDITIONS	EER	ESEER	SEER
NUMBER of POINTS:	1	4	FULL CURVE
TEMPERATURE:			
LOAD:			



EER is the efficiency of AC at 1 defined point (e.g., 46 or 35CDB)

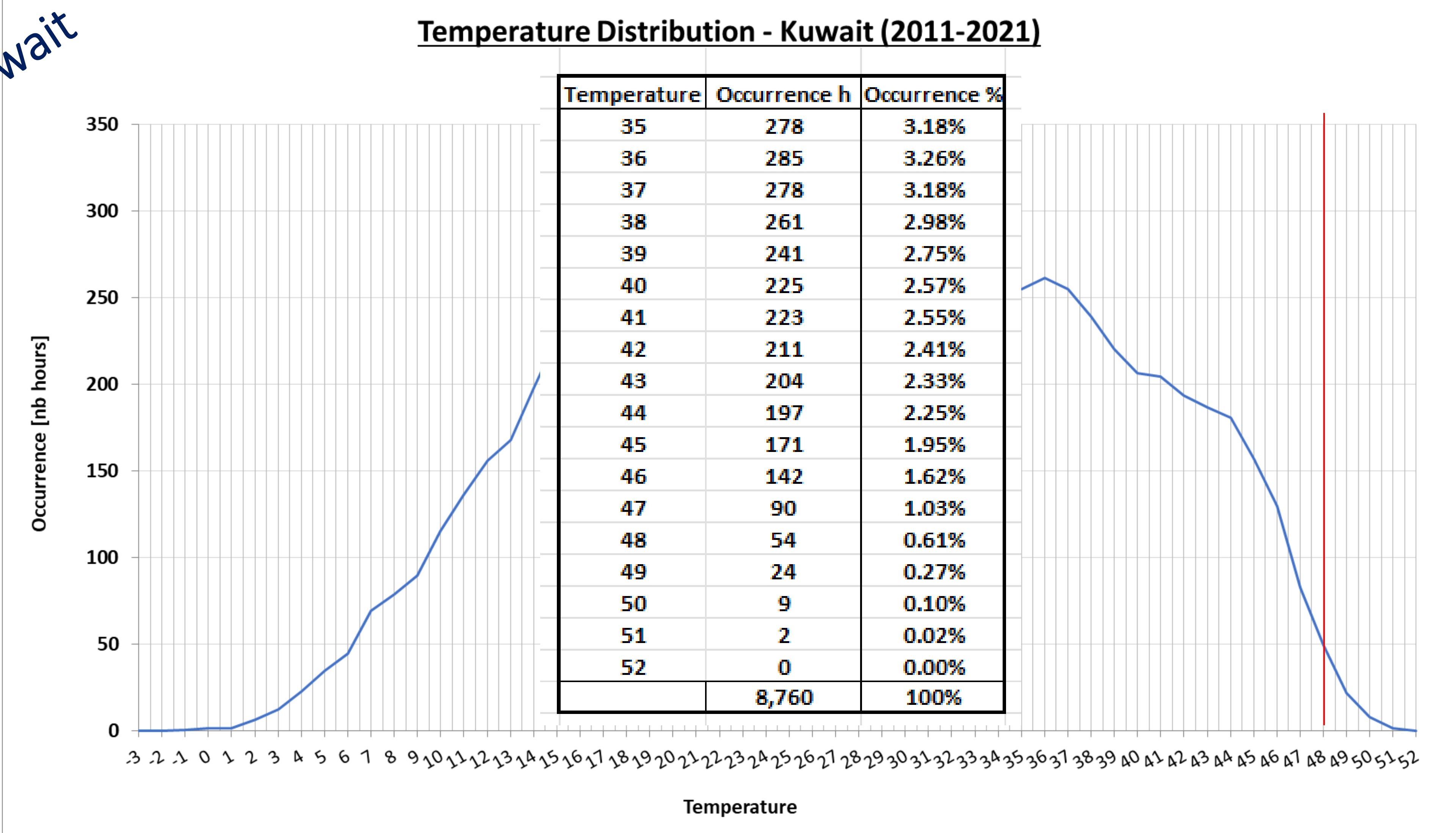
ESEER indicates the efficiency of AC based on 4 points.

SEER indicates the efficiency of AC over the full temperature distribution curve

Bin Hours – Average # of hours per year at each temperature point

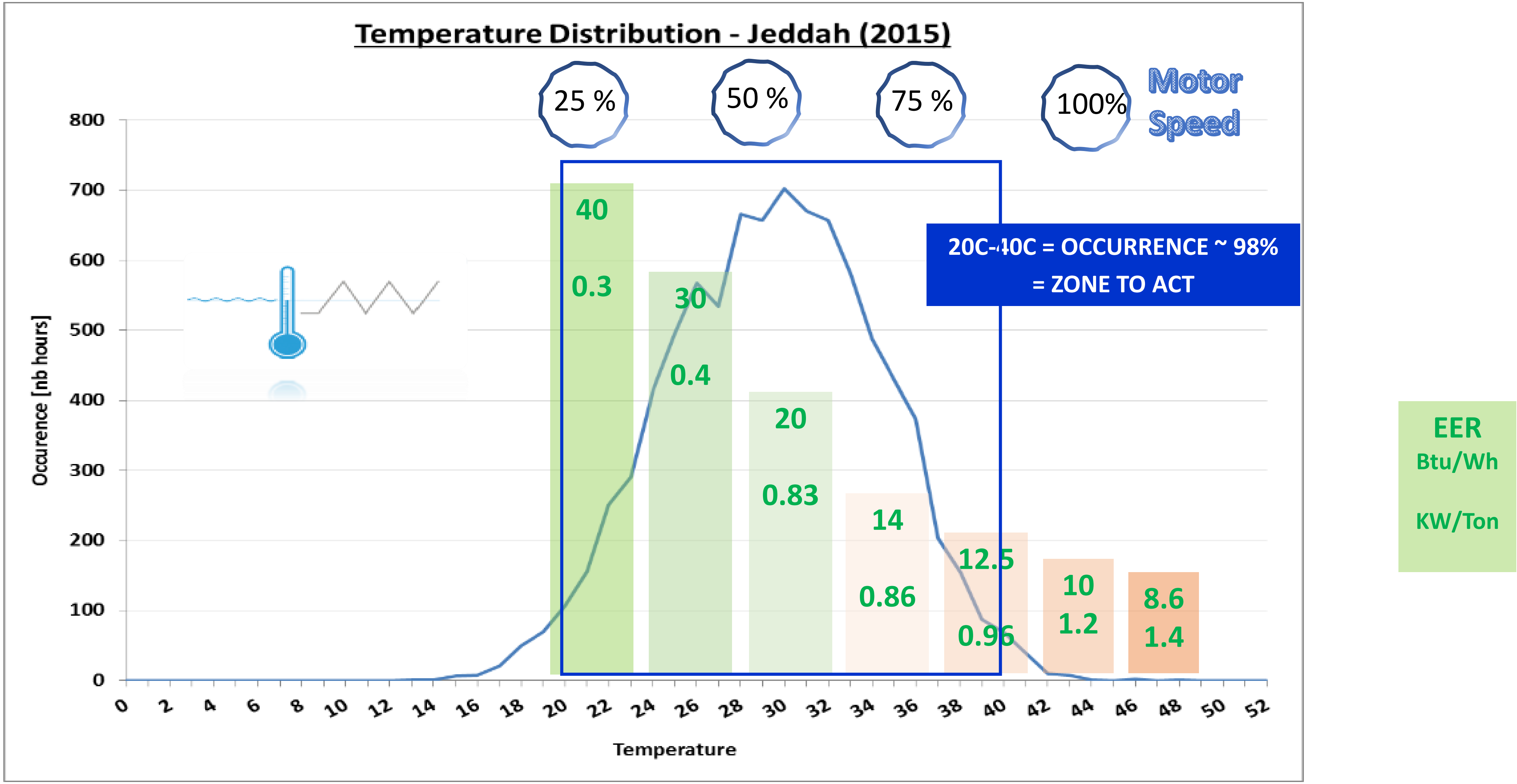
- Measure equipment power consumption at all operating temperatures.

Example: Kuwait



Temperature	Occurrence h	Occurrence %
35	278	3.18%
36	285	3.26%
37	278	3.18%
38	261	2.98%
39	241	2.75%
40	225	2.57%
41	223	2.55%
42	211	2.41%
43	204	2.33%
44	197	2.25%
45	171	1.95%
46	142	1.62%
47	90	1.03%
48	54	0.61%
49	24	0.27%
50	9	0.10%
51	2	0.02%
52	0	0.00%
	8,760	100%

Example of VRF/Inverter Product's EER



Energy Consumption of Chiilers

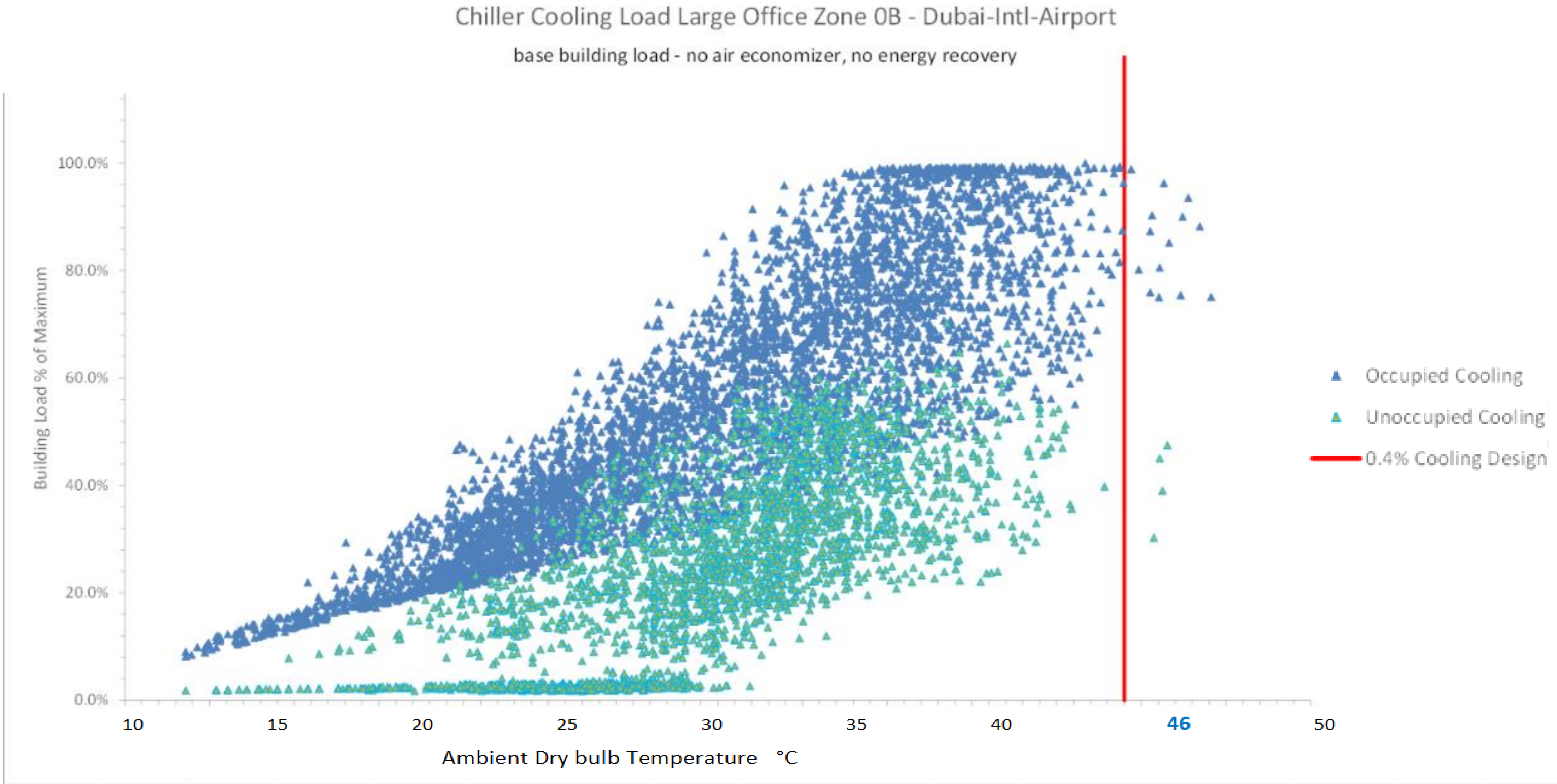
Chiller **efficiency** is only a single component of many that contribute to the total energy consumption of a chiller plant. It also depends on the following elements:

- Weather data
- Building load characteristics
- Operational hours
- Energy drawn by auxiliaries such as pumps and cooling towers, fan coil units
- Economizer capabilities
- Other

IPLV = 0.01A + 0.42B + 0.45C + 0.12D

A = kW/tonR at **100%** Capacity @ **35°C** and 30°C for Air and Water
B = kW/tonR at **75%** Capacity @ **27°C** and 24.5°C for Air and Water
C = kW/tonR at **50%** Capacity @ **19°C** and 19°C for Air and Water
D = kW/tonR at **25%** Capacity @ **13°C** and 19°C for Air and Water

Office Load Profile Data Example



Building Load Profile and Type Data

Building operation category examples:

Hospitals

District Cooling

Offices

Residential

Hotels

Mix use/Other

3

Energy Efficiency Saving Practices

Efficient Cooling Contributes to Sustainable Development Goals

Energy Saving Technologies Examples

- Variable speed drive and electronically commutated motors (ECMs)
- Variable stage compressors
- Controls that ensure operation reflects demand (inverter / VRF / VRT)
- BMS building energy management systems
- Programmable / smart controls
- Demand-controlled ventilation; fresh air systems with carbon dioxide sensors
- Demand response programs via controlling thermostats and variable capacity systems
- Occupancy sensors
- Desiccant dehumidification and cooling systems
- Energy recovery ventilation
- Geothermal heat pumps
- Solar powered air conditioners
- Micro channel heat exchangers
- Airside economizer
- Integrated Heat Recovery
- IoT

Energy Saving Practices

Commissioning and Re-Commissioning

- Can significantly reduce building energy use by ensuring that the HVAC equipment meets the owner's performance requirements and **continues to operate as designed**
- Most energy regulations and standards focus on unit design, but less attention is paid to **certification, installation, and operation**
- Studies have shown that significant energy can be saved by proper **installation and maintenance** of units, which also reduces **system failure**
- Would reduce the overall energy of a building as well as reduce refrigerant leaks through **routine maintenance** of the units
- New technologies in diagnostics and prognostics including **predictive maintenance** and integrated building control systems including **BMS**.
- **Corrosion protection** of heat exchangers

4

HVAC Equipment Standards and Certification

Energy Efficiency

Energy efficiency regulators across the globe are constantly working to develop meaningful minimum energy performance standards (MEPS) for their countries. Regulators often request guidance, information, and tools from the Air-Conditioning, Heating, and Refrigeration Institute (AHRI) on its standards, certification program, and Directory of Certified Product Performance, all highlighted below, to design and enforce MEPS.

AHRI supports regulators around the world by developing key components of the energy efficiency regulatory process for a variety of products in the heating, ventilation, air conditioning, and refrigeration (HVACR) and water heating industry. A summary of the resources used by countries seeking to avoid the expense of designing MEPS and building and operating new testing laboratories is provided below.

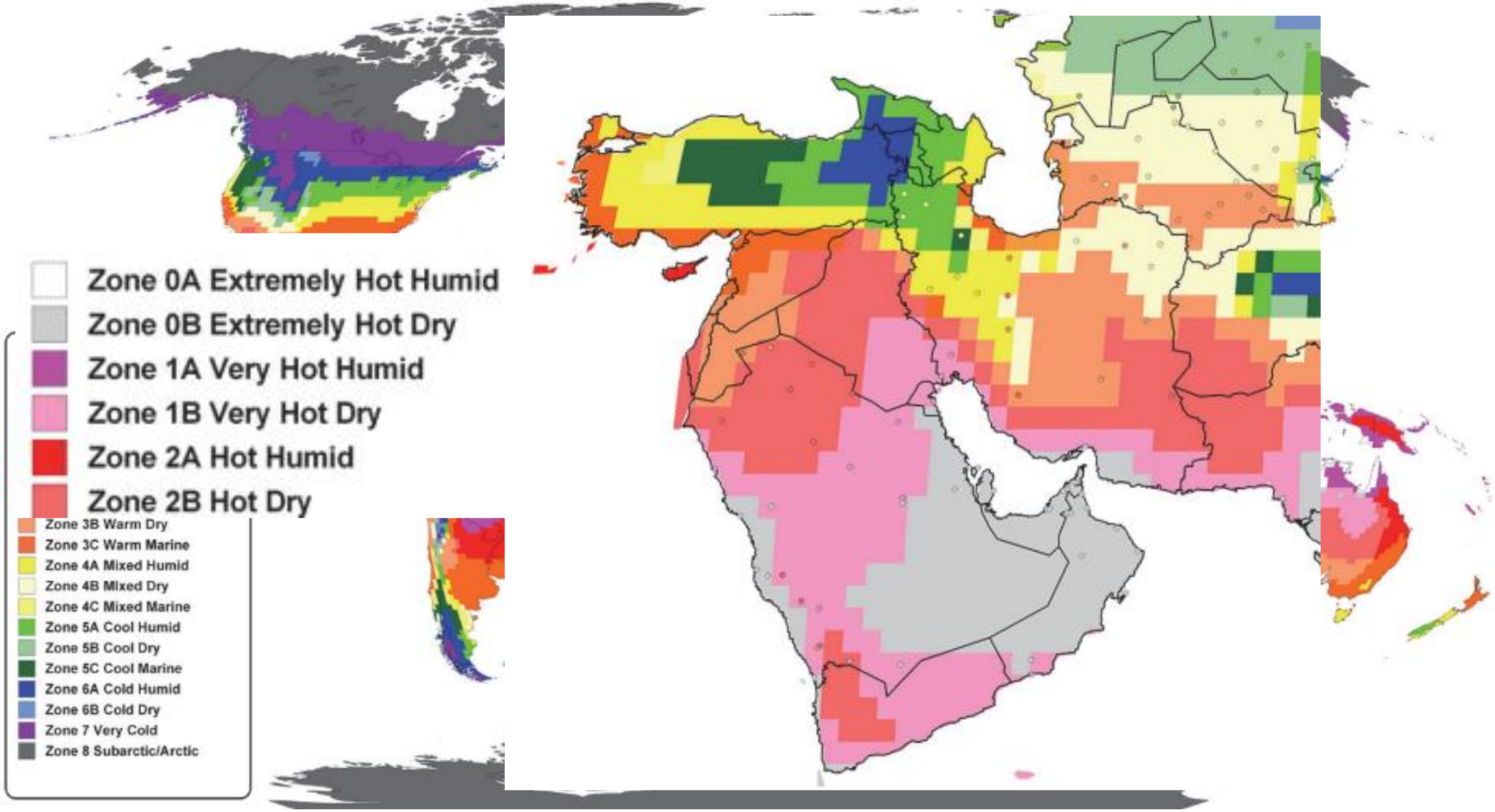
Energy Efficiency

THREE KEY COMPONENTS OF SUCCESSFUL ENERGY EFFICIENCY PROGRAMS		
Proven Testing and Rating Standards	**Certification Process**	**Compliance Verification for Enforcement**
1. Countries reference AHRI Standards in MEPS	2. Countries reference AHRI Certified products as compliant to MEPS	3. Countries use the AHRI Directory to verify AHRI Certified equipment during importation
• AHRI standards: Used across the globe and FREE to download at www.ahrinet.org • Globally recognized as International Standards by the World Trade Organization • Developed through an accredited standards process • Available in metric (SI) and imperial units	• AHRI Certification Programs: Nearly 1,300 participants representing over 70 percent of all HVACR products manufactured globally • Verifies performance (energy efficiency and capacity) ratings • An AHRI certificate is issued for each certified model • Tested in accredited laboratories	• Free and publicly available on-demand online • Meet energy efficiency goals • Easily validate the performance of AHRI Certified equipment • Search for AHRI certificates for all certified equipment • Facilitate compliance to energy efficiency policies
See more information about AHRI standards.	See more information on the AHRI Certification Program.	See more information about the AHRI Directory.

Global Climates and GCC

CLIMATE ZONES IN ASHRAE 90.1

ANNEX A1 REFERENCE ASHRAE 169 FOR CLIMATE ZONE DESIGN



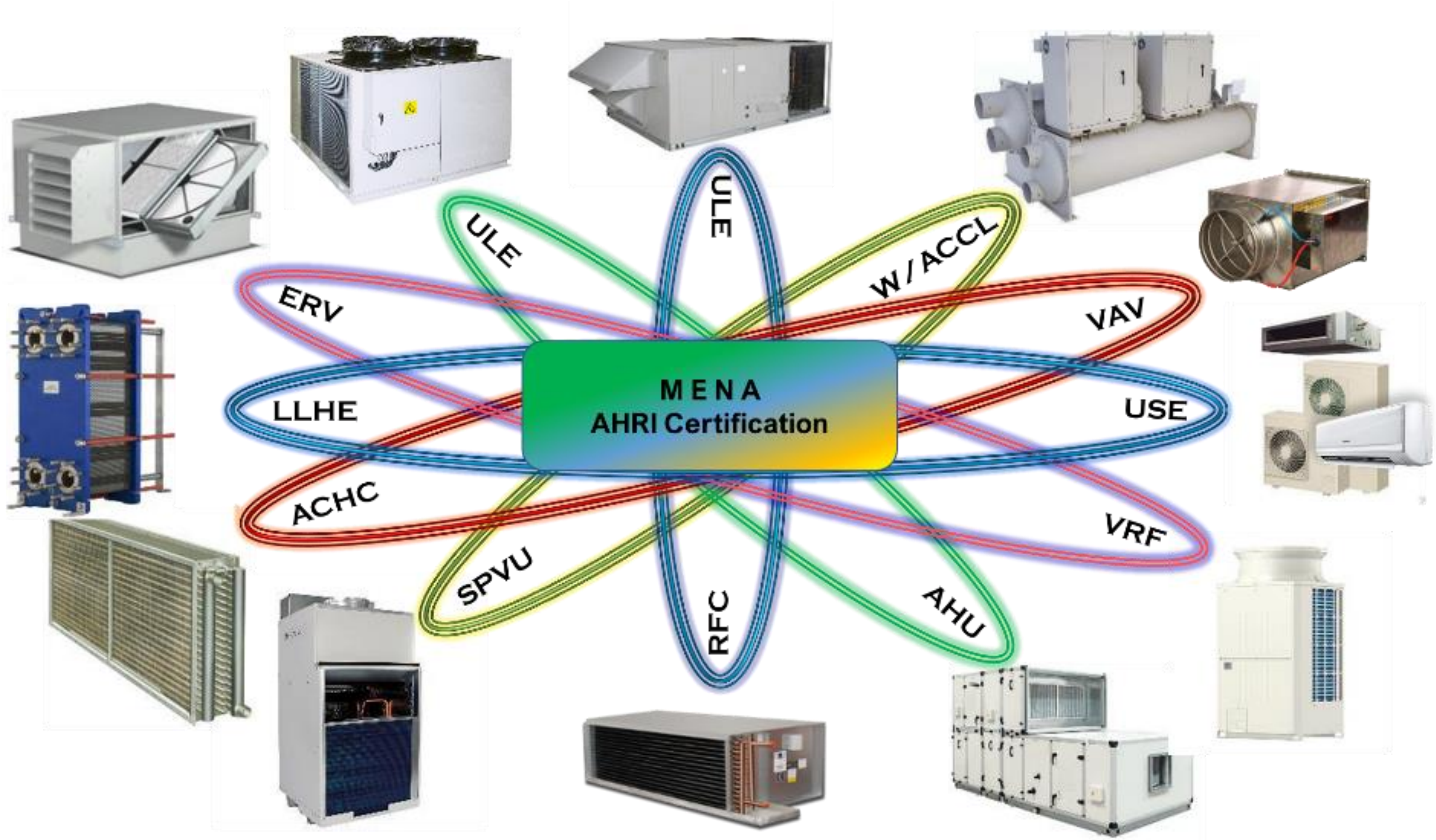
AHRI Efficiency Rating Standards

	Name	AHRI Standard	Yr	SI	50 Hz	International Directory /Certficate	T3 46 C	T3 (Max) 52 C	Description
1	WCCL & ACCL (Chillers)	550/590 - 551/591	2020	X	Yes	X	Yes,	Yes	550/590 (IP) & 551/591 (SI), Performance Rating of Water-chilling and Heat Pump Water-heating Packages Using the Vapor Compression Cycle
2	Unitary Large	340/360	2019		Yes	X	Yes	Yes	Performance Rating of Commercial and Industrial Unitary Air-conditioning and Heat Pump Equipment > 65K BTU/h <250K Btu/h
3	Unitary Small	211/241-0B/1B	2021	X	Yes	X	Yes	Yes	Performance Rating of Unitary AC & Air-source Heat Pump < 65K Btu/h bbbb
4	VAV (Variable Air Volume)	880-881	2017	X	Yes	X	Not Required	N/A	Performance Rating of Air Terminals
5	VRF (Variable Refrigerant Flow)	1230	2021		Yes	X	In Progress	Yes	1230 Performance Rating of Multi-split AC and HP
6	AHU (Air Handling Units & Casing)	430/1350 - 431	2020	X	Yes	X	Yes	Yes	430 (IP) & 431 (SI) Performance Rating of Central Station Air-handling Units Supply Fans & 1350 & 1351 of AHU Casing
7	RFC (Room Fan Coils)	440-441	2019	X	Yes	X	Not Required	No	Performance Rating of Fan-coil Units
8	ACHC (Forced Circ Coils)	410	2001		N/A	X	Not Required	N/A	410 Forced-Circulation Air-Cooling and Air-Heating Coils
9	LLHE (Heat Exchangers)	400-401	2015	X	N/A	X	Not Required	N/A	400 (IP) & 401 (SI), Performance Rating of Liquid to Liquid Heat Exchangers
10	ERV (Energy Recovery Ventilation)	1060-1061	2018	X	Yes	X	Yes *	No	1060 (IP) & 1061 (SI), Performance Rating of Air-to-Air Exchangers for Energy Recovery Ventilation
11	DCOM EQP	1360-1361	2017	X	Yes	X	Not Required	N/A	Performance Rating of Computer and Data Processing Room Air Conditioners
12	TSE (Thermal Storage Equipment)	900-901	2014	X					Performance Rating of Computer and Data Processing Room Air Conditioners
13	SPVU (Single Packaged Vertical Unit)	490	2003						Performance Rating of Computer and Data Processing Room Air Conditioners

For SI units add 1 to the standard (e.g. 400 --> 401)

** Max temperature 49* °C

Equipment Certified By AHRI



AHRI Standard 211/241-0B/1B (SI)

2021 Standard for

Performance Rating of Unitary Air-conditioning & Air-source Heat Pump Equipment

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2111 Wilson Boulevard, Suite 500
Arlington, VA 22201, USA
www.ahrinet.org
PH 703.524.8800
FX 703.562.1942

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Table 9. Required Tests – Hot Climate

Test Name	Air-cooled Product Type		
	Single Stage System	Two-stage System	Variable Stage System
Cooling Mode			
$T_{3,Full}$ or $T_{4,Full}$ [2]	R	R	R
$T_{1,Full}$	R	R	R
$T_{1,Int}$			R
$T_{1,Low}$		R	R
B_{Full}	R		
B_{Low}		R	R
C_{Full}	O [3]	O [3]	
C_{Low}		O [3]	
D_{Full}	O [3]	O [3]	
D_{Low}		O [3]	
F_{Low}		O [3]	O [3]
G_{Low}			O [3]
I_{Low}			O [3]
Cooling Mode Operation Tests			
Voltage Tolerance	R	R	R
Low Temperature Cooling	R	R	R
Insulation Efficiency	R	R	R
Condensate Disposal	R	R	R
Maximum Operating Conditions	R	R	R
Extra High Maximum Operating Conditions	O [4]	O [4]	O [4]

Notes:
1. "R" means Required, "O" means Optional, and a blank cell indicates test is not applicable for the given product type.
2. Where required, depending on climate zone.
3. Refer to Section 6.1.3.1.
4. May be required in some regions

Importance of Certification

Equipment Selection Criteria

- First cost
- Total cost of ownership
- Suitability
- Acquire, installation & commissioning Time
- Ease and cost of operations and maintenance
- Experience and reputation of the manufacturer
- Impact on other building design elements
- Noise criteria
- Lifespan
- Energy benefits
- Scalability, staging, and modularity
- Redundancy and failure-node risk
- Environmental health attributes
- Safety
- Compliance with codes & Regulations
- Certification

Watch Out !!

"AHRI CERTIFIED" IS NOT TO BE CONFUSED WITH:

"RATED OR TESTED PER AHRI STD"

≠

Manufacturer selects a special sample – Not Random

It DOES NOT MEAN compliance to standards or test method

Self Assessment: There IS NO independent verification of claim

There ARE NO clear test methods or basis of calculation

It IS NOT possible to fairly or accurately compare suppliers' performance

What is AHRI Certification?

Performance certification programs that certify residential and commercial equipment

- Capacity
- **Energy Efficiency**
- Pressure Drop
- **Power Consumption**
- Refrigerant Purity
- **Water Consumption Rate/Usage**
- Selection rating software
- **Sound Rating**
- Fan Speed
- **Seasonal Energy Efficiency Ratio**
- Sensible and Latent Effectiveness
- **Air Transfer Ratio**

Uses recognized industry test standards

- AHRI
- ASHRAE
- EN
- ISO/IEC
- Regional (CSA, ISHRAE/IS)

Verify equipment performance ratings through extensive and continuous testing

Types of AHRI Test labs:

Contracted 3rd Party Labs

Manufacturers' own witness test stands *

Compliance to ISO/IEC 17025

Testing and Calibration Laboratories

- Quality management system like ISO 9001
- Applies to labs in any industry
- Compliance measured against lab's own quality system
- Audited by individuals without relevant HVACR industry experience
- Audit cycle depends on auditor

Compliance to AHRI 140

Performance rating of Air-Conditioning and Heating Equipment Test Stands

- Specific for HVACR industry
- Technical standard used to assess and qualify labs for HVACR testing
- Compliance measured against industry approved standard
- Audited by AHRI or assigned industry professionals
- Annual audits

* Limited to 2 programs will be expanded to 4 programs in the near future.

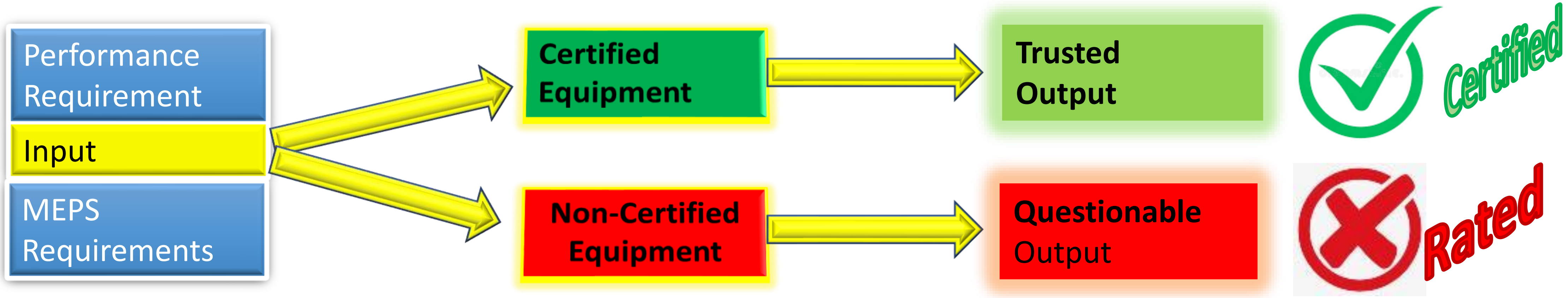
AHRI Standard 140: Extensive Test Requirements

- Full System Psychrometric Round Robin Testing
- Air Flow Measurement Apparatus
- Air Flow Measurement Apparatus Leakage
- External Static Pressure Measurement

- Zero Load
- Latent Heat Measurement
- Sensible Heat Measurement
- Maximum Capacity Test
- Thermal Energy Storage Effect for CD Testing

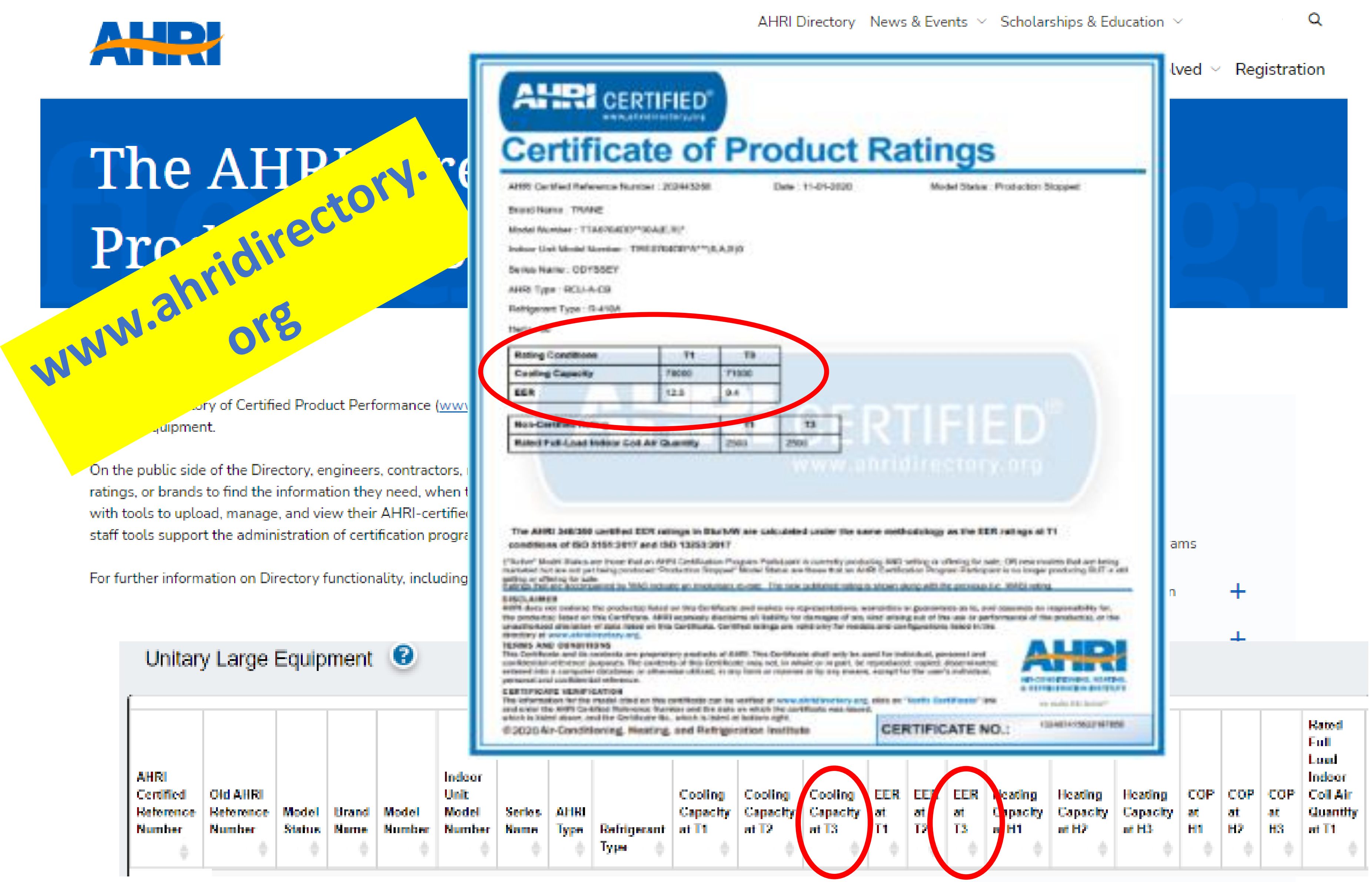
AHRI Certification Program

AHRI CERTIFICATION AS A COMPLIANCE TOOL BOTH FOR MEPS / GREEN BUILDINGS



- Ensure product meets MEPS requirements
- Confidence and increased reliability of performance ratings
- Apples-to-apples comparisons
- Up-to-date and accurate data
- Continuous performance verification over the product's lifetime
- **AHRI Certification is a key tool for compliance with MEPS and green buildings**

AHRI Directory of Certified Product Performance



شكرا جزيلا

Thank you

Nabil Shahin

Technical Director

Air-Conditioning, Heating, and Refrigeration Institute

nshahin@ahrinet.org

+971 50 7378 748

www.ahrinet.org

Environmental Benefits of Use of Circulating Fans

Presentation Outline

- LDCF Fan Basics
- Thermal Comfort
- Energy Savings
- Increasing Resilience
- Specifications to Achieve Project Goals

Large Diameter Ceiling Fans 101

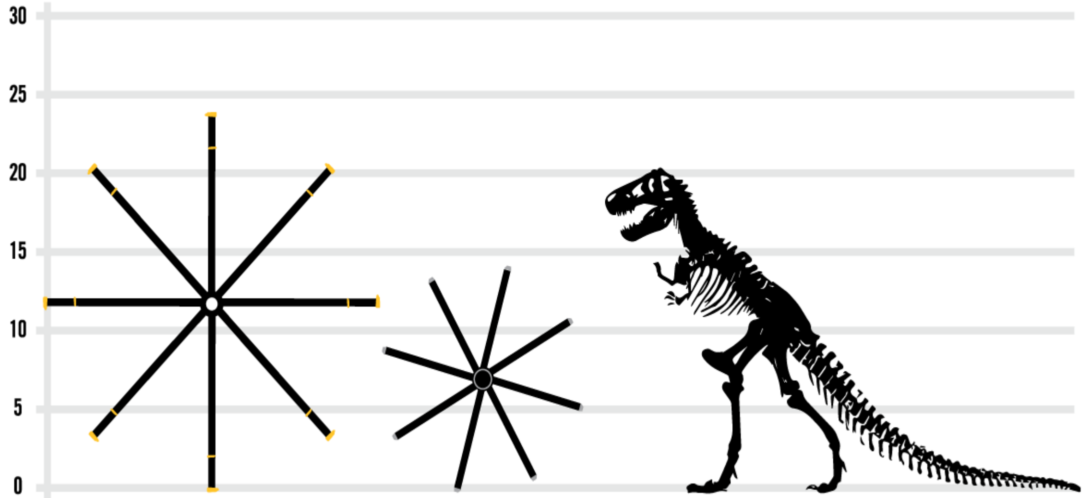
Defining Large-Diameter Ceiling Fans (LDCF)

- Ceiling fan - “a non portable device that is suspended from a ceiling for circulating air via the rotation of fan blades.”

  - 42 U.S.C § 6291.Definitions

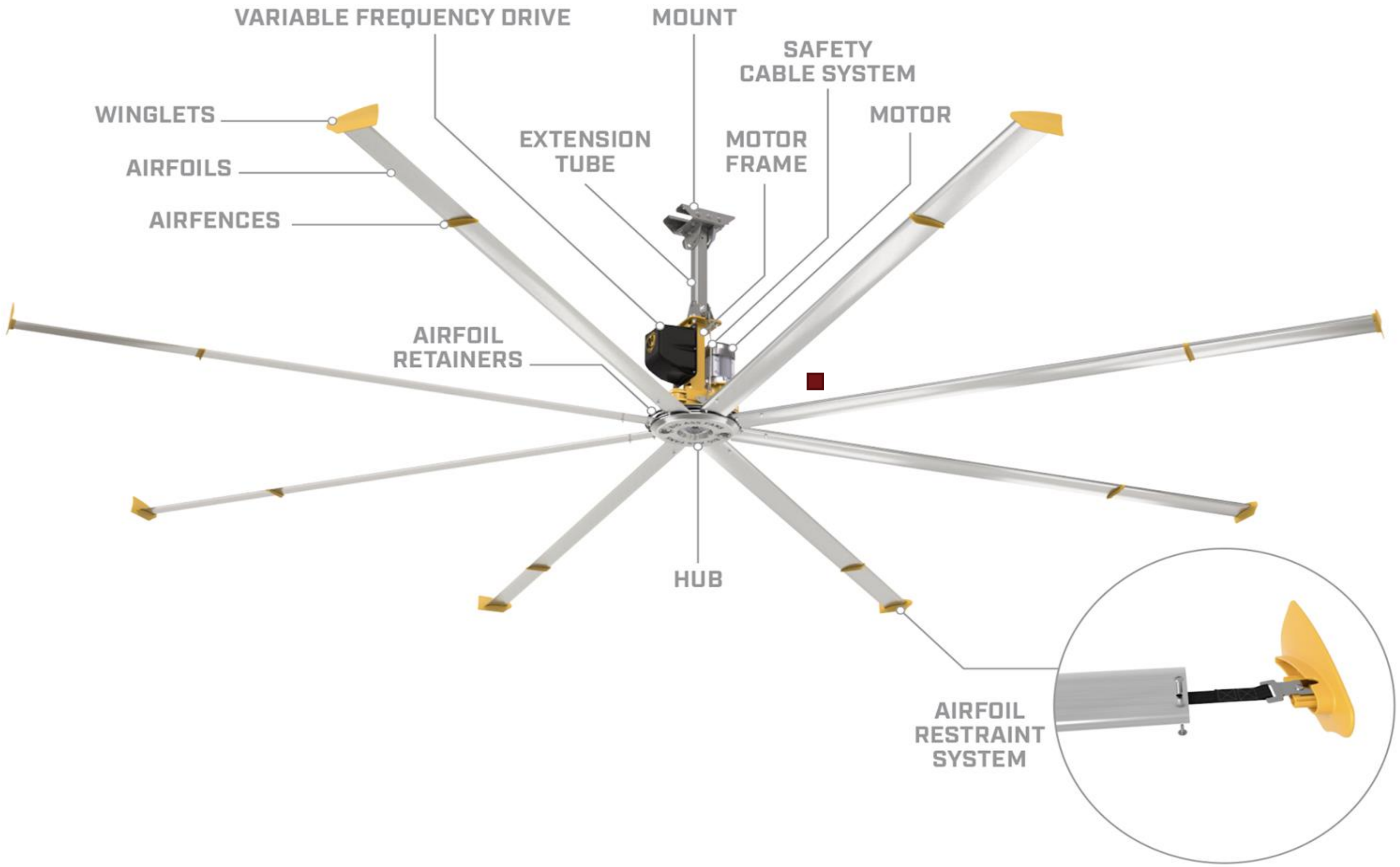
- Large-diameter ceiling fan – “a ceiling fan that is greater than seven feet in diameter.”

  - 10 CFR 430, Appendix U to Subpart B

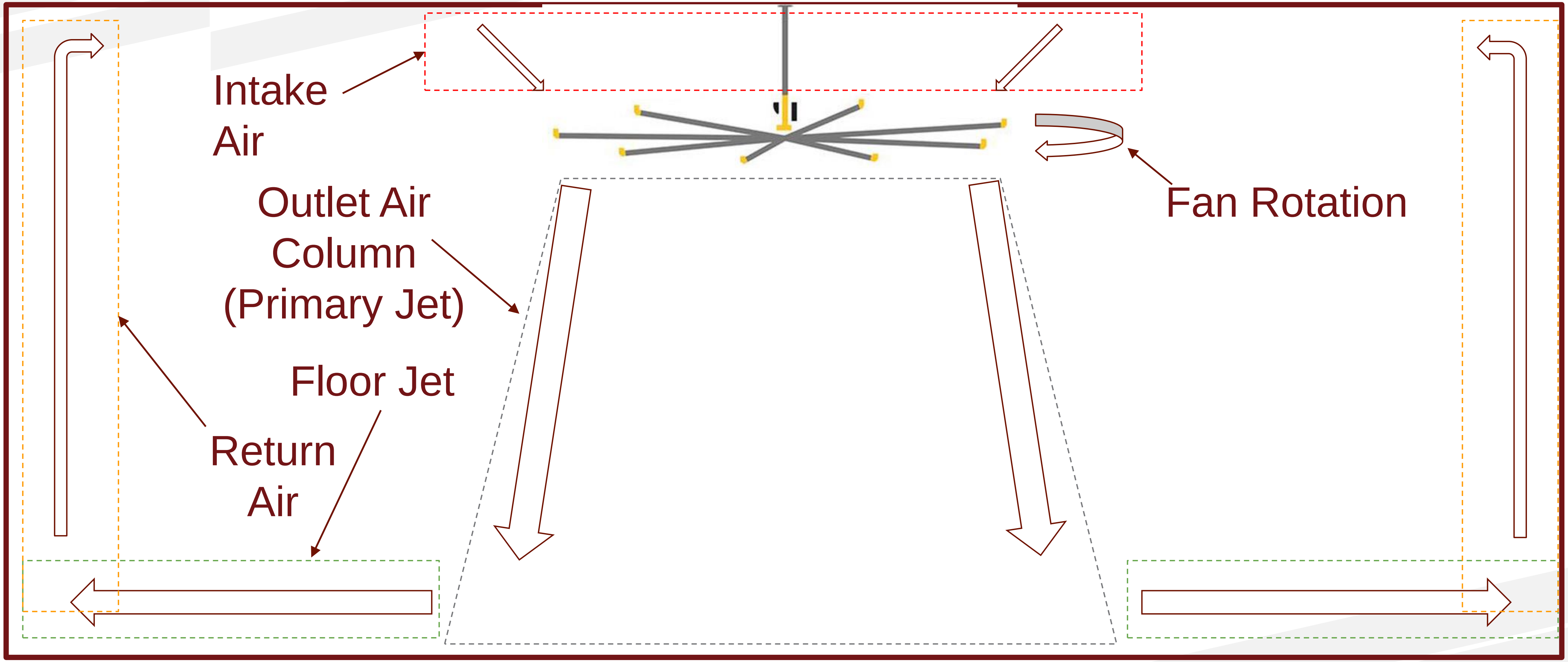


What is an HVLS Fan

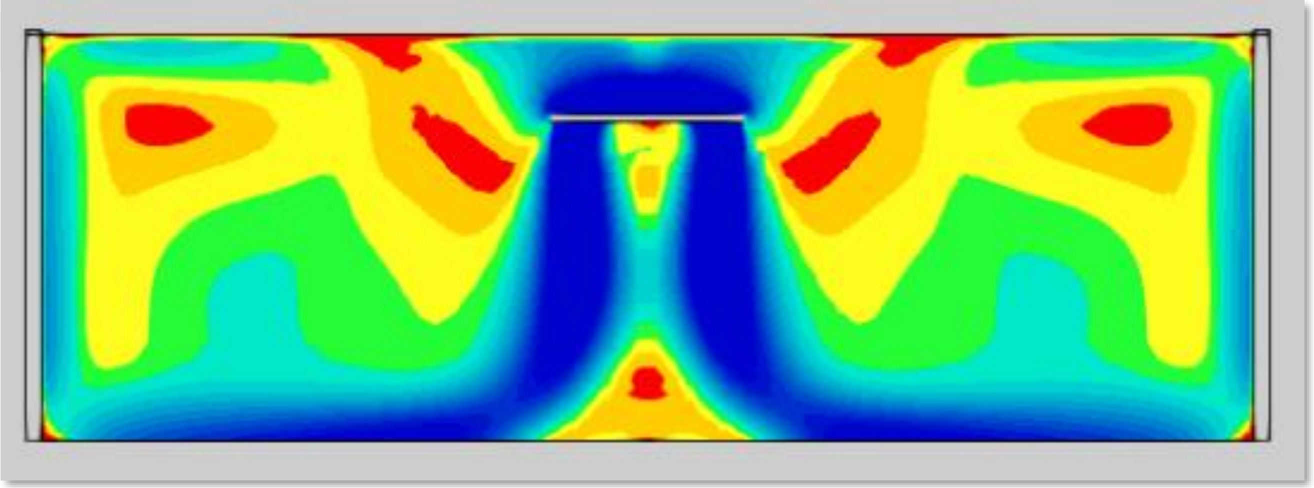
- Air circulating fan
  - Ceiling fan
- Large = >7’ (2.1m) Diameter
- Low RPM - 24’ (7.3m) Fan ~60 RPM
- Low HP - ≤2.5 hp (1.85kW) motor
- 2 to 8 blades
- Tip speeds 1,100-5,500 fpm (5.6-28m/s)

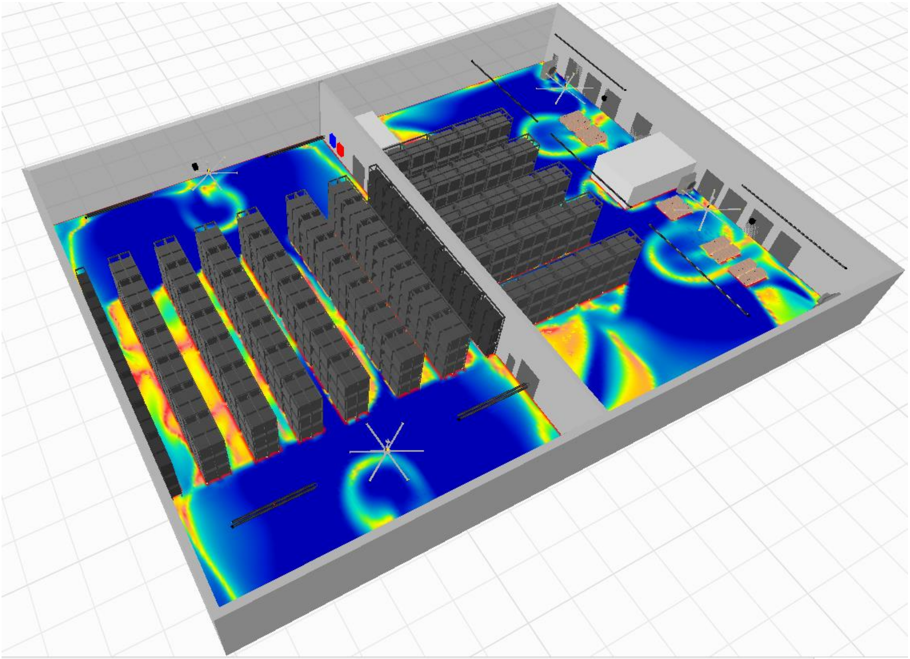


What Does an HVLS Fan Do?



Visualizing LDCF/HVLS Fan Performance





North Storage *(Airflow measured at Standing height)*

PRIMARY USE	INDOOR SUMMER TEMP	INDOOR HUMIDITY
Warehouse	80 °F	60%

	No Fans	With Fans
AVERAGE AIR VELOCITY	20ft/min	224.05ft/min
AVERAGE AIR TEMP	80 °F	80 °F
COOLING EFFECT	0 °F	9.79 °F
COOLING COVERAGE	0%	100%

With Fans PMV = 0.12

No Fans PMV = 1.24

Cold (-3) | Cool | Slightly Cool | Neutral (0) | Slightly Warm | Warm | Hot (+3)

LDCF Applications Overview

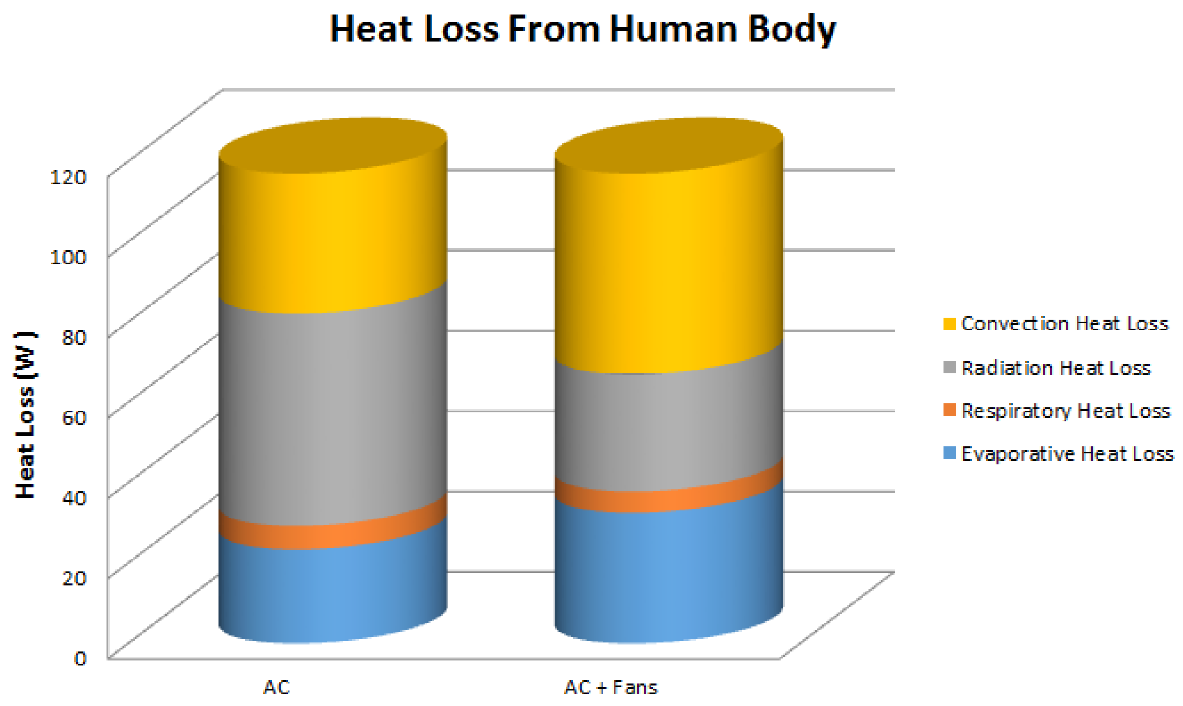
- Indoor Environmental Quality
  - Occupant thermal comfort
  - Indoor air quality (IAQ)
  - Acoustical performance

- Energy savings
  - Heating
  - Cooling
  - Innovative HVAC Systems

Using LDCF to:
Improve Thermal Comfort

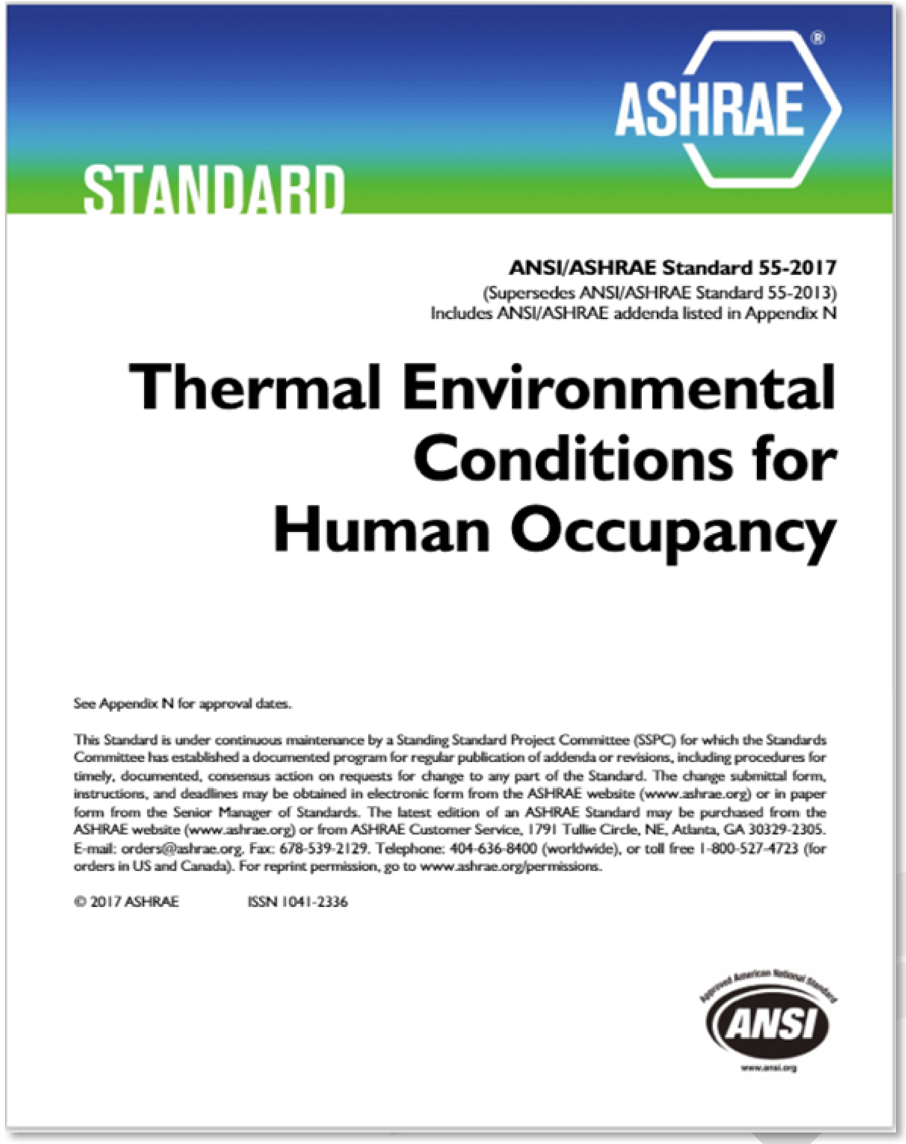
Thermal Comfort – Elevated Air Speed

- Most common comfort application for fans
- Increased heat transfer from the human body
- Sensible & latent heat transfer
  - Sensible at < ~99 °F (37 °C)
  - Latent at < 100% RH



Thermal Comfort – Average Air Speed

- ANSI/ASHRAE Standard 55-2020
  - Average air speed
    - Seated – 4”, 24”, and 43” AFF (0.1, 0.6, and 1.1m)
    - Standing – 4”, 43”, and 67” AFF (0.1, 1.1, and 1.7m)
  - Standard Effective Temperature (SET)
  - Cooling effect calculated using average air speed
  - CBE Thermal Comfort Tool
    - Quantify comfort impact
    - Determine target average air speeds
    - Evaluate different design scenarios



ASHRAE

STANDARD

ANSI/ASHRAE Standard 55-2017
(Supersedes ANSI/ASHRAE Standard 55-2013)
Includes ANSI/ASHRAE addenda listed in Appendix N

Thermal Environmental Conditions for Human Occupancy

See Appendix N for approval dates.

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 website (www.ashrae.org) or in paper form from the Senior Manager of Standards. The latest edition of an ASHRAE Standard may be purchased from the ASHRAE website (www.ashrae.org) or from ASHRAE Customer Service, 1791 Tullie Circle, NE, Atlanta, GA 30329-2305. E-mail: orders@ashrae.org. Fax: 678-539-2129. 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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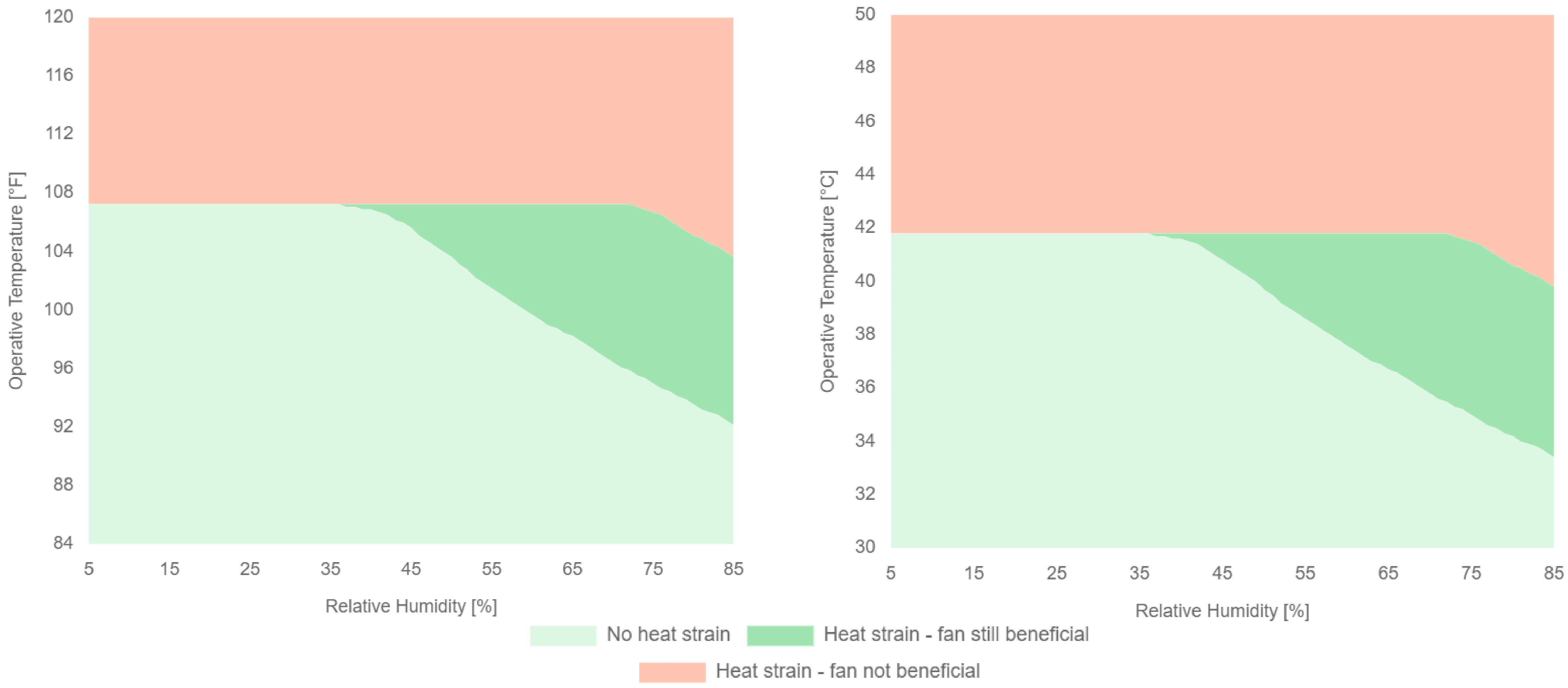
ANSI

Use of Air Movement with High Temp/Humidity

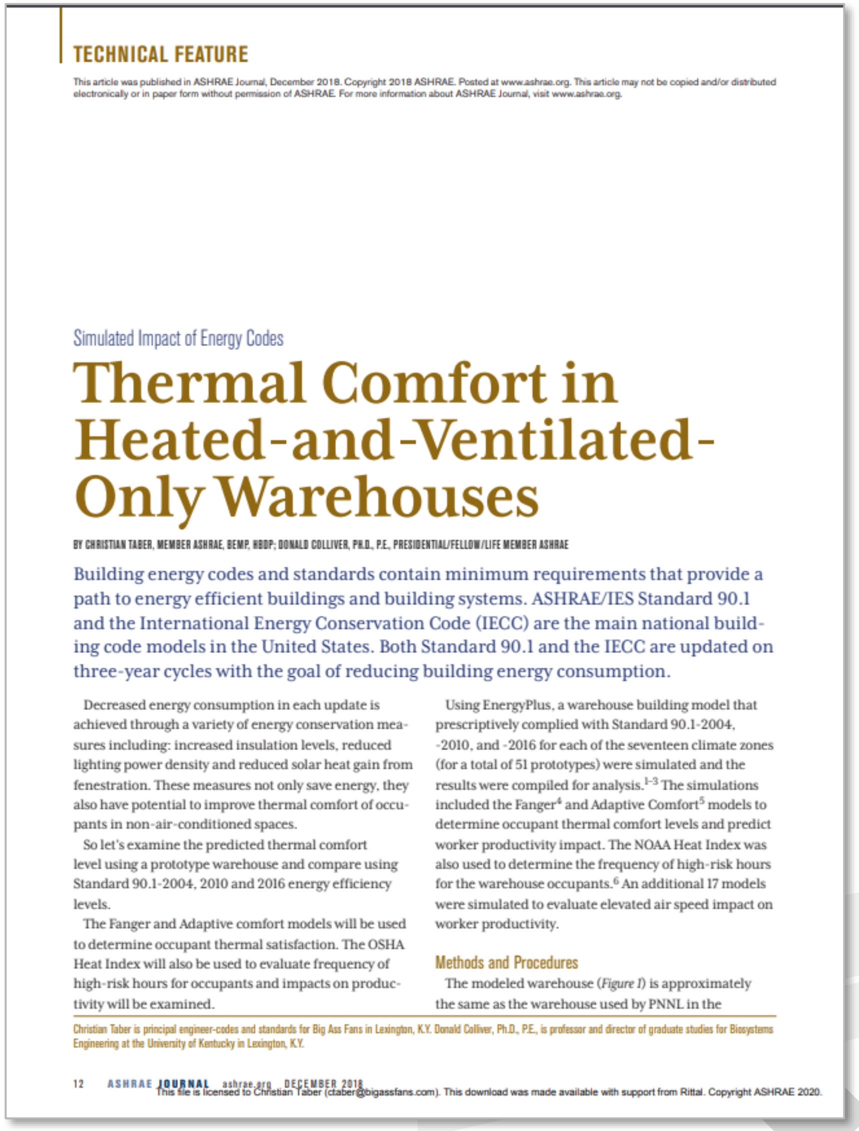


Tool: https://comfort.cbe.berkeley.edu/fan_heatwaves

(1) Tartarini, F., Schiavon, S., Cheung, T., Hoyt, T., 2020. CBE Thermal Comfort Tool : online tool for thermal comfort calculations and visualizations. SoftwareX 12, 100563. https://doi.org/10.1016/j.softx.2020.100563

Thermal Comfort – Additional Information

- ANSI/ASHRAE Standard 55-2020
- *Thermal Comfort in Heated-and-Ventilated-Only Warehouses*,
  - ASHRAE Journal, Dec 2018
- Center for the Built Environment
  - Numerous Publications



TECHNICAL FEATURE

Simulated Impact of Energy Codes

Thermal Comfort in Heated-and-Ventilated-Only Warehouses

BY CHRISTIAN TABER, MEMBER ASHRAE, BEMP, HBDP; DONALD COLLIVER, PH.D., P.E., PRESIDENTIAL/FELLOW/LIFE MEMBER ASHRAE

Building energy codes and standards contain minimum requirements that provide a path to energy efficient buildings and building systems. ASHRAE/IES Standard 90.1 and the International Energy Conservation Code (IECC) are the main national building code models in the United States. Both Standard 90.1 and the IECC are updated on three-year cycles with the goal of reducing building energy consumption.

Decreased energy consumption in each update is achieved through a variety of energy conservation measures including: increased insulation levels, reduced lighting power density and reduced solar heat gain from fenestration. These measures not only save energy, they also have potential to improve thermal comfort of occupants in non-air-conditioned spaces.

So let's examine the predicted thermal comfort level using a prototype warehouse and compare using Standard 90.1-2004, 2010 and 2016 energy efficiency levels.

The Fanger and Adaptive comfort models will be used to determine occupant thermal satisfaction. The OSHA Heat Index will also be used to evaluate frequency of high-risk hours for occupants and impacts on productivity will be examined.

Using EnergyPlus, a warehouse building model that prescriptively complied with Standard 90.1-2004, -2010, and -2016 for each of the seventeen climate zones (for a total of 51 prototypes) were simulated and the results were compiled for analysis.[1-3] The simulations included the Fanger[4] and Adaptive Comfort[5] models to determine occupant thermal comfort levels and predict worker productivity impact. The NOAA Heat Index was also used to determine the frequency of high-risk hours for the warehouse occupants.[6] An additional 17 models were simulated to evaluate elevated air speed impact on worker productivity.

Methods and Procedures

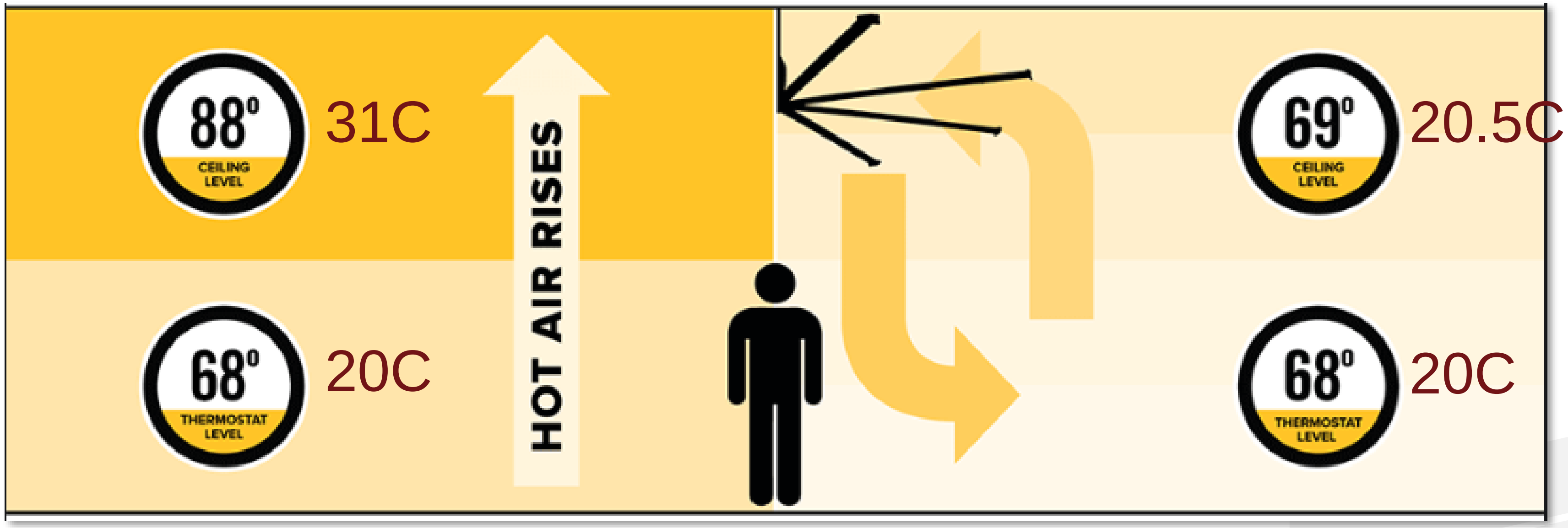
The modeled warehouse (*Figure 1*) is approximately the same as the warehouse used by PNNL in the

Christian Taber is principal engineer-codes and standards for Big Ass Fans in Lexington, K.Y. Donald Colliver, Ph.D., P.E., is professor and director of graduate studies for Biosystems Engineering at the University of Kentucky in Lexington, K.Y.

Using LDCF to:
Decrease Building Energy Use

Thermal Mixing (Destratification)

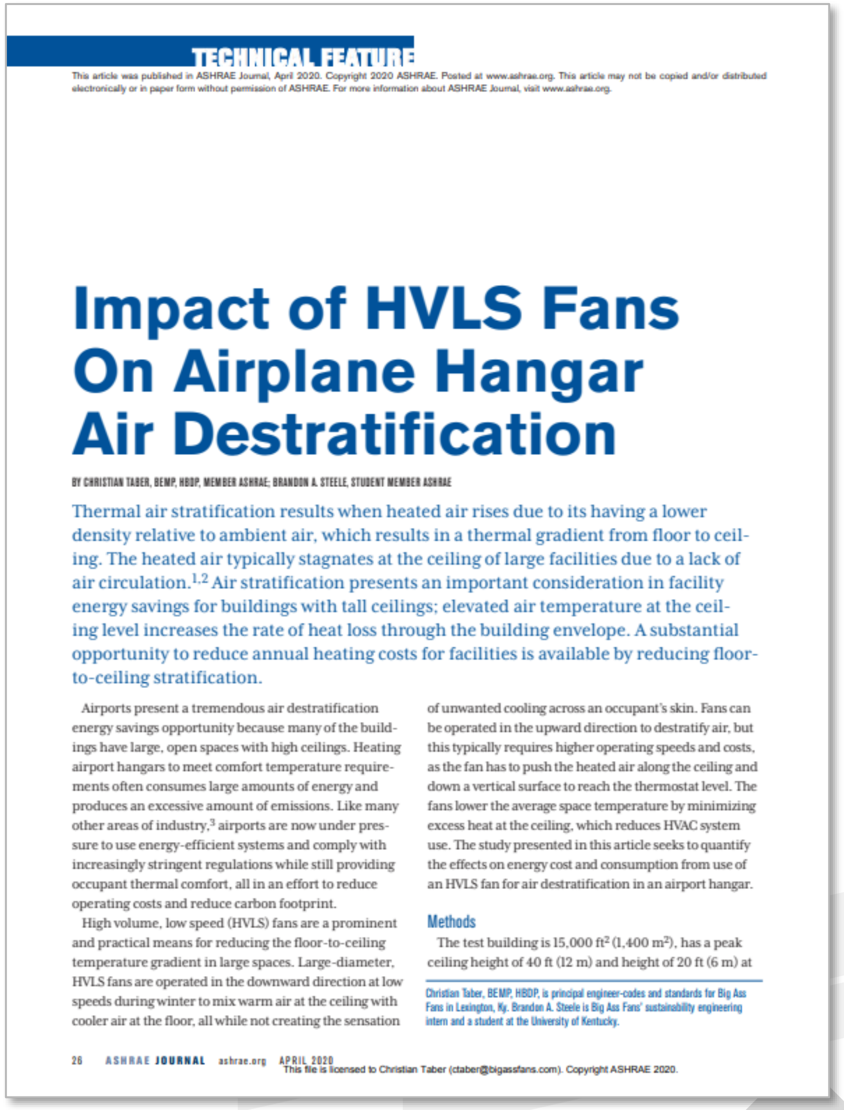
- Most common energy saving application
- Mixing stratified layers of air
- High ceilings, overhead supply/return ideal



Heating Savings - Additional Information

- *Impact of HVLS Fans on Airplane Hangar Air Destratification*
  - ASHRAE Journal, April 2020

- *Optimizing Winter Heating: Is reversing the direction of your ceiling fan the best way to achieve thermal destratification?*
  - Sonya Milonova, Harvard School of Public Health



TECHNICAL FEATURE

Impact of HVLS Fans On Airplane Hangar Air Destratification

BY CHRISTIAN TABER, BEMP, HBDP, MEMBER ASHRAE; BRANDON A. STEELE, STUDENT MEMBER ASHRAE

Thermal air stratification results when heated air rises due to its having a lower density relative to ambient air, which results in a thermal gradient from floor to ceiling. The heated air typically stagnates at the ceiling of large facilities due to a lack of air circulation.[1,2] Air stratification presents an important consideration in facility energy savings for buildings with tall ceilings; elevated air temperature at the ceiling level increases the rate of heat loss through the building envelope. A substantial opportunity to reduce annual heating costs for facilities is available by reducing floor-to-ceiling stratification.

Airports present a tremendous air destratification energy savings opportunity because many of the buildings have large, open spaces with high ceilings. Heating airport hangars to meet comfort temperature requirements often consumes large amounts of energy and produces an excessive amount of emissions. Like many other areas of industry,[3] airports are now under pressure to use energy-efficient systems and comply with increasingly stringent regulations while still providing occupant thermal comfort, all in an effort to reduce operating costs and reduce carbon footprint.

High volume, low speed (HVLS) fans are a prominent and practical means for reducing the floor-to-ceiling temperature gradient in large spaces. Large-diameter, HVLS fans are operated in the downward direction at low speeds during winter to mix warm air at the ceiling with cooler air at the floor, all while not creating the sensation of unwanted cooling across an occupant's skin. Fans can be operated in the upward direction to destratify air, but this typically requires higher operating speeds and costs, as the fan has to push the heated air along the ceiling and down a vertical surface to reach the thermostat level. The fans lower the average space temperature by minimizing excess heat at the ceiling, which reduces HVAC system use. The study presented in this article seeks to quantify the effects on energy cost and consumption from use of an HVLS fan for air destratification in an airport hangar.

Methods

The test building is 15,000 ft^2 (1,400 m^2), has a peak ceiling height of 40 ft (12 m) and height of 20 ft (6 m) at

Christian Taber, BEMP, HBDP, is principal engineer-codes and standards for Big Ass Fans in Lexington, Ky. Brandon A. Steele is Big Ass Fans' sustainability engineering intern and a student at the University of Kentucky.

Cooling Energy Savings

- What does it do
  - Increase convective & evaporative heat loss
  - Distribution and mixing
- What is the design criteria
  - Spaces with AC – 0.5 m/s to 1.0 m/s
- What is the result
  - Equal comfort at higher dry bulb temperatures
  - Reduced cooling energy use
  - Reduced duct work
  - Redundancy for increased resiliency
  - Reduced AC capacity OR
  - Excess capacity for future climate

CEC - EPIC Project 16-013

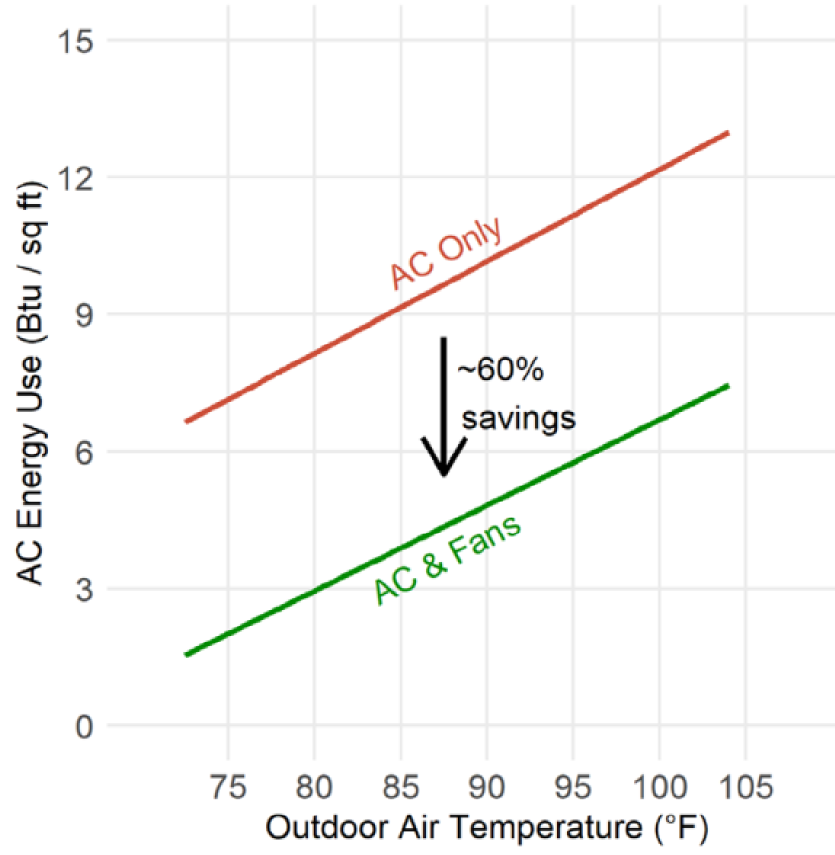
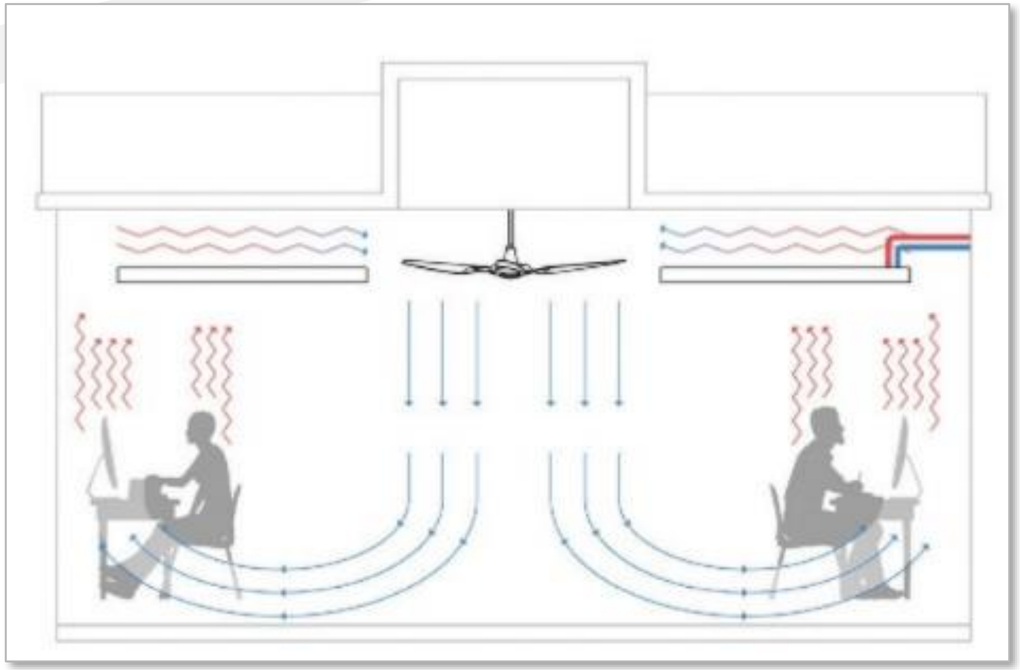


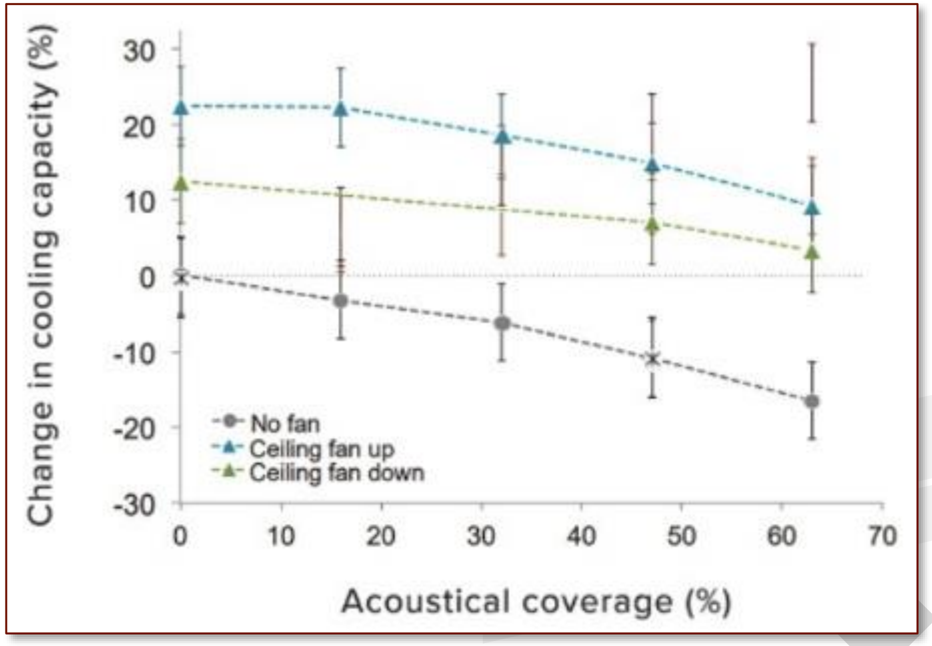
Figure 1. HVAC energy use in the common room was reduced by 60% by raising setpoints and using fans to cool occupants when the temperature was above 74 °F.

Note: 100 fpm = 0.5 m/s

Innovative HVAC Systems

- What does it do
  - Reduce required materials
  - Increases heat transfer
- What is the design criteria
  - Increased air speed
- What is the result
  - Instant cooling of occupants (forward)
  - Increased system capacity (forward and reverse)
  - Increased air distribution (forward and reverse)





Example System: Overhead Radiant + Fans

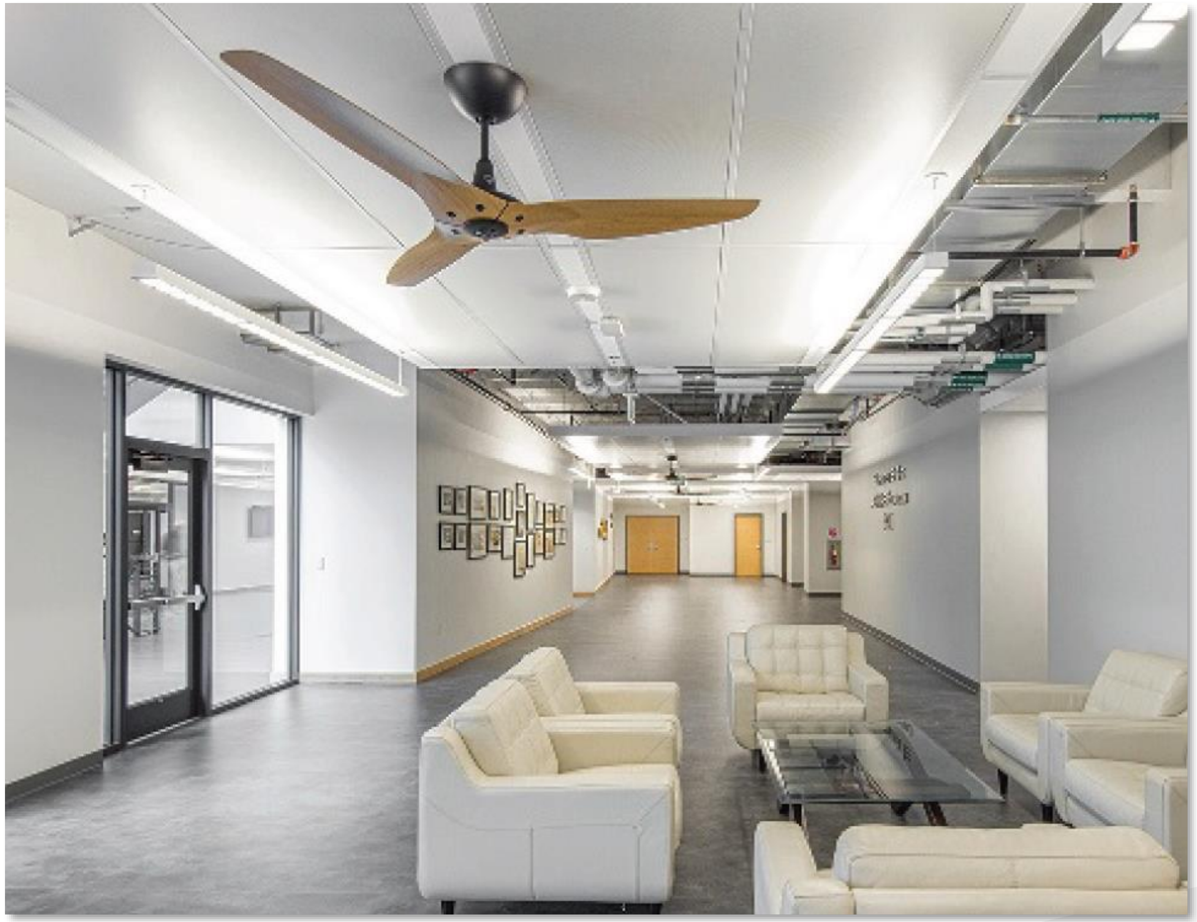


Image Source: ASHRAE GLOBAL HEADQUARTERS TRANSFORMING BUILDINGS FOR A SUSTAINABLE FUTURE

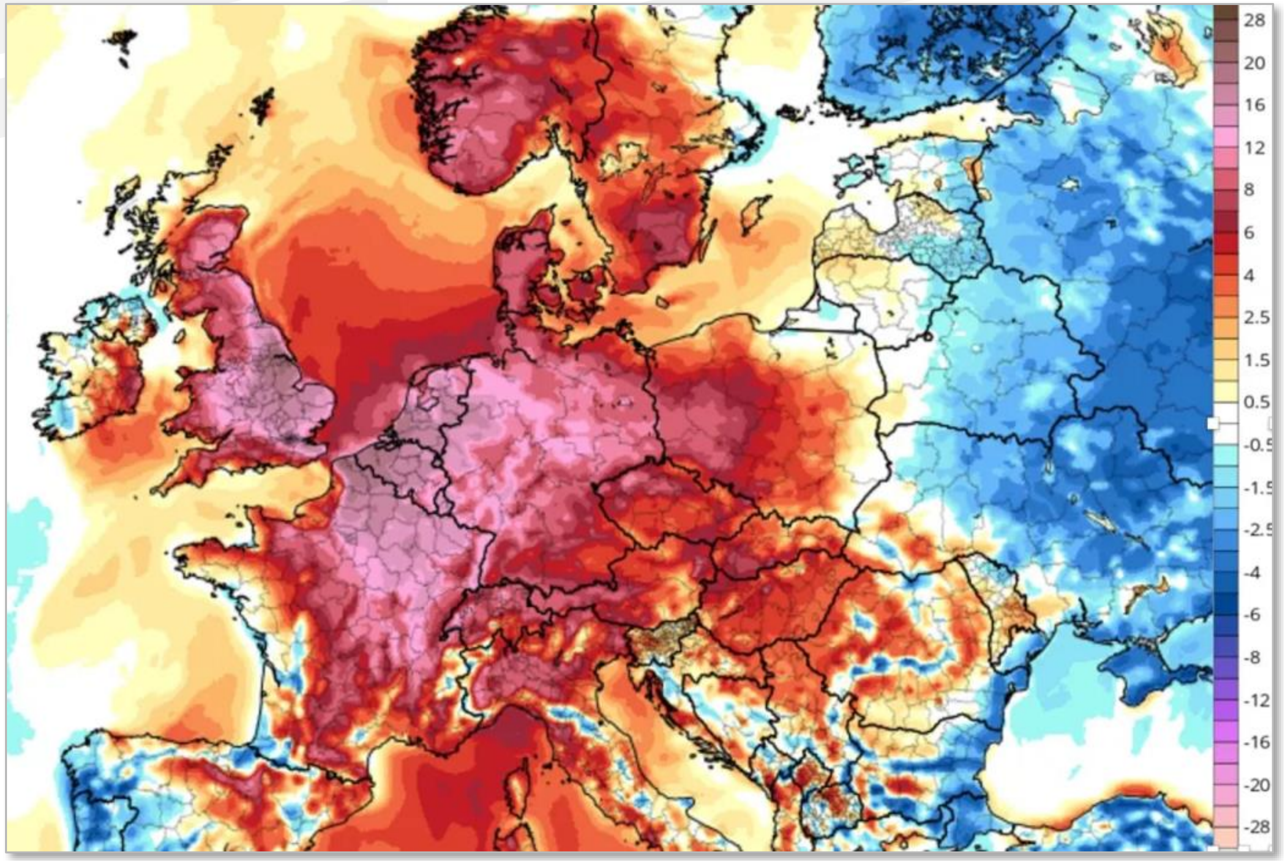
Additional Information

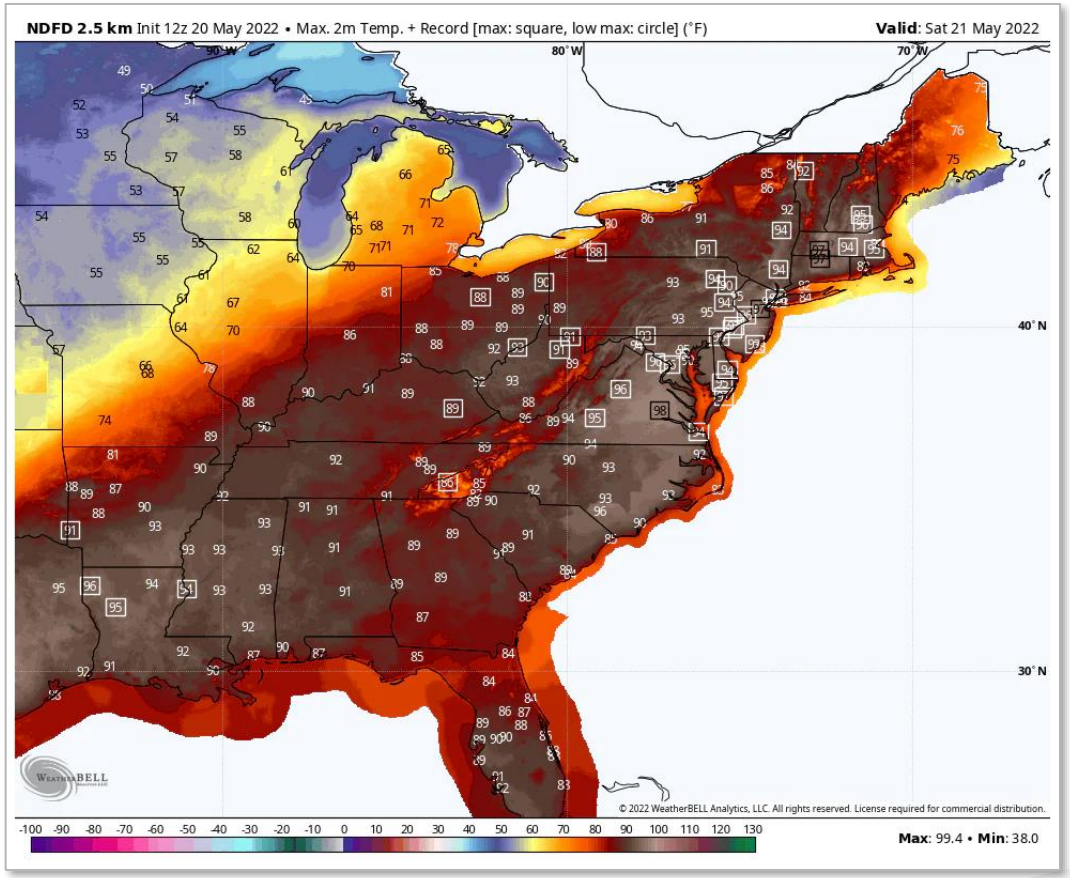
- ANSI/ASHRAE Standard 55-2020
- Center for the Built Environment Case Studies
- Integrating Smart Ceiling Fans and Communicating Thermostats to Provide Energy-Efficient Comfort
  - CEC Final Report
- ASHRAE Global Headquarters
  - Transforming Buildings for a Sustainable Future

Using LDCF to:

Increase Resilience During Extreme Events

Local Extreme Events – Heatwave Examples





Heat waves: increasing in frequency, magnitude, and often the most memorable and wide-spread resilience events, more than 15,000 deaths in 2022 attributed to heat (1)

Image Source: Yale Climate Connections, The Washington Post

(1) SOURCE: World Health Organization: Statement – Climate change is already killing us, but strong action now can prevent more deaths

Global Climatic Changes: City Analogues

- Analysis of 520 climates if major cities around the world and the shift due to climate change under RCP 4.5 scenario.
- To increase public context and impact, each current city climate (current city/climate) is paired to another existing different climate that best represents climate in the locale in 2050.
  - *Examples: London → Barcelona; Seattle, WA → San Francisco, CA; Stockholm → Budapest, etc.*
- 19 bioclimatic variables considered, 77% of cities shifted to a new climate by 2050 with RCP 4.5 model and 22% of cities will experience climate not currently seen in any major cities.
  - Northern hemisphere cities shifted on average 1000km south (warmer) with currently tropical cities shifting to drier conditions.

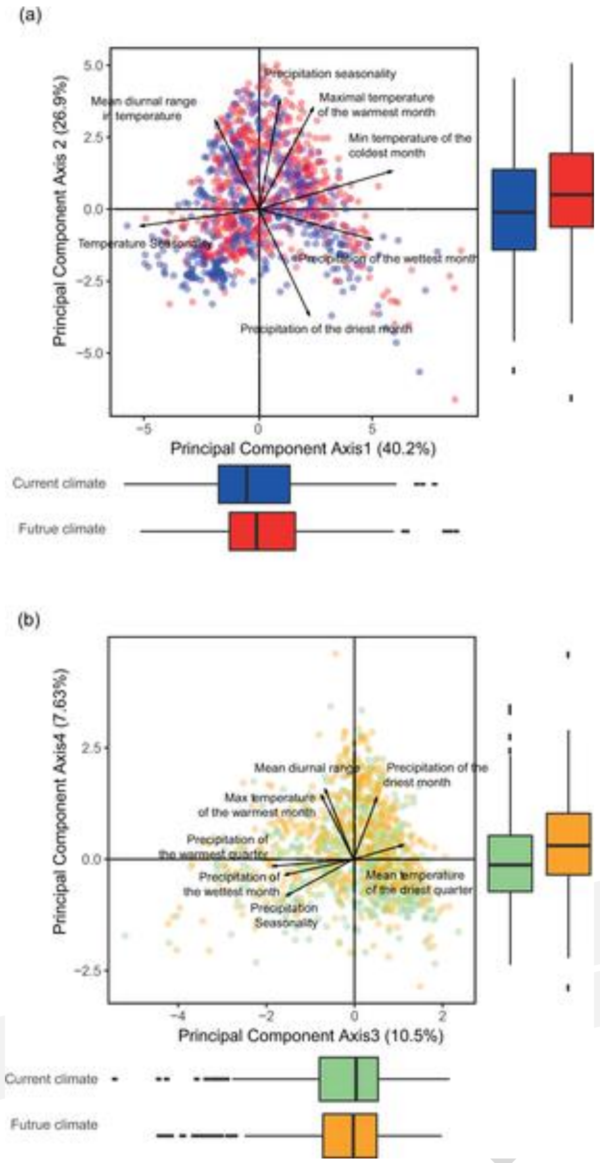


Image Source: ETH Zurich, Crowther Lab: Cities of the Future, Visualizing Climate Change to Inspire Action

Global Climatic Changes:

Below: Change in Hottest Month Average Highs

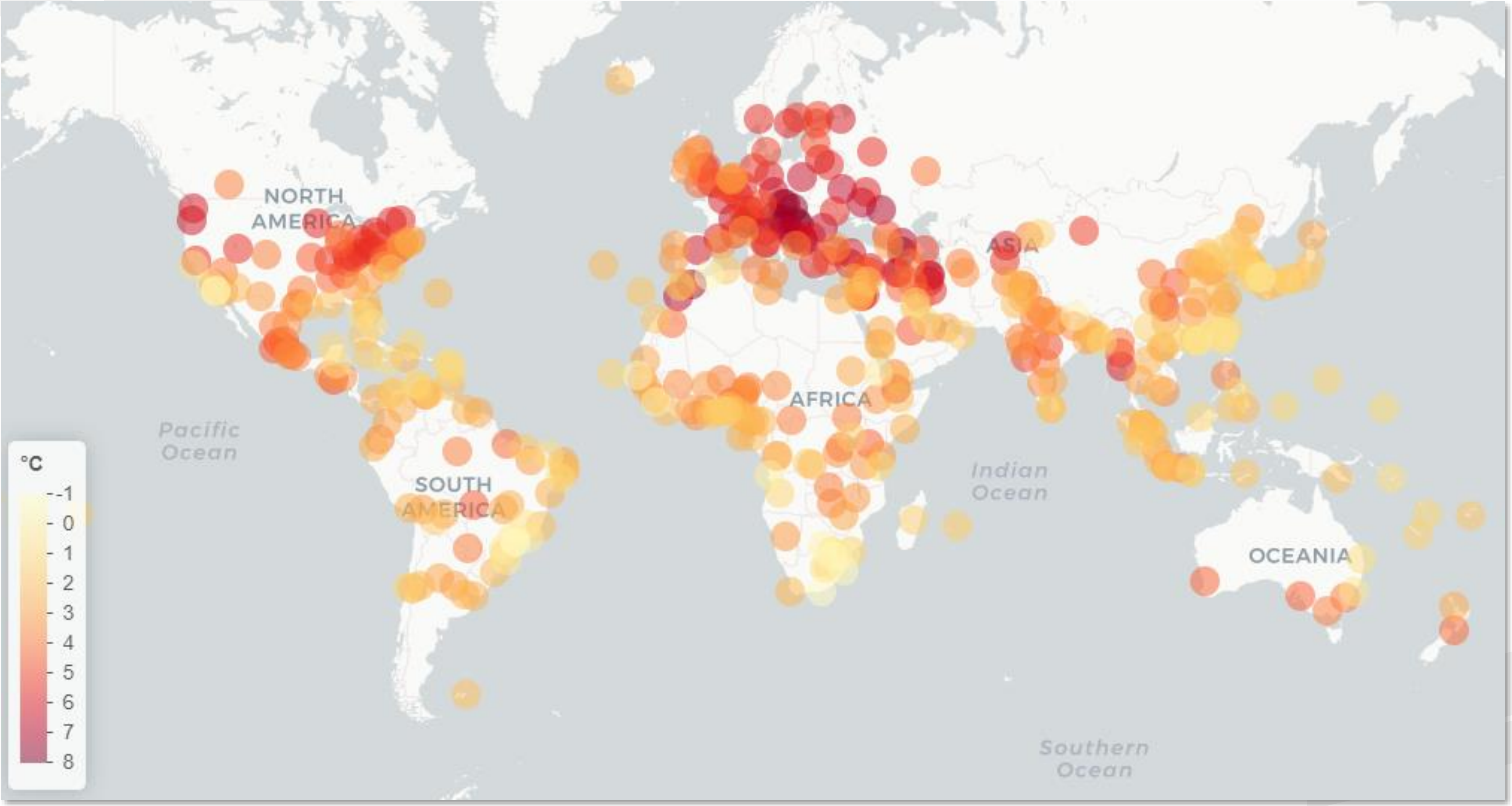
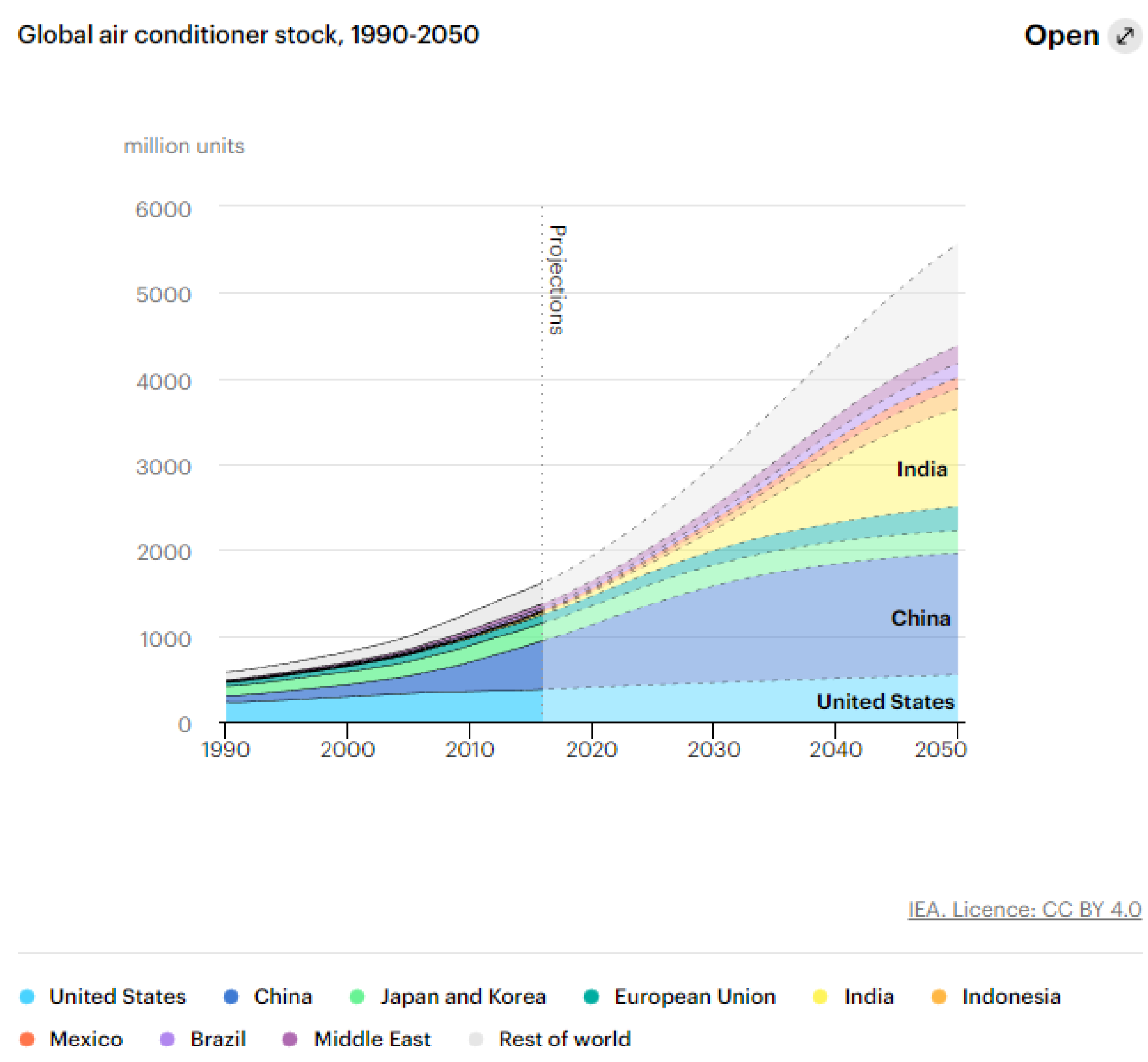


Image Source: ETH Zurich, Crowther Lab: Cities of the Future, Visualizing Climate Change to Inspire Action

Demand for Cooling, Industry Changes



ENVIRONMENT

Seattle is no longer the U.S.'s least air conditioned big city

After years of lethal heat waves, Seattleites are embracing A/C as a necessity rather than a luxury.

by Hannah Weinberger / December 29, 2022

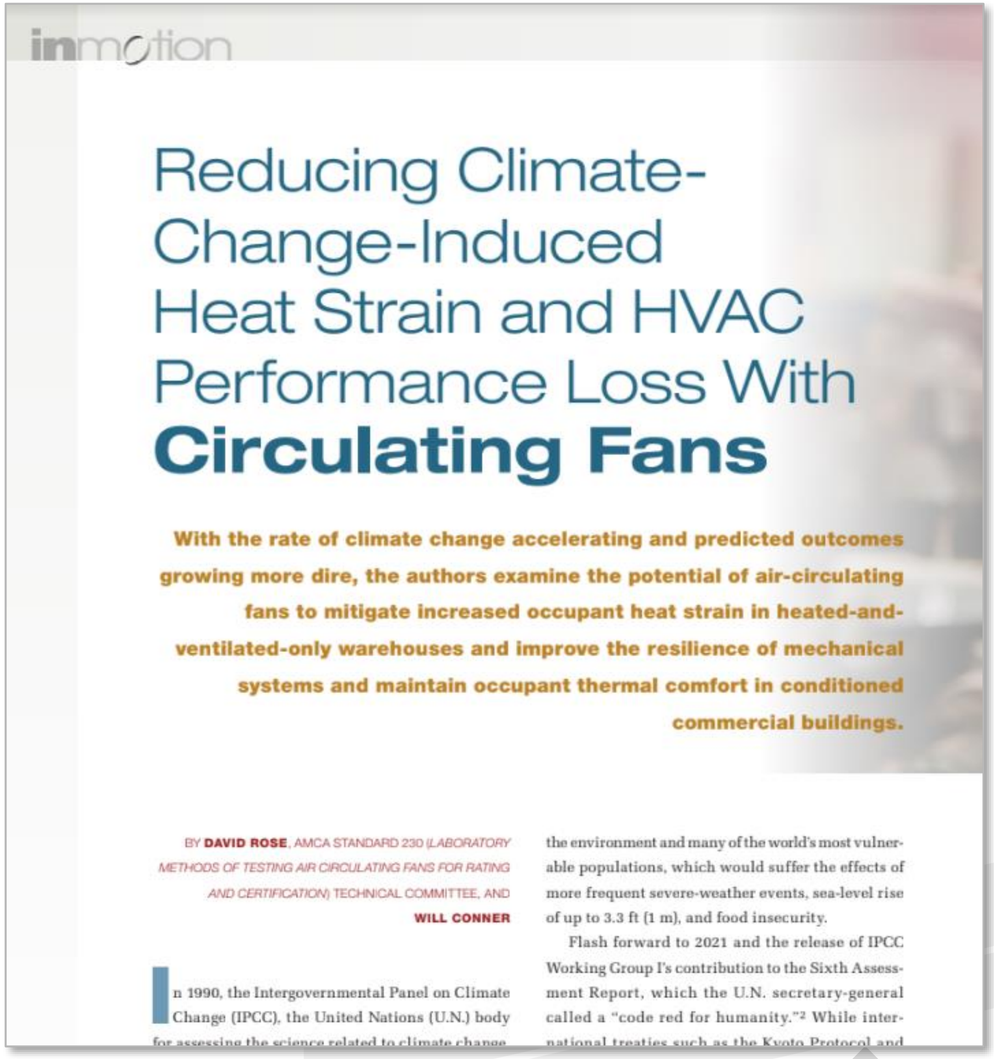
When Fred Woo and his family moved from San Diego to Seattle a decade ago, they brought their portable air conditioning unit with them, thinking it wouldn't be necessary in our historically temperate climate. They were right — for a while.

Image Source: IEA, Crosscut - Hannah Weinberger

Mitigating Effects of Climate Change with Fans

- **Unconditioned Warehouse Environment**
  - ***Can fans mitigate occupant heat stress increases in future conditions?***
  - **Methods:** Energy modeling and analysis of a DOE warehouse reference building
  - **Tools:** Commercially available building energy simulation software, TMY3 data, CBE Python thermal comfort code, NWS heat index tool.

- **Conditioned Office Environment**
  - ***Can fans mitigate increase in peak cooling load and energy use in future conditions?***
  - **Methods:** Energy modeling and analysis of a DOE medium office reference building
  - **Tools:** Commercially available building energy simulation software, TMY3 data, CBE Python thermal comfort code.


inmotion

Reducing Climate-Change-Induced Heat Strain and HVAC Performance Loss With **Circulating Fans**

With the rate of climate change accelerating and predicted outcomes growing more dire, the authors examine the potential of air-circulating fans to mitigate increased occupant heat strain in heated-and-ventilated-only warehouses and improve the resilience of mechanical systems and maintain occupant thermal comfort in conditioned commercial buildings.

BY **DAVID ROSE**, AMCA STANDARD 230 (*LABORATORY METHODS OF TESTING AIR CIRCULATING FANS FOR RATING AND CERTIFICATION*) TECHNICAL COMMITTEE, AND **WILL CONNER**

In 1990, the Intergovernmental Panel on Climate Change (IPCC), the United Nations (U.N.) body

the environment and many of the world's most vulnerable populations, which would suffer the effects of more frequent severe-weather events, sea-level rise of up to 3.3 ft (1 m), and food insecurity.

Flash forward to 2021 and the release of IPCC Working Group I's contribution to the Sixth Assessment Report, which the U.N. secretary-general called a "code red for humanity."[2] While inter-

Image Source: AMCA In-Motion 2022, Reducing Climate Change … With Circulating Fans

Heat Stress Resilience – Typical Warehouse

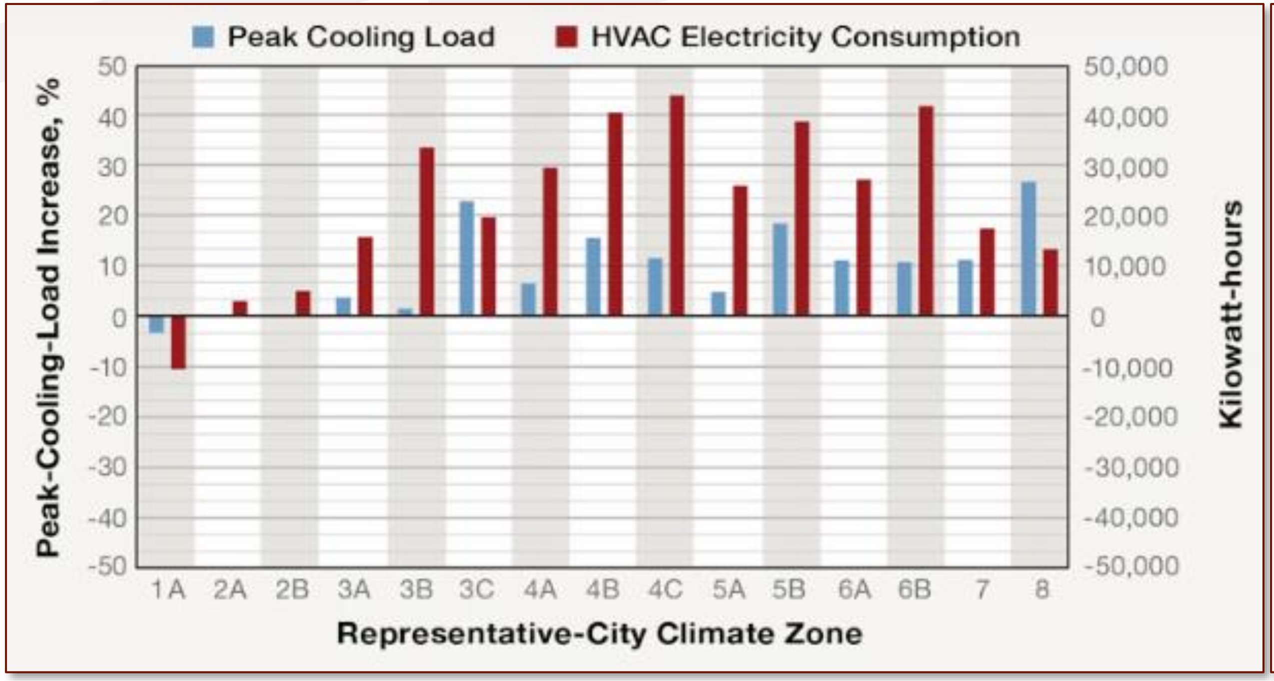
Representative City	CZ	Current Weather				Dangerous Hours
		Neutral	Very Warm	Hot	Very Hot	
Miami, Fla.	1A	1,709	2,348	2,991	1,712	4,703
Houston, Texas	2A	3,775	1,551	2,312	1,122	3,434
Phoenix, Ariz.	2B	3,184	1,783	2,639	1,154	3,793
Atlanta, Ga.	3A	4,854	1,604	1,804	498	2,302
Las Vegas, Nev.	3B	4,482	1,179	2,653	446	3,099
San Francisco, Calif.	3C	8,465	295	0	0	0
Baltimore, Md.	4A	5,866	1,595	1,275	24	1,299
Albuquerque, N.M.	4B	5,337	1,868	1,548	7	1,555
Seattle, Wash.	4C	8,261	494	5	0	5
Chicago, Ill.	5A	6,214	1,916	622	8	630
Boulder, Colo.	5B	6,319	1,922	519	0	519
Minneapolis, Minn.	6A	6,711	1,582	466	1	467
Helena, Mont.	6B	7,175	1,371	214	0	214
Duluth, Minn.	7	7,958	786	16	0	16
Fairbanks, Alaska	8	8,175	585	0	0	0

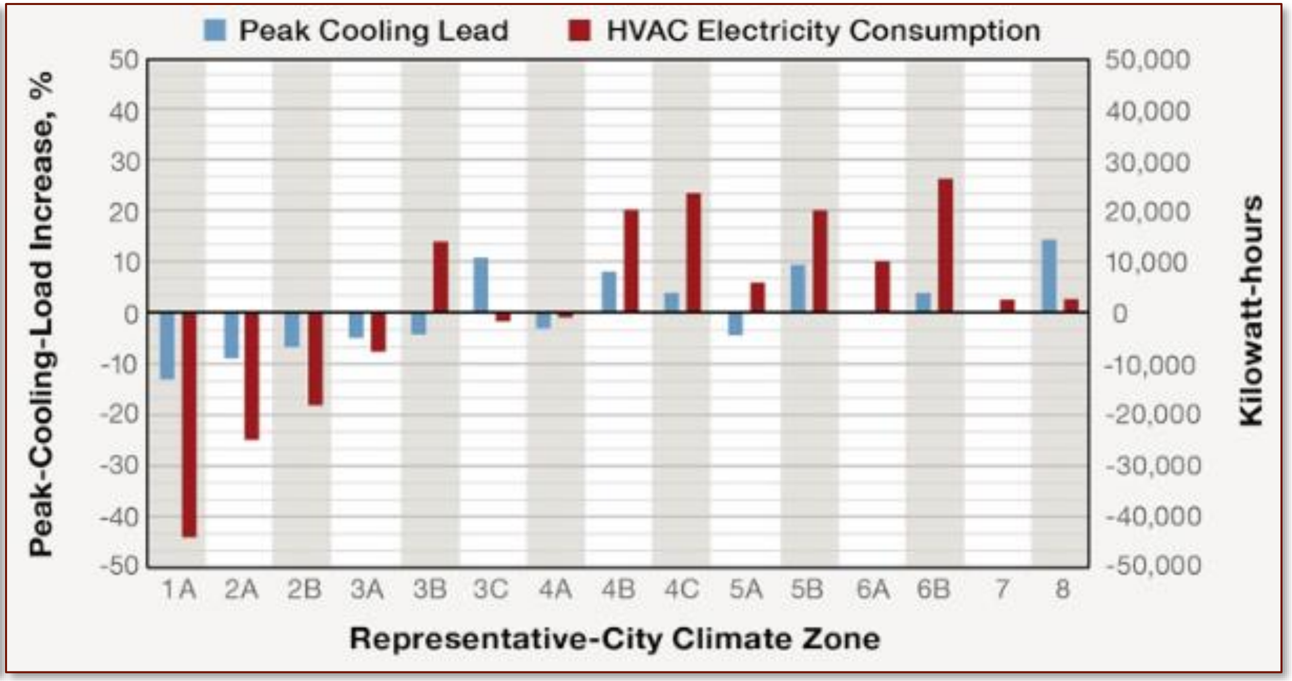
Future City Analog	Future Weather				Change in Dangerous Hours vs. Current
	Neutral	Very Warm	Hot	Very Hot	
Rio de Janeiro, Brazil	467	3,147	4,039	1,107	443 (9%)
Jacksonville, Fla.	3,853	1,895	2,416	596	-422 (-12%)
Kuwait City, Kuwait	2,594	1,594	3,511	1,061	779 (21%)
Memphis, Tenn.	4,858	1,485	1,953	464	115 (5%)
Phoenix, Ariz.	3,184	1,783	2,639	1,154	694 (22%)
Lisbon, Portugal	6,098	2,472	190	0	190 (NL)
Nashville, Tenn.	4,856	1,611	1,937	356	994 (77%)
El Paso, Texas	4,342	1,380	2,900	138	1,483 (95%)
San Francisco, Calif.	8,465	295	0	0	-5 (-100%)
St. Louis, Mo.	5,688	1,294	1,660	118	1,148 (182%)
Amarillo, Texas	5,883	1,438	1,421	18	920 (177%)
Kansas City, Mo.	5,791	1,283	1,640	46	1,219 (261%)
Salt Lake City, Utah	6,207	1,288	1,260	5	1,051 (491%)
Toledo, Ohio	6,341	1,930	489	0	473 (2,956%)
Winnipeg, Canada	7,289	1,145	326	0	326 (NL)

Future City Analog	Future Weather With Fans				Change in Dangerous Hours vs. Current
	Neutral	Very Warm	Hot	Very Hot	
Rio de Janeiro, Brazil	1,899	4,236	2,514	111	-2,078 (-44%)
Jacksonville, Fla.	5,085	1,895	1,748	32	-1,654 (-48%)
Kuwait City, Kuwait	3,388	1,590	3,749	33	-11 (0%)
Memphis, Tenn.	5,733	1,530	1,489	8	-805 (-35%)
Phoenix, Ariz.	4,103	1,668	2,890	99	-110 (-4%)
Lisbon, Portugal	7,560	1,200	0	0	0 (NL)
Nashville, Tenn.	5,652	1,982	1,114	12	-173 (-13%)
El Paso, Texas	4,926	2,085	1,749	0	194 (12%)
San Francisco, Calif.	8,754	6	0	0	-5 (-100%)
St. Louis, Mo.	6,271	1,908	581	0	-49 (-8%)
Amarillo, Texas	6,509	1,758	493	0	-26 (-5%)
Kansas City, Mo.	6,432	1,795	533	0	66 (14%)
Salt Lake City, Utah	6,686	1,738	336	0	122 (57%)
Toledo, Ohio	7,401	1,302	57	0	41 (256%)
Winnipeg, Canada	7,995	731	34	0	34 (NL)

Image Source: AMCA In-Motion 2022, Reducing Climate Change … With Circulating Fans

HVAC Performance Loss – Typical Office





Without fans: significant increases in both peak load and annual energy consumption.

With Fans: Reduced or significant mitigations in anticipated peak load and annual energy consumption

Image Source: AMCA In-Motion 2022, Reducing Climate Change … With Circulating Fans

Specifying LDCF for:
Thermal Comfort, Efficiency, & Resilience

Fan Safety Standards - UL 507 & CSA Standard 22.2 No. 113

- Third party safety standard for fans
  - Provides a minimum safety level, but does not cover industrial impact testing
  - Requires blades have smooth/rounded leading edges, safe electrical systems, etc.

- Designates ceiling fans into two categories
  - Safe to mount with blades ≥7 ft (2.1m) blade height - “Residential”
  - Safe to mount with blades ≥10 ft (3.05m) blade height - “Non-residential”
  - Classification based on blade thickness and tip speed

Table 90.1
Ceiling-suspended fans from 2.1 meters (7 feet) to less than 3.05 meters (10 feet) above floor

Air flow	Maximum speed at tip of blades,		Minimum thickness of edges of blades,	
	m/s	(feet per minute)	mm	(inch)
Downward	16.3	(3200)	3.2	(1/8)
Downward	20.3	(4000)	4.8	(3/16)
Upward	16.3	(3200)	4.8	(3/16)
Upward	12.2	(2400)	3.2	(1/8)

NFPA 13 (11.1.7 & 12.1.4) & 72

NFPA 13

11.1.7 High Volume Low Speed (HVLS) Fans. The installation of HVLS fans in buildings equipped with sprinklers, including ESFR sprinklers, shall comply with the following:

(1) The maximum fan diameter shall be 24 ft (7.3 m).

(2) The HVLS fan shall be centered approximately between four adjacent sprinklers.

(3) The vertical clearance from the HVLS fan to sprinkler deflector shall be a minimum of 3 ft (0.9 m).

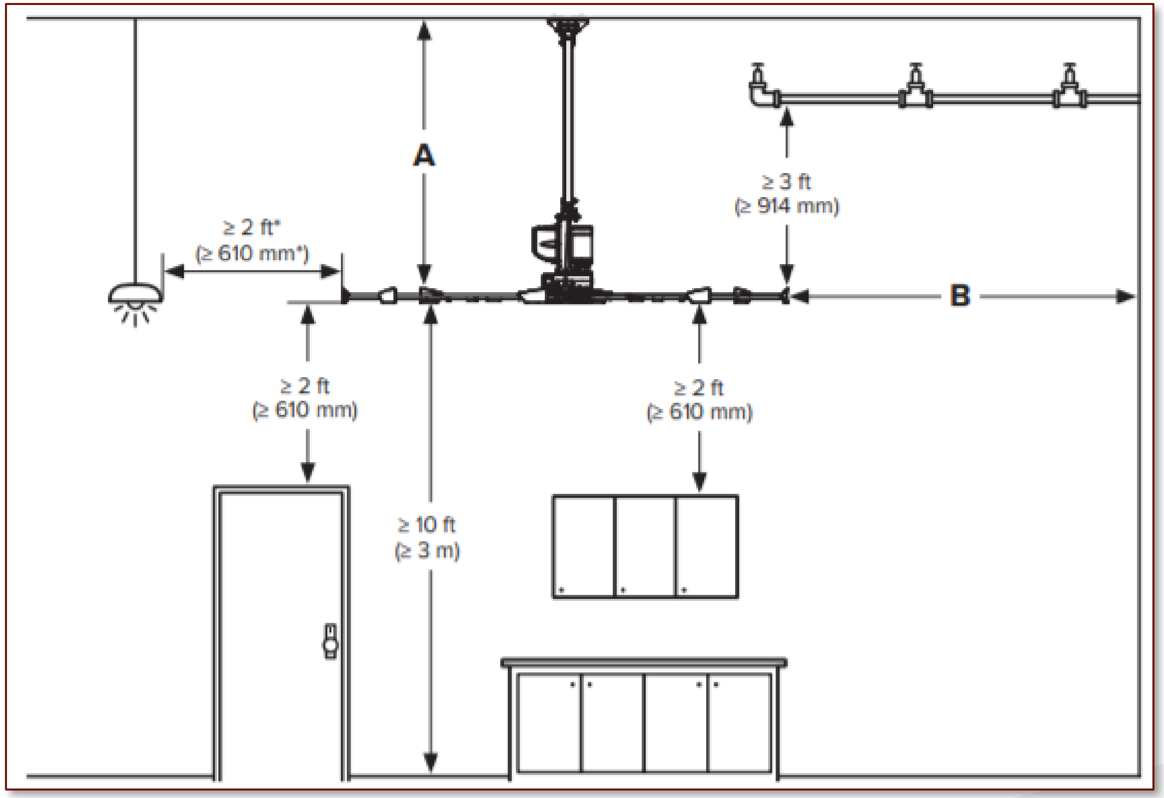
(4) All HVLS fans shall be interlocked to shut down immediately upon receiving a waterflow signal from the alarm system in accordance with the requirements of NFPA 72.

NFPA 72

Where required by NFPA 13, all HVLS large-diameter ceiling fans shall be interlocked to shut down upon actuation of a sprinkler waterflow switch that indicates waterflow in the area served by the fans.

Installation for Safety

- HVLS blade clearances
  - ≥ 2 ft (610mm) from objects
  - ≥ 3 ft (914mm) below sprinkler head
  - To wall ≥ diameter x 0.5
  - ≥ 2.5x diameter center to center
  - ~To ceiling ≥ diameter / 4 + 2 ft



- HVLS Blade Height
  - 10 ft (3.05m) above floor (UL 507)
  - ≥ diameter x 0.75

Air Movement and Control Association International (AMCA)

- Not-for-profit international association of the world's manufacturers of fans, louvers, dampers, air curtains, airflow measurement stations, acoustic attenuators, and other air system components.
  - Publishes and distributes standards, references, and application manuals
  - Provides third party certification of HVLS Fan performance
  - AMCA Publications 11 & 211 - Details of the Certified Ratings Program
  - AMCA 230 - Method of test for airflow and power
  - AMCA 208 - FEI (CFEI) efficiency metric
  - AMCA 340 - Method of test for sound performance (coming soon)

Why Does AMCA Certification Matter?

Claimed Performance – Example Non-Certified HVLS Fans*

Diameter	Input Power	Airflow	Output Power	Efficiency
24 ft (7.3m)	1.50 kW	389,746 cfm (184 m^3/s)	2.12 kW	141%
24 ft (7.3m)	1.50 kW	377,000 cfm (178 m^3/s)	1.92 kW	128%
24 ft (7.3m)	1.50 kW	360,210 cfm (170 m^3/s)	1.67 kW	111%

*Via google search for HVLS Fans in Middle East, three different manufacturers

AMCA Certified Performance – Mean of Three Fans**

Diameter	Input Power	Airflow	Output Power	Efficiency
24 ft (7.3m)	1.49 kW	254,987 cfm (120 m^3/s)	0.59 kW	40%

**Via AMCA certified product search (amca.org), three different manufacturers

Fan Specifications - Minimum Specifications

1. Large-diameter ceiling fans must comply with AMCA Publication 211 and be certified to bear the AMCA Certified Ratings Program seal. They shall be tested for air performance in accordance with ANSI/AMCA Standard 230.
2. The fan assembly, as a system (with and without light kit), shall be Intertek/ETL-certified and built pursuant to the guidelines set forth by UL standard 507 and CSA standard 22.2 No. 113.
3. Large-diameter ceiling fans shall be installed per the requirements of NFPA 13 & NFPA 72.
4. Fans shall be installed in accordance with manufacturer's instructions.

Stated directly - LDCF shall comply with the relevant requirements found in the IMC and ASHRAE 90.1.

Fan Specifications – Performance Based

- Ceiling fan sizing, placement, and performance shall be verified using computational fluid dynamics (CFD) analysis. At a minimum, the input data for the CFD analysis shall include the ceiling fan(s), significant obstructions to airflow at the floor level, and the actual space dimensions. As verification of cooling performance, the submittal shall include results of the CFD analysis including, at a minimum, the following performance metrics determined in accordance with ANSI/ASHRAE Standard 55: average air speed, average cooling effect from elevated air speed, Predicted Mean Vote, and Predicted Percentage Dissatisfied for seated and/or standing occupants in each occupied zone.

- Ceiling fan sizing, placement, and performance shall be verified using computational fluid dynamics (CFD) analysis. At a minimum, the input data for the CFD analysis shall include the ceiling fan(s), air speed at the floor level, and the actual space dimensions. As verification of destratification performance, the submittal shall include demonstration of the fan jet reaching the floor level and verification of a minimum of two air turnovers per hour at a fan operating speed that does not generate a draft over a significant portion of the occupied floor area.

Q & A

Thank you for your time!

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PDH credits and participation certificates will be issued electronically within 30 days, once all attendance records are checked and online evaluations are received.

Attendees will receive an email at the address provided on your registration, listing the credit hours awarded and a link to a printable certificate of completion. For any questions, please contact Lisa Cherney, AMCA Education Manger (lcherney@amca.org).