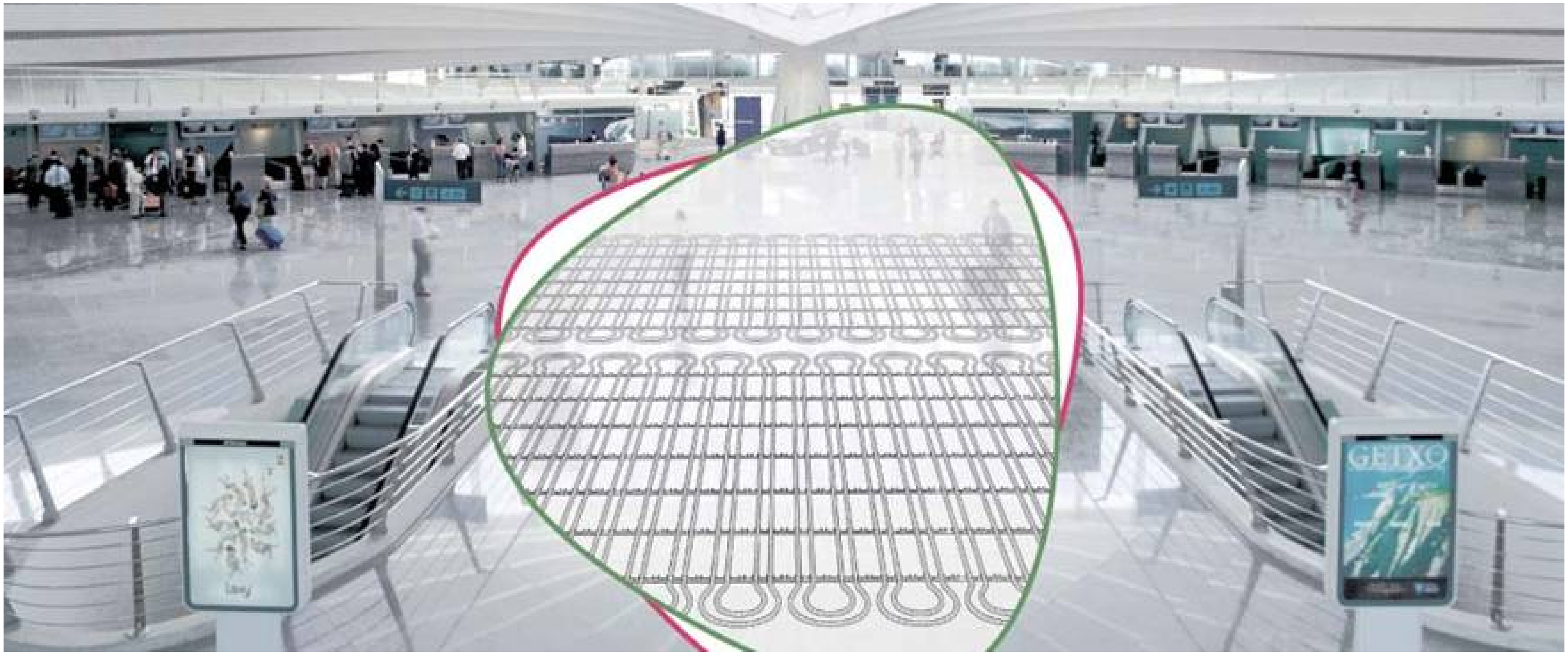
Unlimited Polymer Solutions



RADIANT COOLING SYSTEMS

OPPORTUNITIES FOR RADIANT COOLING IN NORTH AMERICAN CONSTRUCTION

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www.rehau.com

Construction
Automotive
Industry

LEARNING OBJECTIVES OF THIS COURSE

BY THE END OF THIS COURSE, PARTICIPANTS SHOULD BE ABLE TO:

1. Explain the basic principles of radiant cooling systems and the factors that affect the output capacities
2. Define the meaning of a “hybrid” HVAC system and how it can be optimized to address the concern of condensation
3. Discuss how a hybrid HVAC system using radiant cooling leads to an improved building environment
4. Describe how a hybrid HVAC system using radiant cooling can reduce initial investment costs
5. Explain how a hybrid HVAC system using radiant cooling can reduce operating costs through reduced energy consumption and maintenance
6. Demonstrate how a hybrid HVAC system using radiant cooling can affect the net present value of the investment
7. Summarize the advantages of having a radiant system from an specifier’s perspective

PROLOGUE: RADIANT COOLING SYSTEMS

CORE COMPONENTS USED IN RADIANT HEATING AND COOLING INSTALLATIONS

- Crosslinked polyethylene (PEX) pipes
- Distribution manifolds

CROSSLINKED POLYETHYLENE (PEX) PIPES

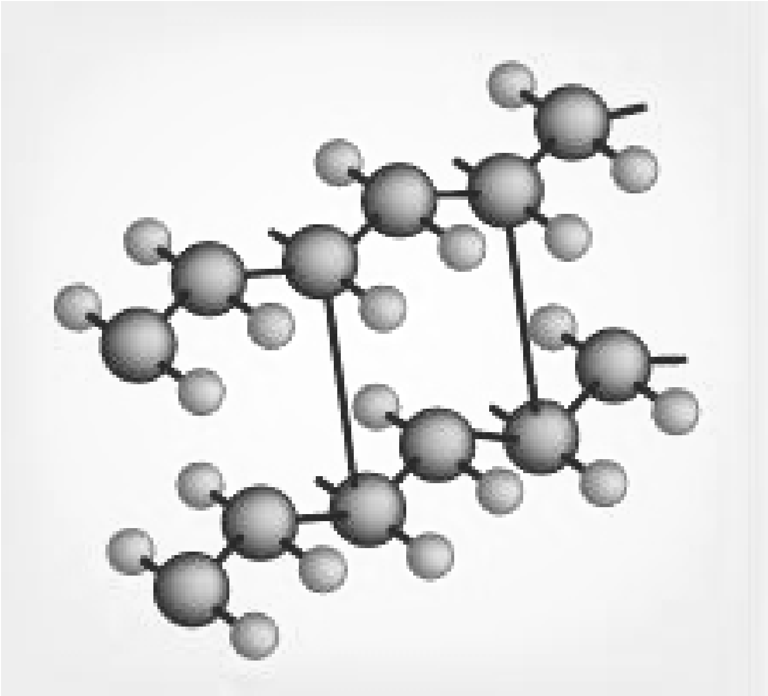
INTRODUCTION

History

- Development work started in Germany in 1968 for the first PEX pipes
- Series production began in 1972 for PEX pipes for radiant heating applications
- PEX pipes are now used for multiple fluid-based applications around the globe

Capabilities of PEX pipes

- Toughness to withstand jobsite conditions
- High pressure and thermal capabilities
- High flexibility for making tight bends
- Wide range of diameters and coil lengths
- Proven long life with more than 40 years experience



PEXa molecule

CROSSLINKED POLYETHYLENE (PEX) PIPES

AVAILABLE SIZES

- Sizes 3/8, 1/2, 5/8 and 3/4 in. are most commonly used as radiant heating and cooling pipes* within floors, walls or ceilings

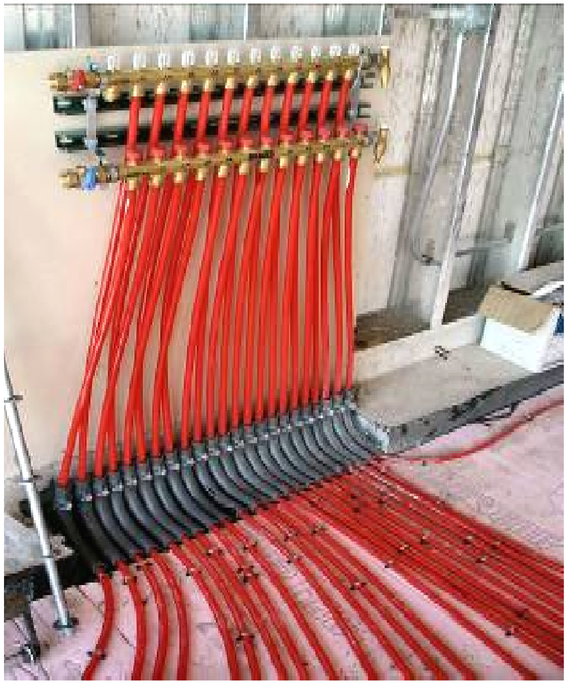
- Larger sizes 1, 1 1/4, 1 1/2 and 2 in. are used to supply heated or cooled fluid to distribution manifolds and other hydronic components

* Note: Radiant cooling applications are most commonly designed with 5/8 or 3/4 in. diameters

DISTRIBUTION MANIFOLDS

REQUIRED IN ALL RADIANT SYSTEMS FOR CONTROL OF DISTRIBUTION PIPING

- A typical circuit of radiant pipe covers 150 to 250 ft^2 (14 to 23 m^2); typical project uses many circuits of pipe
- Circuits are connected to factory-assembled distribution manifolds to control flow
- Examples:


1. PRINCIPLES OF RADIANT COOLING

BASIC PHYSICAL PHENOMENA

Whenever there is a temperature difference between two objects, both objects will attempt to equalize the temperature. The energy transfer required to approach equivalent temperatures occurs through radiation.

Radiant energy travels from “hot” to “cold” through a space, without heating the space itself.

PRINCIPLES OF RADIANT COOLING

BASIC PHYSICAL PHENOMENA

MODES OF HEAT TRANSFER FROM OUR BODIES

Conduction – Direct contact
- Ex: Hand on a hot plate, feet on a cool floor

Evaporation – Energy transfers with the vapor associated from perspiration and breathing
- Ex: Moisture lost through sweating in warm conditions

Convection – A fluid transfers the energy (air is a fluid)
- Ex: Air being heated by a warm floor becomes buoyant; warm air gently rises while cold air falls

Radiation – Warm objects radiate heat waves to cooler objects in line of sight
- Ex: Sun heating the earth or people warmed near a bonfire; no air is involved

PRINCIPLES OF RADIANT COOLING

BASIC PHYSICAL PHENOMENA
HUMAN COMFORT

- **Heat emission from the human body occurs through four modes of transfer:**
  - Conduction (~5%)
  - Evaporation (~20%)
  - Convection (~30%)
  - Radiation (~45%)

- Our bodies radiate heat to any surface in line of sight which is cooler than our bodies' surface temperature of 85° to 90°F (29 to 32°C)
  - Reducing surrounding surface temperatures draws more heat from our bodies via radiation

- Humans feel most comfortable when they can regulate at least 45% of their heat emission through radiation

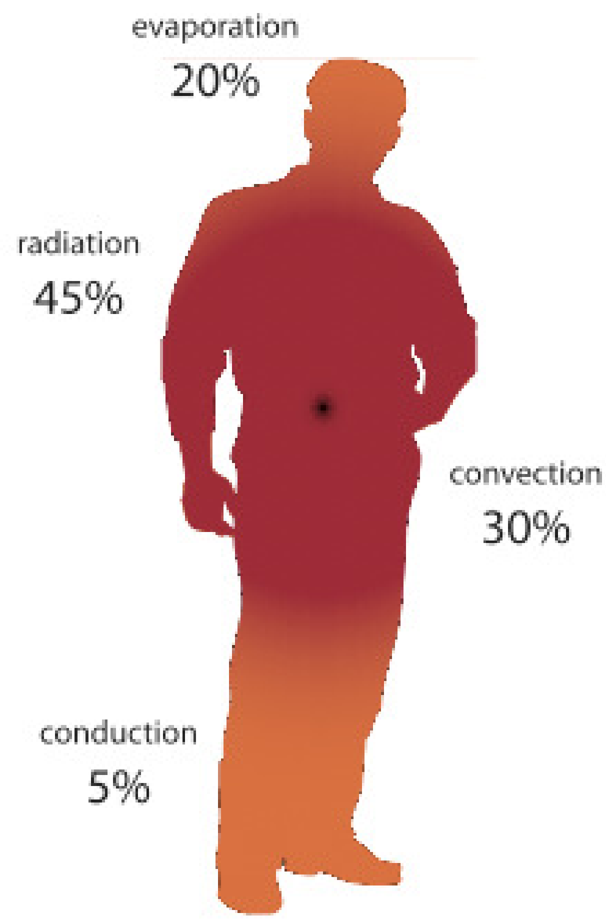


Image courtesy of RPA

PRINCIPLES OF RADIANT COOLING

OVERVIEW OF RADIANT COOLING SYSTEMS

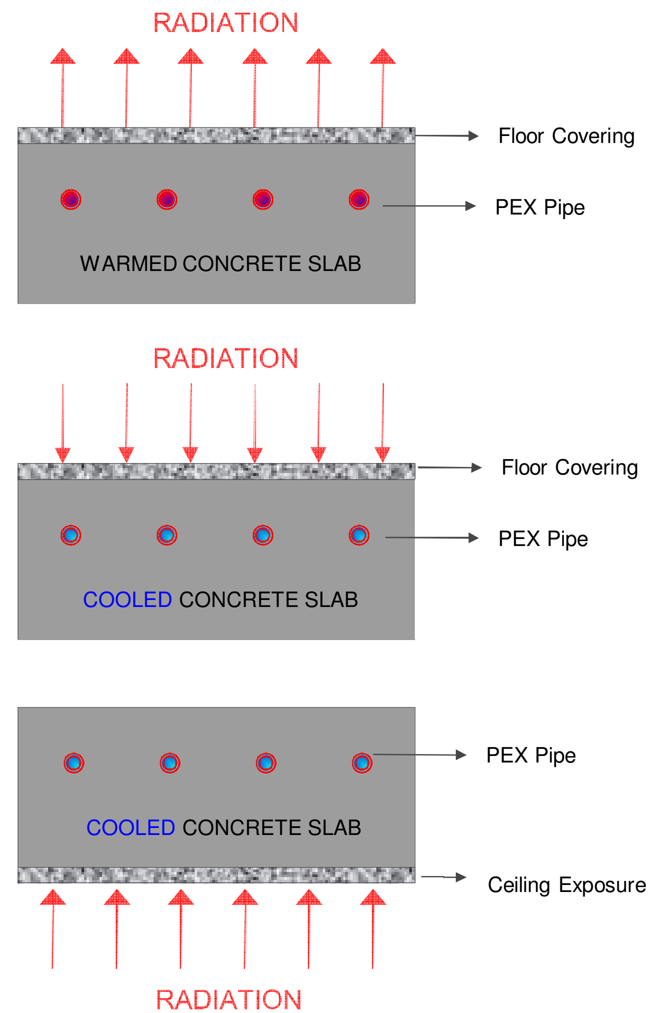
HEAT TRANSFER

In a radiant heating system, warm fluid circulates through PEX pipes which are integrated in the floor structure

- Heat radiates up from the warmed floor, providing a comfortable environment by warming people and objects
- Warm air also rises due to natural convection

A radiant cooling system works with the reverse energy transfer process, providing a comfortable environment by absorbing heat from the space

- Heat transferred through the floor is removed from the space via the circulating fluid
- In cooling mode, the same network of pipes is used as in the heating mode
- In some applications pipes can be embedded into the ceiling or even the wall



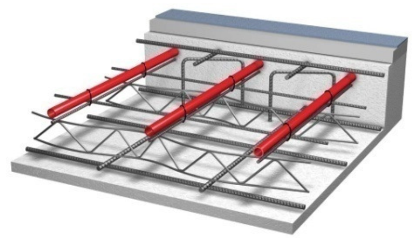
PRINCIPLES OF RADIANT COOLING

OVERVIEW OF RADIANT COOLING SYSTEMS

INSTALLATION TYPES

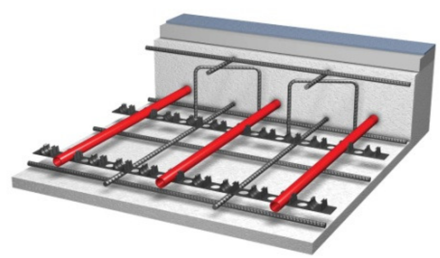
Thermally Activated Building System (TABS)

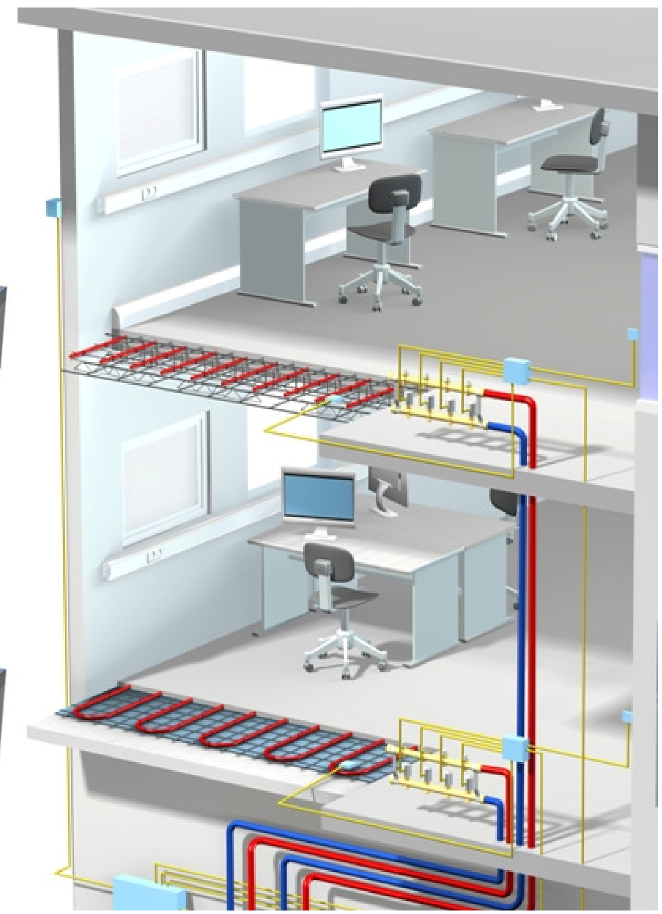
- a.k.a. TAS, BATISO, BKT
- Without insulation underneath to condition the space above and below
- Heated/cooled floor and ceiling
- Bi-directional



Radiant Floor Cooling and Floor Heating (FC/FH)

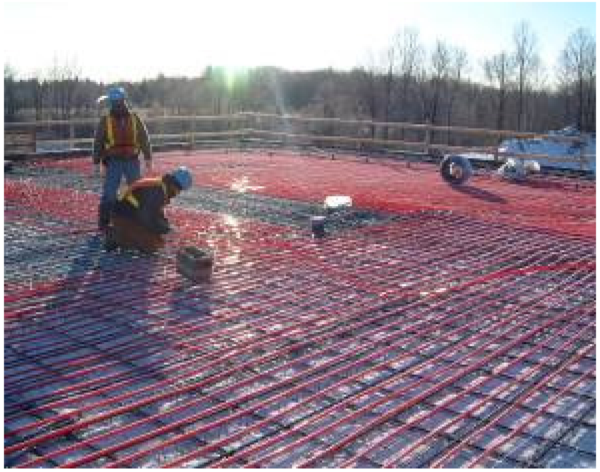
- With insulation underneath to condition the space above
- Heated/cooled floor
- Uni-directional





PRINCIPLES OF RADIANT COOLING

THERMALLY ACTIVATED BUILDING SYSTEM EXAMPLE WITH EXPOSED DUCTWORK AND CEILINGS
WOODBRIDGE, ONTARIO



PRINCIPLES OF RADIANT COOLING

TEMPERATURE SET POINTS

From years of adjusting thermostats, we have been conditioned to believe that air temperature alone translates to comfort, but this is not necessarily true.

We have to consider:

1. **Air temperature**
   Space's air temperature, monitored by thermostat as "set point temperature"

2. **Mean radiant temperature (MRT)**
   Average temperature of surrounding surfaces

3. **Operative room temperature**
   Weighted average of mean radiant temperature and the conditioned space's air temperature

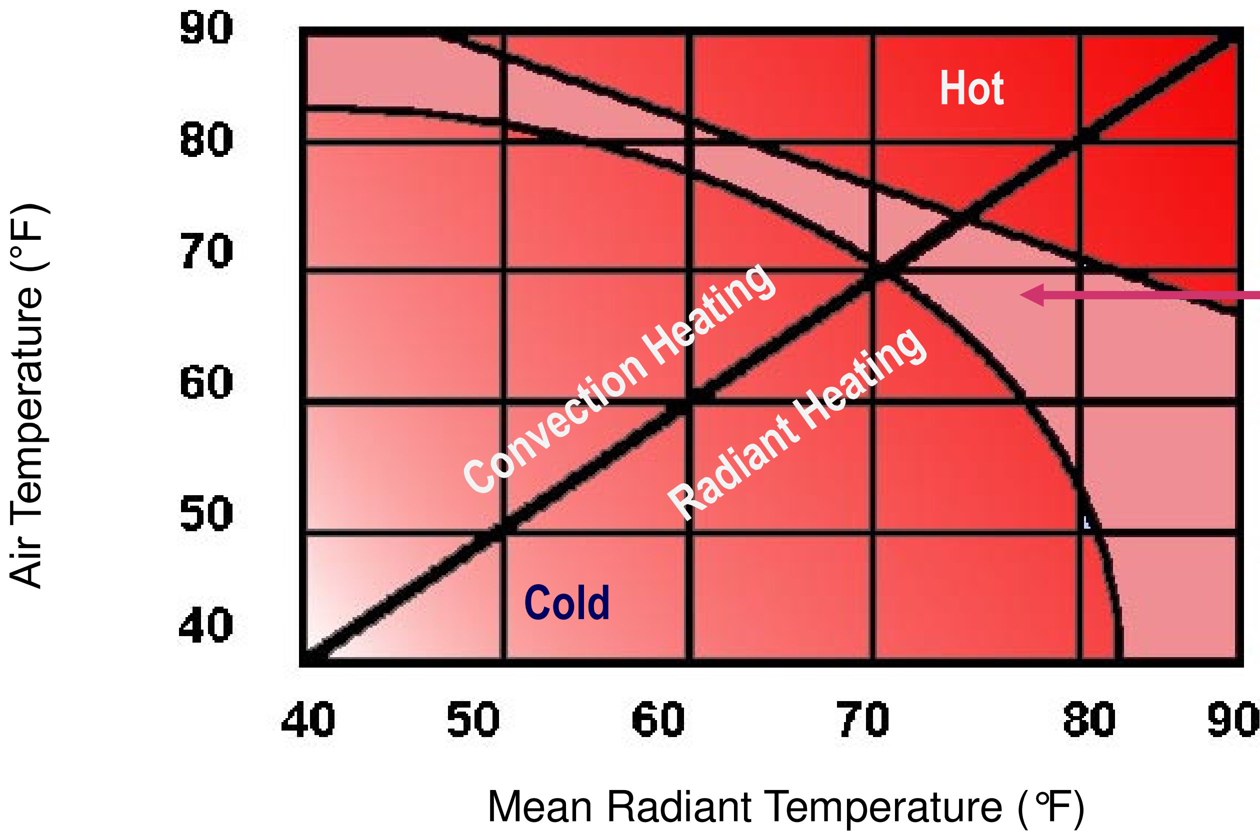
The **operative temperature** is what we perceive on our skin in a room and what is most important to consider when specifying a radiant system.

Higher air temperature set points during the cooling season and lower set points during the heating season are possible with radiant systems.

PRINCIPLES OF RADIANT COOLING

TEMPERATURE SET POINTS

THE EFFECTS OF MEAN RADIANT TEMPERATURE ON COMFORT



Pink area is the approximate comfort zone

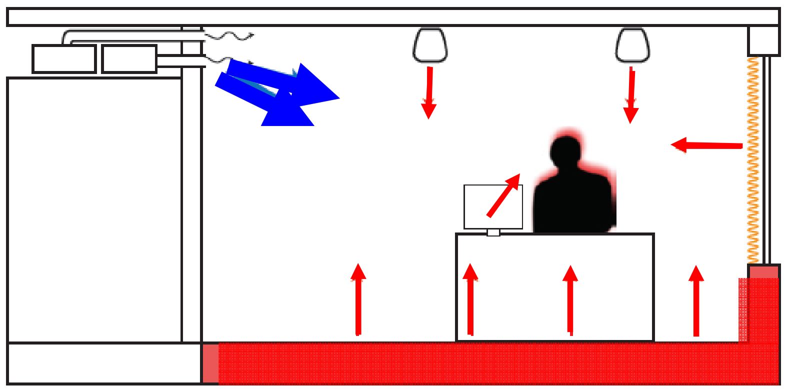
MRT comfort graph originally published in *Architectural Forum*, January 1939

PRINCIPLES OF RADIANT COOLING

TEMPERATURE SET POINTS

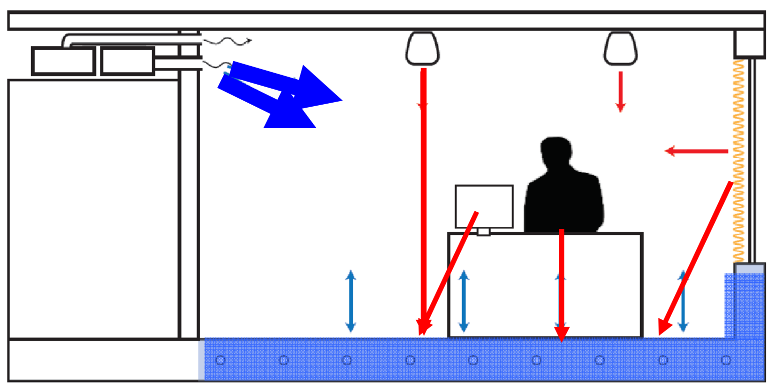
Spaces with 100% forced-air systems have higher mean radiant temperatures due to solar gains and office equipment

- Occupant turns down the air set point, trying to counter radiant loads using cooler air
- This requires **more air movement, inefficiently countering MRT**



With an air-based system in combination with a radiant cooling system, surface temperatures are lower

- This increases the heat emitted from the occupant to surrounding surfaces via radiation
- Occupant feels comfortable within the space, which **removes the need for a lower air temperature and/or increased air flow**
- Most efficiently counters heat loads



PRINCIPLES OF RADIANT COOLING

RADIANT COOLING CAPACITIES

THEORY

- $\dot{q}$: Specific heating/cooling capacity in W/m² or Btu/(h·ft²)
- HTC: Heat transfer coefficient
- $T_{SURFACE}$: Average surface temperature
- T_{AIR}: Air temperature

$$\dot{q} = HTC\left(T_{SURFACE} - T_{AIR}\right)$$

Cooling	Ceiling	~1.9 Btu/(h·ft² F)
	Floor	~1.2 Btu/(h·ft² F)
Heating	Ceiling	~1.1 Btu/(h·ft² F)
	Floor	~1.9 Btu/(h·ft² F)

- ~ 60% more output from ceiling cooling system vs. floor cooling system
- Reverse for heating mode

Heat transfer coefficient (HTC) values can be approximated based on values from DIN EN 1264 and 15377

FACTORS AFFECTING OUTPUT CAPACITIES

RADIANT COOLING CAPACITIES
PERFORMANCE OF RADIANT FLOORS AND CEILINGS

For comfort, ASHRAE *Standard 55* limits floor temperature range to:

- Greater than 66℉ (19℃) in cooling mode
- Less than 84℉ (29℃) in heating mode

Typical capacities based on setpoints adjusted for radiant systems:

		$T_{SURFACE}$	OUTPUT
Floor	Heating	78-84℉	19-31 Btu/(h·ft^2)
	Cooling	66-70℉	8-12 Btu/(h·ft^2)
Ceiling	Heating	78-84℉	11-17 Btu/(h·ft^2)
	Cooling	66-70℉	15-24 Btu/(h·ft^2)

Ceilings are not limited by the ASHRAE 55 floor limit; ceiling values are used only to show capacity comparison

Obtaining a designed surface temperature from a radiant floor system depends on factors such as **average fluid temperature**, **pipe spacing**, **pipe placement**, **floor covering**, **room set point temperature**

PRINCIPLES OF RADIANT COOLING

RADIANT COOLING CAPACITIES

PERFORMANCE OF RADIANT FLOORS

- Obtaining a designed surface temperature from a radiant floor system depends on factors such as **insulation**, **pipe spacing**, **floor construction**, **floor covering**, **room set point temperature**
- Floor surface temperatures less than 66℉ (19℃) should be avoided for comfort reasons, according to ASHRAE *Standard 55*
- Under optimal design conditions, floor cooling capacities of up to **16 Btu/(hr·ft²)** can be achieved*, with more typical capacities in the **8-12 Btu/(h·ft²)** range

  **Olesen, Bjarne. Radiant Floor Cooling Systems, ASHRAE Journal, September 2008*

Compared with the same floor system in **radiant heating** mode:

- Floor surface temperatures over 84℉ (29℃) should be avoided for comfort reasons
- Capacities of up to **32 Btu/(hr·ft²)** can be achieved under optimal design conditions

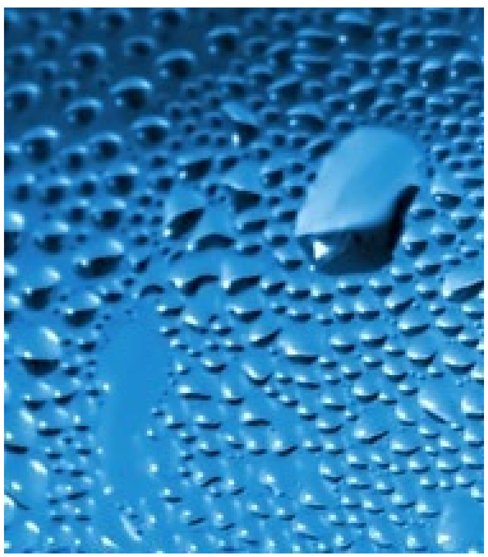
2. ADDRESSING CONCERN OF CONDENSATION

DESIGN CONSIDERATIONS

HUMIDITY AND CONDENSATION

Understanding the basic principles of radiant systems starts to reveal where their many benefits can be found. Many are convinced that radiant heating systems contribute to sustainable building, but still have reservations about radiant cooling.

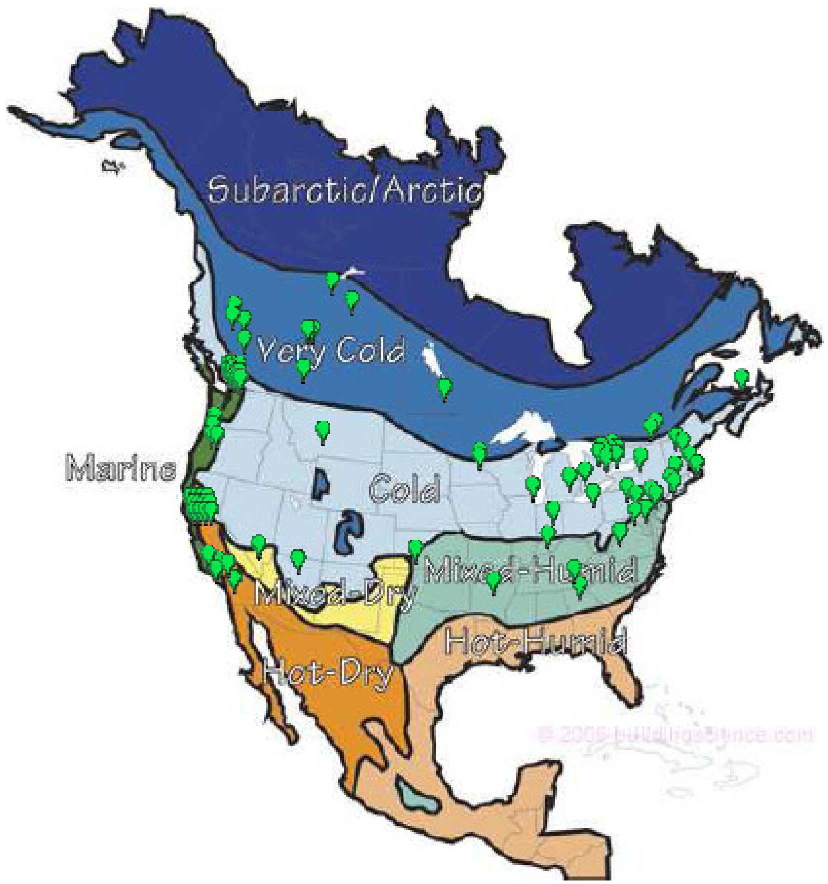
Radiant cooling needs a slightly more sophisticated design approach compared to radiant heating due to **solar gains, occupant loads** and resulting **moisture management issues**, which for most climates of North America pose concerns for specifiers.



When a surface temperature is lower than the dew point, condensation can form

ADDRESSING CONCERN OF CONDENSATION

DESIGN CONSIDERATIONS
HUMIDITY AND CONDENSATION



Sampling of radiant cooling projects in NA

Cooling projects located outside arid climates demonstrate that results are driven by successful design, not climate

- Controls are available to avoid uncomfortable and dangerous condensation

See DOE sponsored research: *Radiant Cooling in US Office Buildings: Towards Eliminating the Perception of Climate-Imposed Barriers*, C.Stetiu (1998): Lawrence Berkeley National Laboratory

Also noteworthy, usage of radiant cooling in "very cold" regions

- Where specifiers have chosen radiant heating, they can easily take advantage of the cooling potential in the existing PEX network
- Addition of radiant cooling minimally increases the initial cost and has many advantages during operation

ADDRESSING CONCERN OF CONDENSATION

DESIGN CONSIDERATIONS
HYBRID SYSTEMS

Successful radiant cooling projects center around understanding the correct balance of an air handling unit (AHU) working in conjunction with a radiant system. These are referred to as "hybrid HVAC systems."

Note: "AHU" is used to indicate any forced-air system used to condition a space (e.g., fan coil, packaged rooftop unit, DOAS).

The radiant system and the AHU work together as a hybrid HVAC system, optimizing system design and performance by decoupling the following portions of the system:

1. Hydronic and air-based
2. MRT and air temperature
3. Sensible (dry) and latent (humid) cooling

ADDRESSING CONCERN OF CONDENSATION

DESIGN CONSIDERATIONS

HYBRID SYSTEMS

Although hydronic conditioning systems have many benefits, they usually can not work alone in commercial applications

Hybrid HVAC systems must have an air-based component for several reasons:

1. AHU is required to meet the building's fresh air requirements, staying consistent with increased building environment standards (e.g., ASHRAE 62.1, LEED)

2. Downsized forced-air components must exist to counter humidity from outside air and from occupants within a building (latent cooling)

ADDRESSING CONCERN OF CONDENSATION

DESIGN CONSIDERATIONS

HYBRID SYSTEMS

The key to preventing condensation lies in a three specific areas:

1. Infiltration

- First and foremost, use a **tight building envelope** to reduce loads associated with non-mechanical infiltration

2. Surface Temperature

- Control surface temperatures by designing cooled surfaces to operate at specific supply temperatures to **prevent the surface from reaching dew point**, which might lead to surface condensation

3. Relative Humidity

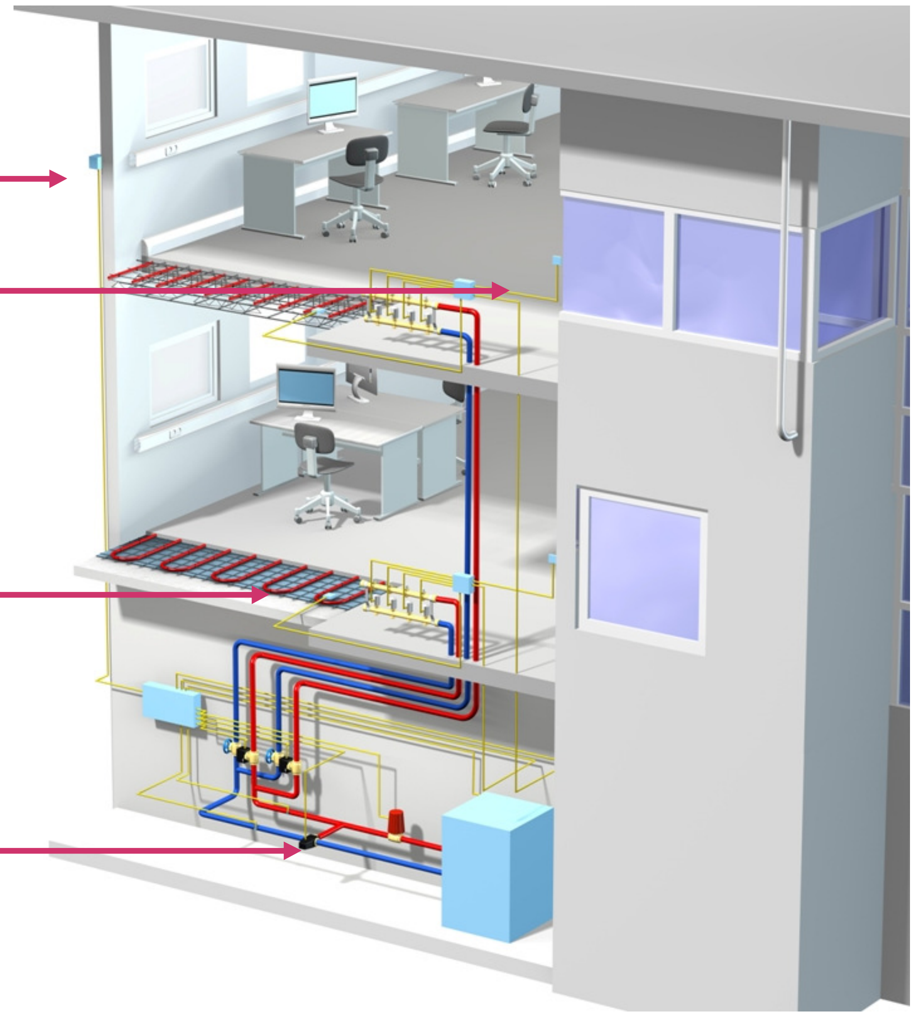
- Control the level of humidity in a building with the AHU to keep the dew point lower than the cooling slab's operating temperatures
- Spaces are typically designed for about 50% maximum relative humidity during peak cooling periods

ADDRESSING CONCERN OF CONDENSATION

DESIGN CONSIDERATIONS

BUILDING CONTROL STRATEGY

- Outdoor temperature sensor on the northern side of the building, not exposed to direct sunlight
- Humidity and temperature sensor(s) in each zone to monitor dew points and set points
- Floor temperature sensor in the upper level of the thermal mass
- Supply and return fluid temperature sensors in the piping network



3. HYBRID HVAC SYSTEMS FOR IMPROVED BUILDING ENVIRONMENT

THERMAL COMFORT

Radiant cooling and heating systems are integral in creating hybrid systems that reach **higher levels of thermal comfort** than their 100% forced-air system counterparts.

- This finding is supported in detail through a research study
- *Concrete Core Temperature Control Systems, 2008 b*y the University of Nuremberg, Germany
- Study evaluates seven common and uncommon heating and cooling systems under North American conditions for a fully simulated commercial building

HYBRID HVAC SYSTEMS FOR IMPROVED BUILDING ENVIRONMENT

CONTENT AND PURPOSE OF STUDY

The study compared several types of commercial heating/cooling systems on the following attributes:

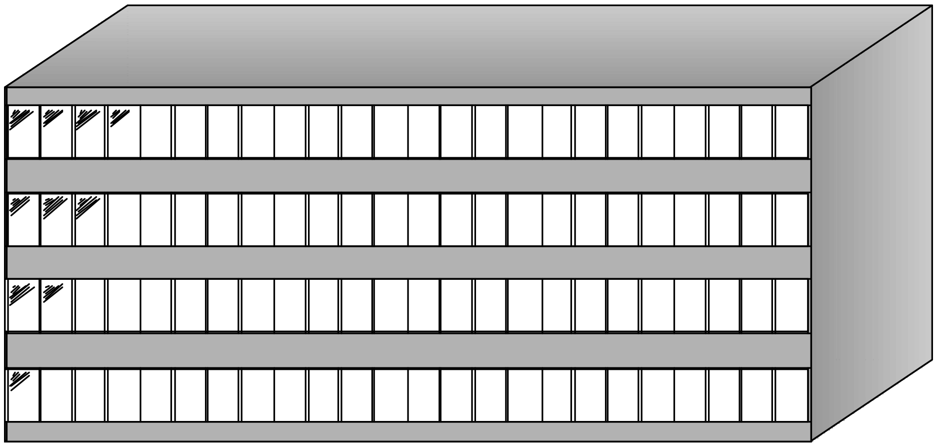
- Thermal comfort (learning objective 3)
- Initial investment cost (learning objective 4)
- Operating costs: energy demand + maintenance costs (learning objective 5)

The study considers the following conditions:

- North American and local building codes and standards (e.g., ASHRAE *Title 24 California Standards and Energy Code*)
- North American construction techniques
- North American energy and investment costs including material and labor
- North American climate

HYBRID HVAC SYSTEMS FOR IMPROVED BUILDING ENVIRONMENT

BASIS OF STUDY



Example of construction type simulated

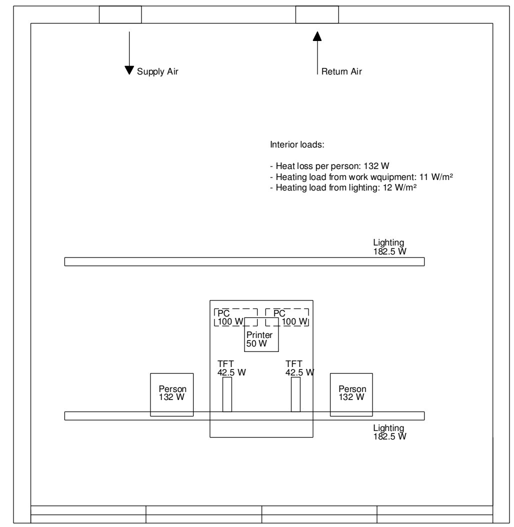
- **Project type:** Four-story poured commercial construction
- **Location:** Sacramento, California
- **Outside design temperatures:** 100°F / 31.5°F (0.4% / 99.6%)
- **Effective area:** Approximately 14,500 ft² total area on four floors
- **Heaviness of construction:** 160 lb/ft², cast-in-place construction

HYBRID HVAC SYSTEMS FOR IMPROVED BUILDING ENVIRONMENT

BASIS OF STUDY

THE REFERENCE OFFICE ROOM

The study focused on a typical occupied office



Office dimensions:	17.7 ft x 18.5 ft x 9.8 ft
Floor Area:	328 ft^2
Volume:	3,210 ft^3
Occupancy:	2 persons
Heat emission per person:	450 Btu/h (seated, office work)
Electrical equipment:	3.5 Btu/(h·ft^2)
Lighting:	3.8 Btu/(h·ft^2)
Normal office hours:	7:30 am to 6:00 pm on weekdays
Operating hours of heating and cooling systems:	6:00 am to 6:00 pm on weekdays

HYBRID HVAC SYSTEMS FOR IMPROVED BUILDING ENVIRONMENT

COMPARED SYSTEMS - OVERVIEW

100% Forced Air System (AHU)	Floor Radiant System (FCH) + downsized AHU	Ceiling Radiant System (CHC) + downsized AHU	Thermally Activated Slab (TAS) + downsized AHU

The three hybrid HVAC systems shown above include a downsized air handling unit (AHU) to decouple and optimize the space's cooling requirements.

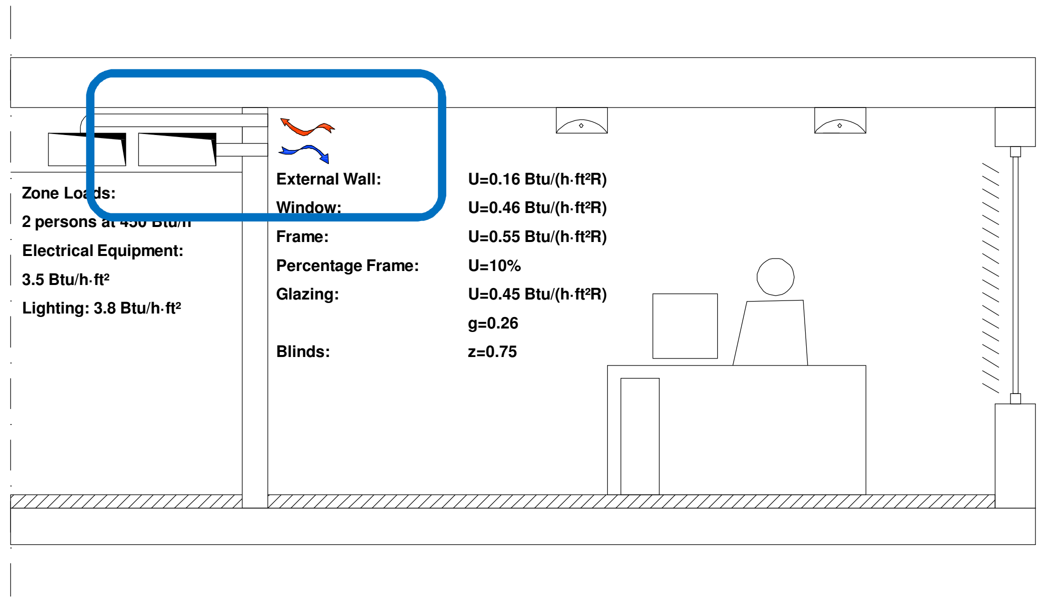
The University of Nuremberg's study compares seven systems, three of which are not very common in North America so they are excluded from this presentation.

HYBRID HVAC SYSTEMS FOR IMPROVED BUILDING ENVIRONMENT

COMPARED SYSTEMS - OVERVIEW

100% Forced Air System (AHU)	Floor Radiant System (FCH) + downsized AHU	Ceiling Radiant System (CHC) + downsized AHU	Thermally Activated Slab (TAS) + downsized AHU

- VAV's positioned in corridor plenum feed the space with conditioned air
- Fresh air supply requirements are met by the air handling unit (AHU)
- Supply air is conditioned to ensure required temperature and humidity



HYBRID HVAC SYSTEMS FOR IMPROVED BUILDING ENVIRONMENT

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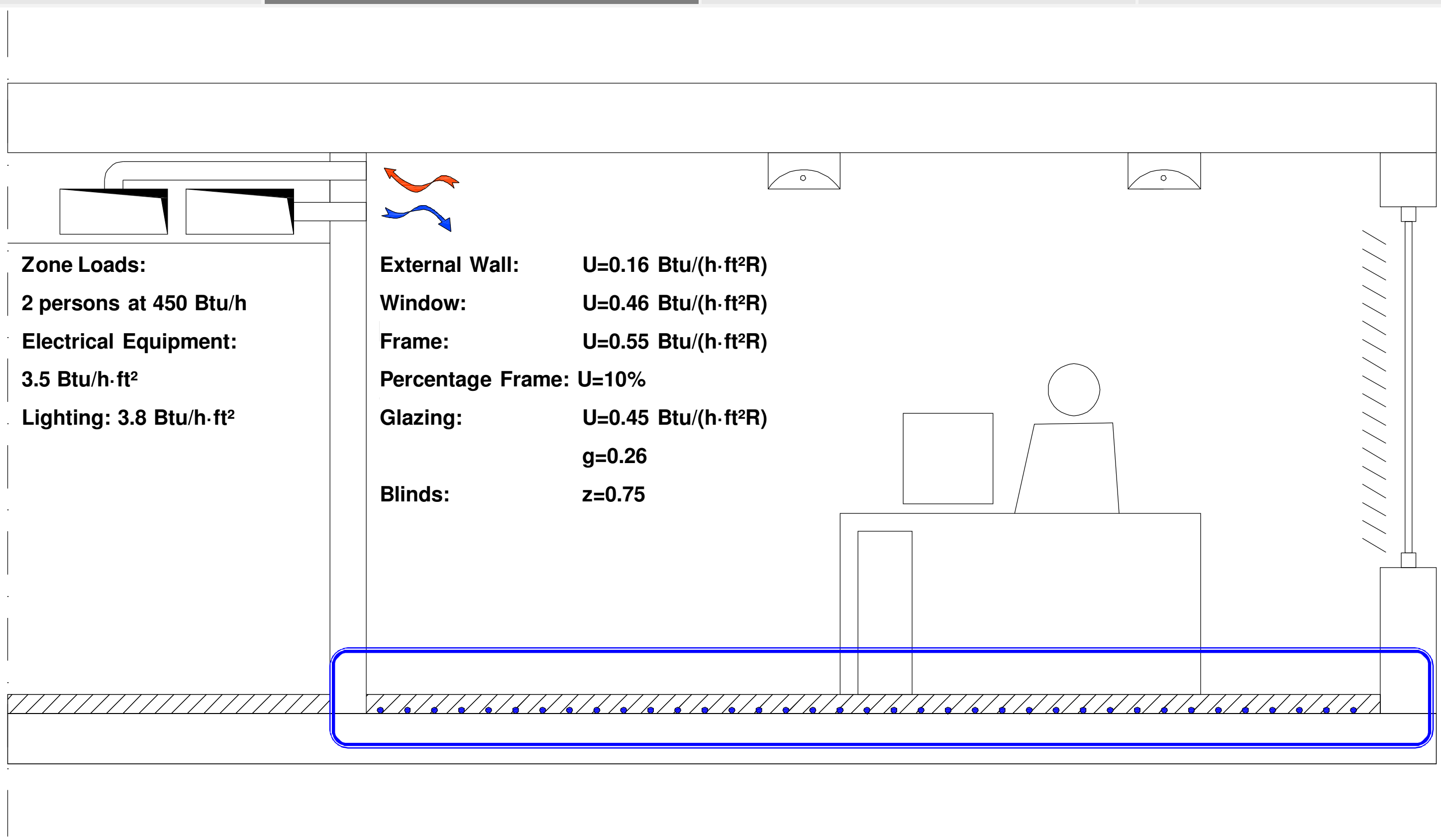

HYBRID HVAC SYSTEMS FOR IMPROVED BUILDING ENVIRONMENT

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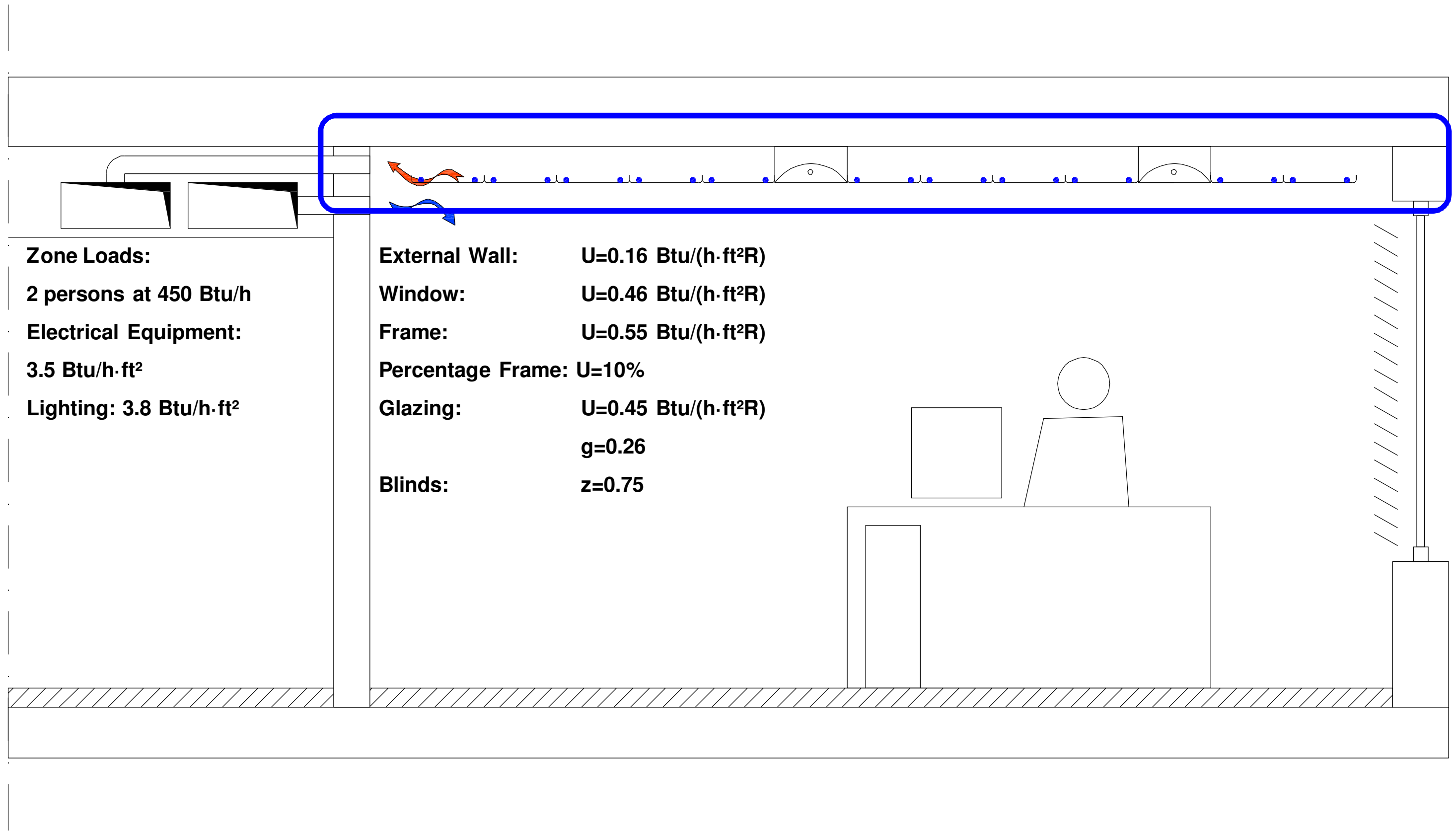

HYBRID HVAC SYSTEMS FOR IMPROVED BUILDING ENVIRONMENT

COMPARED SYSTEMS - OVERVIEW

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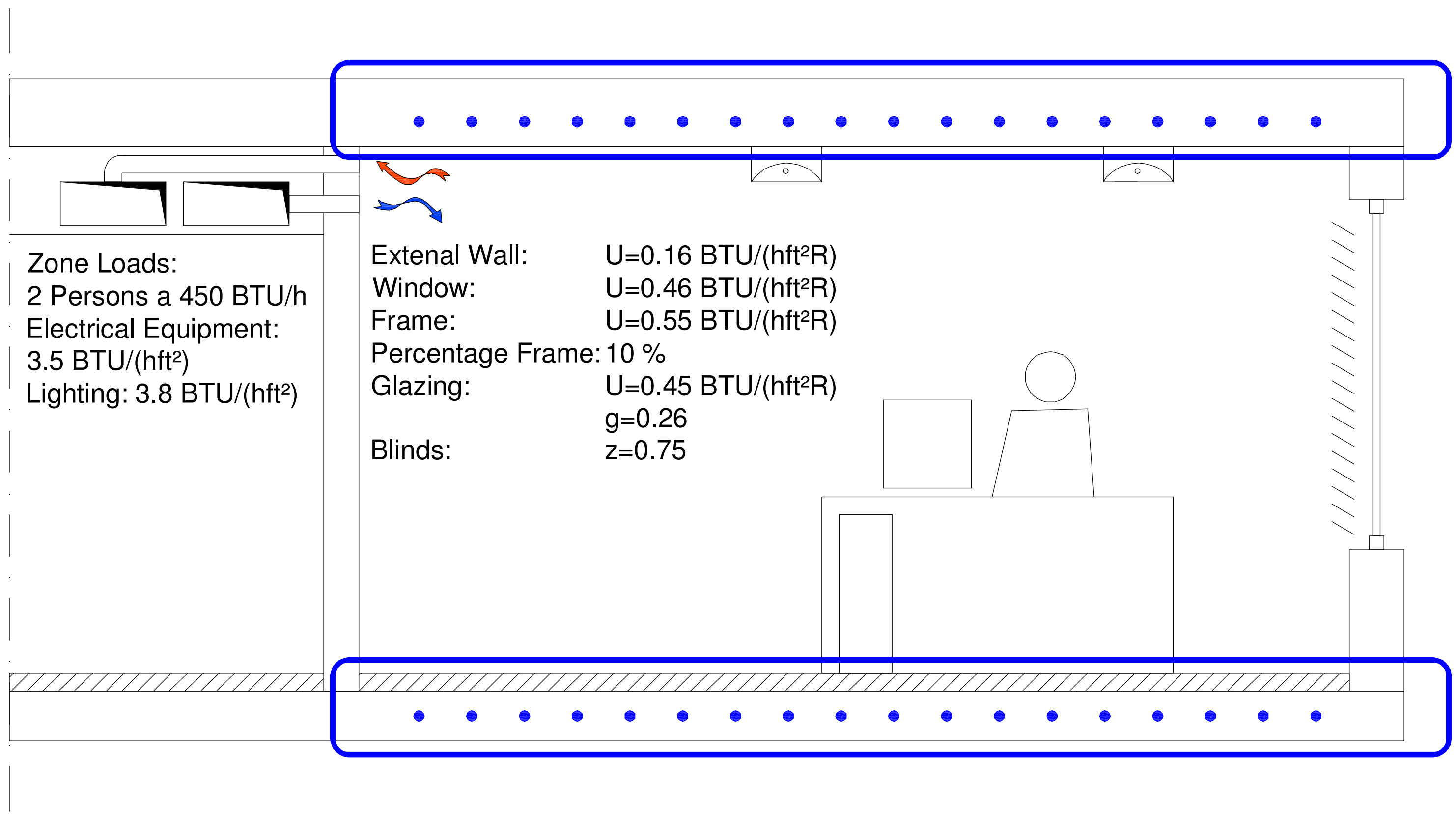


HYBRID HVAC SYSTEMS FOR IMPROVED BUILDING ENVIRONMENT

THERMAL COMFORT

Thermal comfort has a special standing concerning productivity in a work environment.

ASHRAE Standard 55 *Thermal Environmental Conditions for Human Occupancy*

- “Thermal comfort is that condition of mind which expresses satisfaction with the thermal environment.”

The following factors must be considered when thermal comfort is defined:

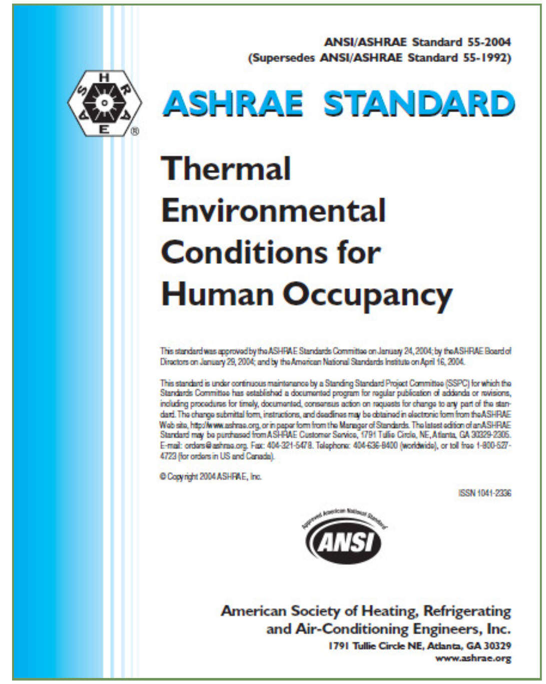
- Clothing insulation
- Metabolic rate
- Air temperature
- Air speed / draft
- Humidity
- Radiant temperature

Creates a broad range of perceived “comfort”

ASHRAE Standard 55 *Thermal Environmental Conditions for Human Occupancy*

Boundaries for thermal comfort according to Standard 55

- Operative temperature:
  - Summer period @ 50% RH: **75**-**80** °F
  - Winter period @ 30% RH: **70**-**77** °F
- Range of the floor temperature: **66**-**84** °F
- Radiant temperature asymmetry:
  - Warm ceiling: < 9 °F
  - Cool ceiling: < 25 °F
  - Warm wall: < 41 °F
  - Cool wall: < 18 °F



- This is the so called **comfort area**, where the percentage of people who are comfortable is optimized. Less than 10% dissatisfied.

HYBRID HVAC SYSTEMS FOR IMPROVED BUILDING ENVIRONMENT

BASIS OF STUDY

DESIGN TEMPERATURES

The study used:

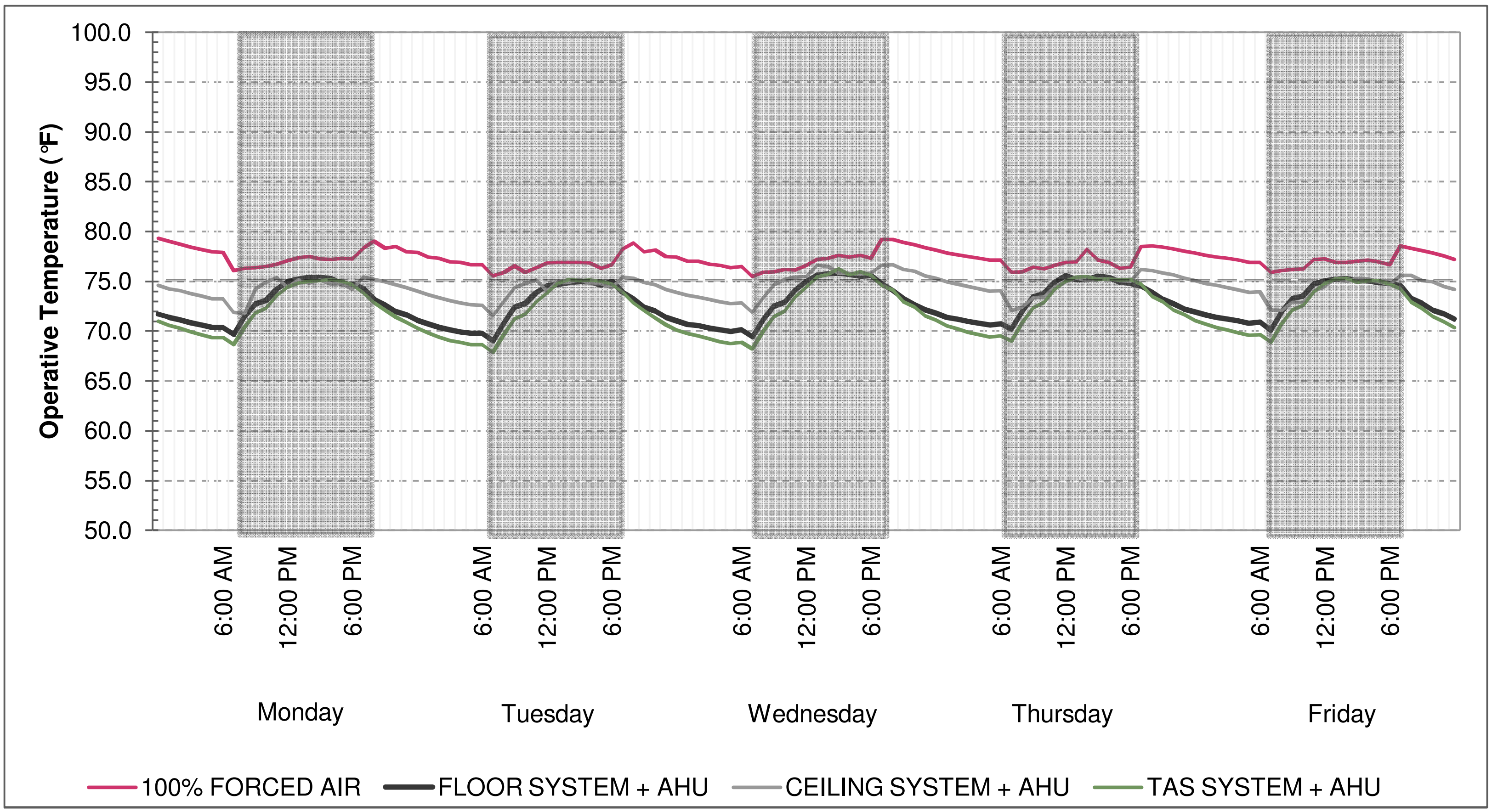
- Cooling period: 75°F
- Heating period: 68°F
- Minimum floor temperature: 66°F
- Maximum floor temperature: 84°F

HYBRID HVAC SYSTEMS FOR IMPROVED BUILDING ENVIRONMENT

RESULTS OF STUDY

OPERATIVE ROOM TEMPERATURES DURING SIMULATED SUMMER WEEK

Indoor operative temperature felt by office occupants during simulated week in summer



Heating/cooling systems are specified and designed for "worst case scenario" with respect to outdoor weather conditions.

- What if the indoor environment is given "worst case scenario" conditions?

Example: The interior loads were doubled on highest cooling load period

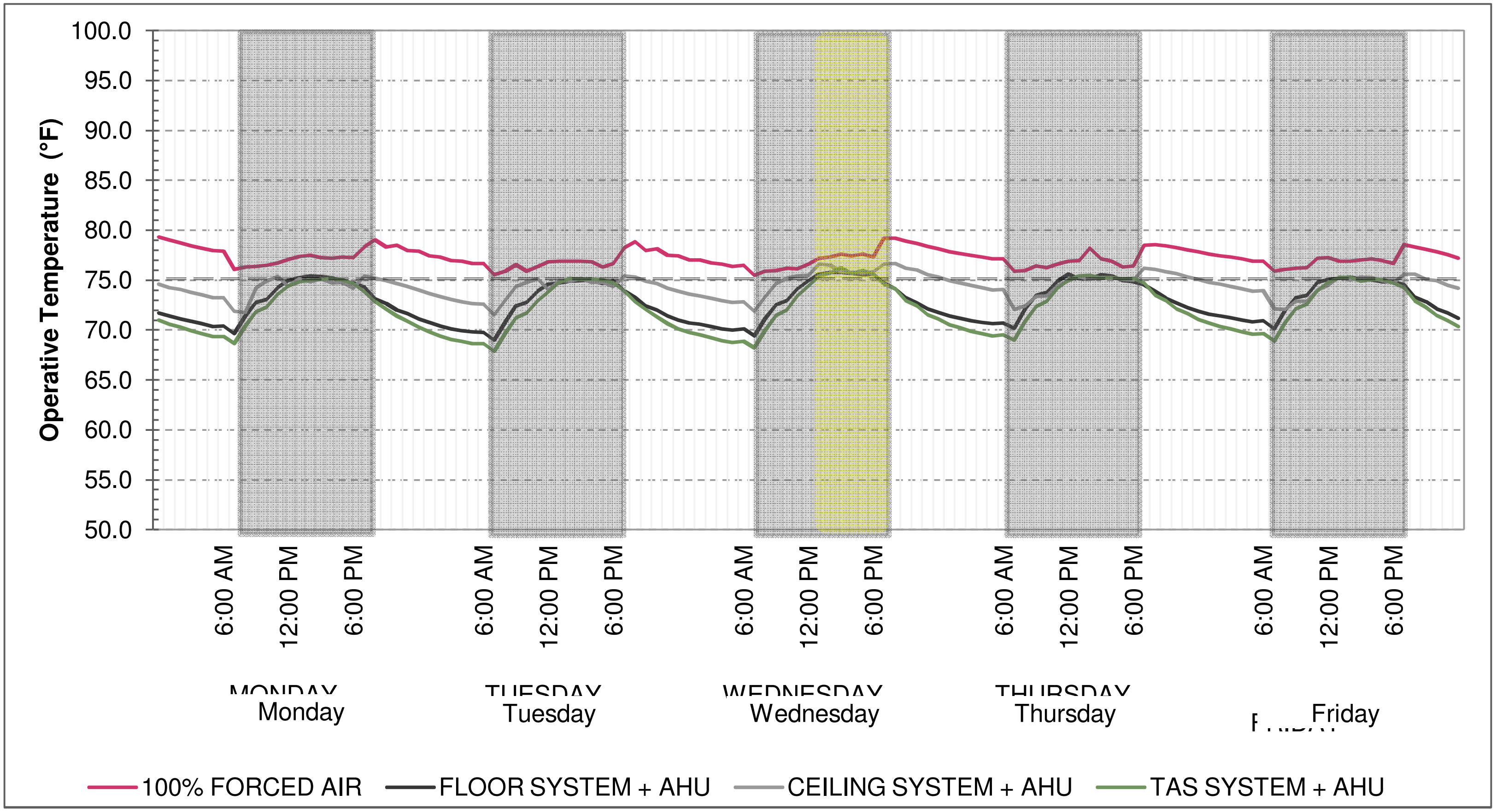
- Assumed room was used for a meeting Wednesday afternoon from 12:00 pm to 6:00 pm
- Assumed twice the occupancy and corresponding equipment loads (e.g., computers, projectors)

HYBRID HVAC SYSTEMS FOR IMPROVED BUILDING ENVIRONMENT

RESULTS OF STUDY

OPERATIVE ROOM TEMPERATURES DURING SIMULATED SUMMER WEEK

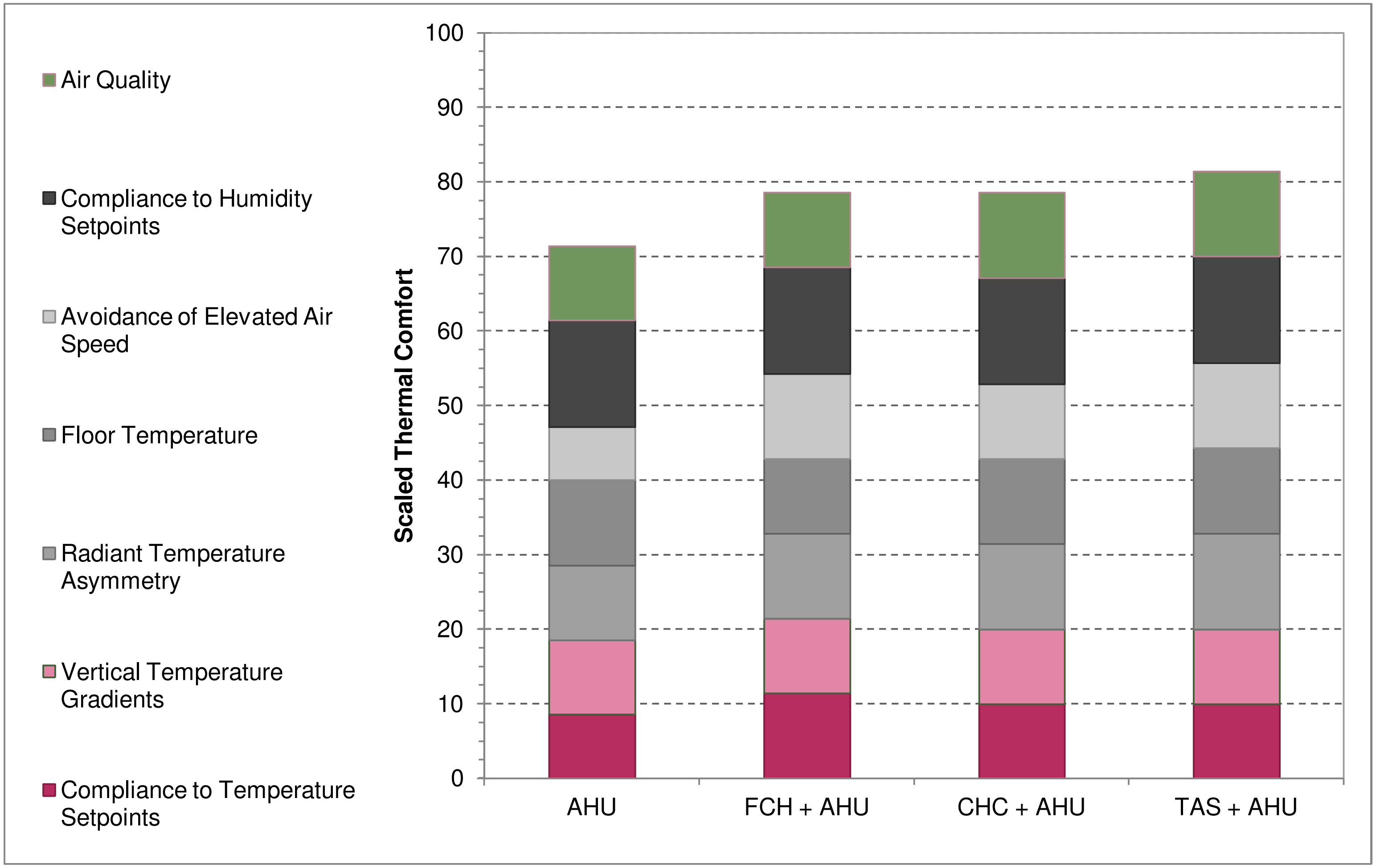
Hybrid systems handled the doubled interior loads during Wednesday afternoon's meeting better than the 100% forced-air system



HYBRID HVAC SYSTEMS FOR IMPROVED BUILDING ENVIRONMENT

RESULTS OF STUDY

THERMAL COMFORT COMPARISON FOR VARIOUS METRICS



4. REDUCED INVESTMENT COSTS

OVERVIEW

A radiant cooling system has significant benefits when used in a hybrid HVAC system to increase economic efficiency for a building.

The study compared the following cost components:

- Initial investment costs
- Operating costs including energy demand and maintenance (learning objective 5)
- Net present value (NPV) (learning objective 6)

REDUCED INVESTMENT COSTS

RESULTS OF STUDY

COOLING LOAD CALCULATION FOR SIZING EQUIPMENT

- Calculated using comprehensive DOE software *Energy Plus*
- Specific cooling load of **23.6 Btu/(h·ft²)** for the office space
- Air change rate of 7.5 (incl. 1.5 external air change) was necessary for handling 100% of the calculated cooling load
- Radiant cooling systems cover part of the cooling load and allow for a significant reduction on the air handling side

Type of Heating/Cooling System	Required Air Change Rate Per Hour	Equivalent cfm for 327 ft^2 Office	Equivalent cfm for Office Building
100% Forced Air (AHU)	7.5 ACH	400 cfm	16,850 cfm
Radiant Floor + AHU	5.0 ACH	268 cfm	11,230 cfm
Radiant Ceiling + AHU	4.0 ACH	214 cfm	8,990 cfm
TAS + AHU	4.0 ACH	214 cfm	8,990 cfm

REDUCED INVESTMENT COSTS

RESULTS OF THE STUDY

INITIAL MATERIAL INVESTMENT COSTS

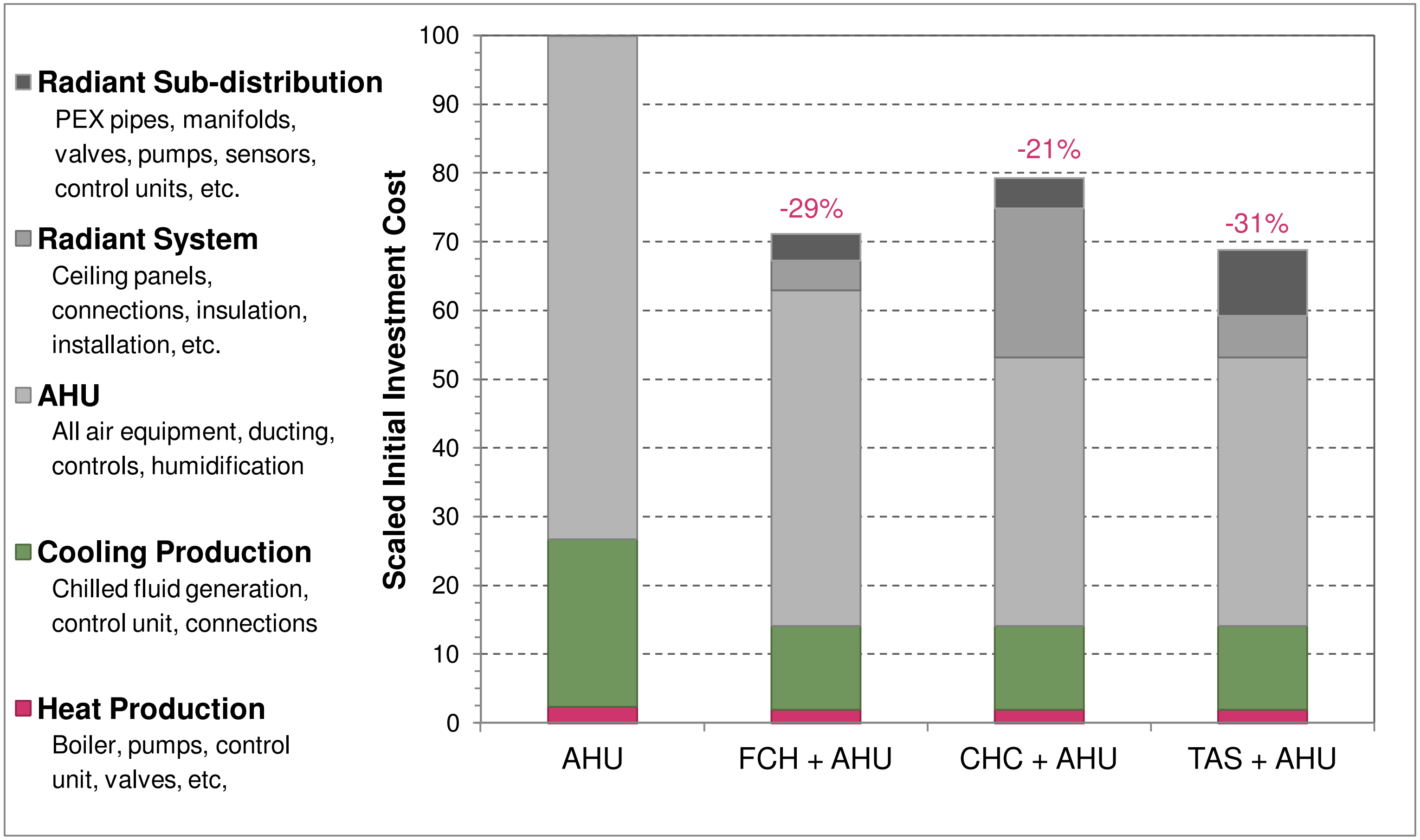
- Specific unit pricing for the geographic region of Sacramento, CA was considered
- A survey of engineers and contractors yielded the following unit pricing

Component	Unit Price	Unit	Machine Life	Service and Maintenance (%)
Heat generation (gas-fired boiler incl. main manifold; pipes incl. insulation, pumps, control system, exhaust system, valves)	0.15	$/(Btu/h)	20	3.5
Cooling production (piston water set, recooling plant, pipes incl. insulation, control system, pumps, valves)	0.38	$/(Btu/h)	15	3
AHU as mixed air system incl. AC device with four thermodynamic air treatment functions, duct system with insulation, outlets, built-in parts such as fire protection valves etc., control system	0.8	$/(ft³/h)	15	3.5
Under floor heating / under floor cooling incl. connection	5	$/ft²	30	1
Sub-distribution FH/FC incl. control system, pipes incl. insulation, pumps, sub-distribution manifold, valves	4.5	$/ft²	20	1.5
Concrete core temperature control incl. connection	3.5	$/ft²	30	1
Sub-distribution concrete core temperature control incl. control system, pipes incl. insulation, pumps, sub-distribution manifolds, valves	5.5	$/ft²	20	1.5
Chilled ceiling incl. connection	25	$/ft²	20	1.5
Sub-distribution chilled ceiling incl. control system, pipes incl. insulation, pumps, sub-distribution manifolds, valves	5	$/ft²	20	1.5

REDUCED INVESTMENT COSTS

RESULTS OF STUDY

INITIAL INVESTMENT COST COMPARISON



5. REDUCED OPERATING COSTS

OVERVIEW

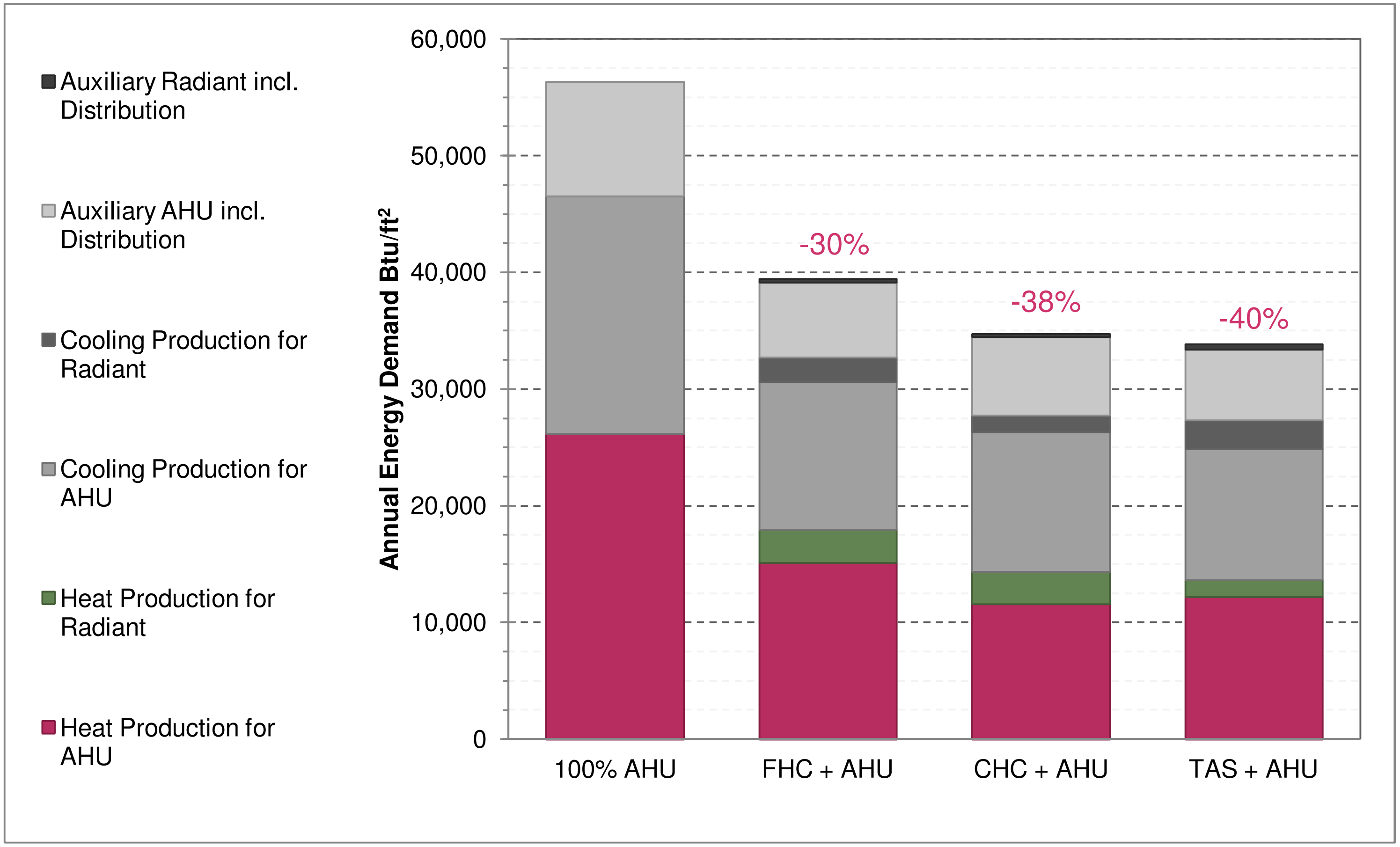
Hybrid HVAC systems incorporating a radiant system can aid in reducing energy consumption

- The study compared the following categories of energy demand:
  - Heat generation
  - Cooling production
  - Auxiliary air handling components (i.e., fans for air distribution)
  - Auxiliary radiant components (i.e., circulator pumps for fluid distribution)

REDUCED OPERATING COSTS

RESULTS OF STUDY

FINAL ENERGY DEMAND COMPARISON

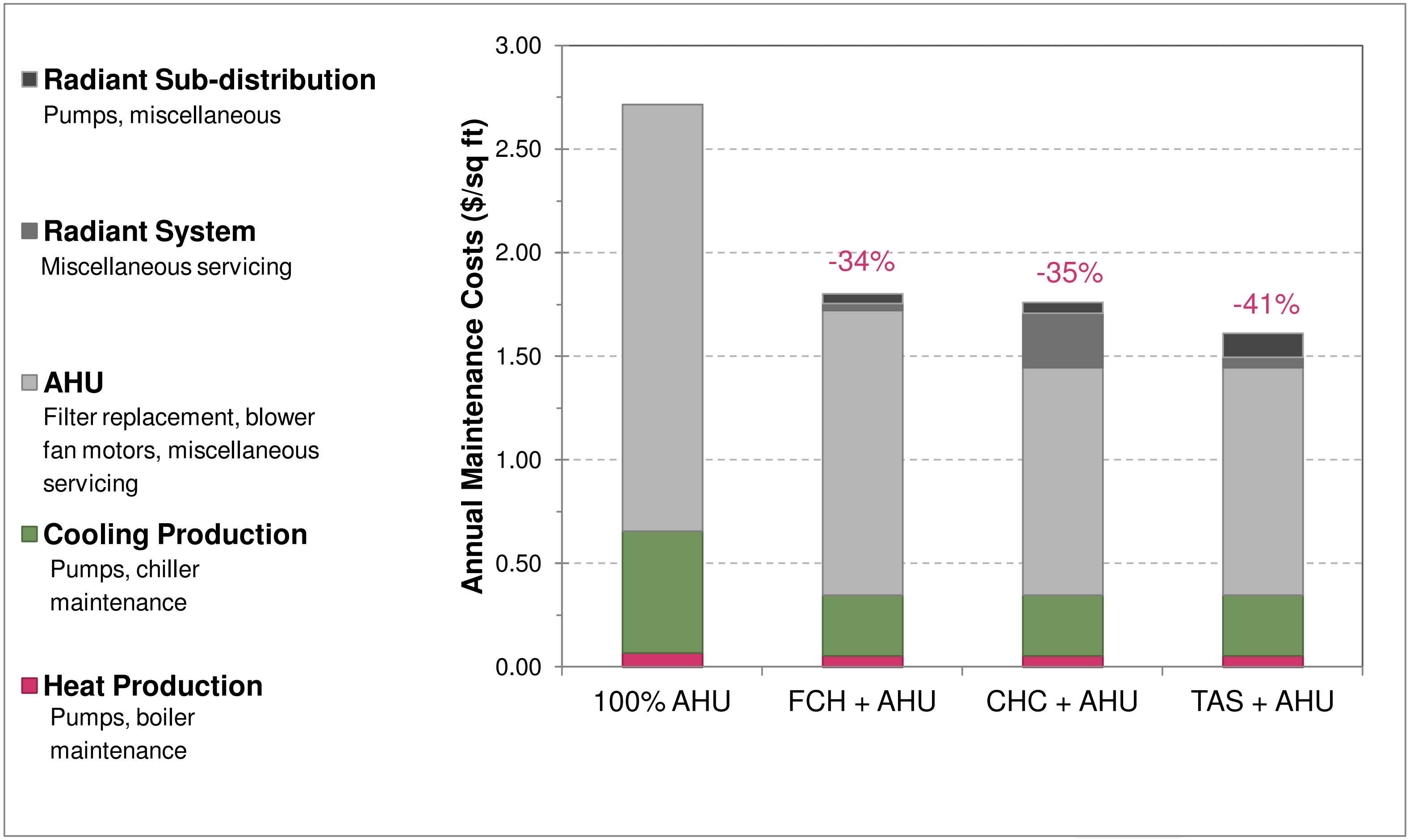


Final energy demand correlates directly with building owner’s operating costs

REDUCED OPERATING COSTS

RESULTS OF STUDY

MAINTENANCE COST COMPARISON



6. NET PRESENT VALUE CALCULATION

OVERVIEW

The net present value (NPV) is defined as the total present value (PV) of a time series of cash flows.

- Present value is the value on a given date of a future payment or series of future payments, discounted to reflect the time value of money and other factors such as investment risk

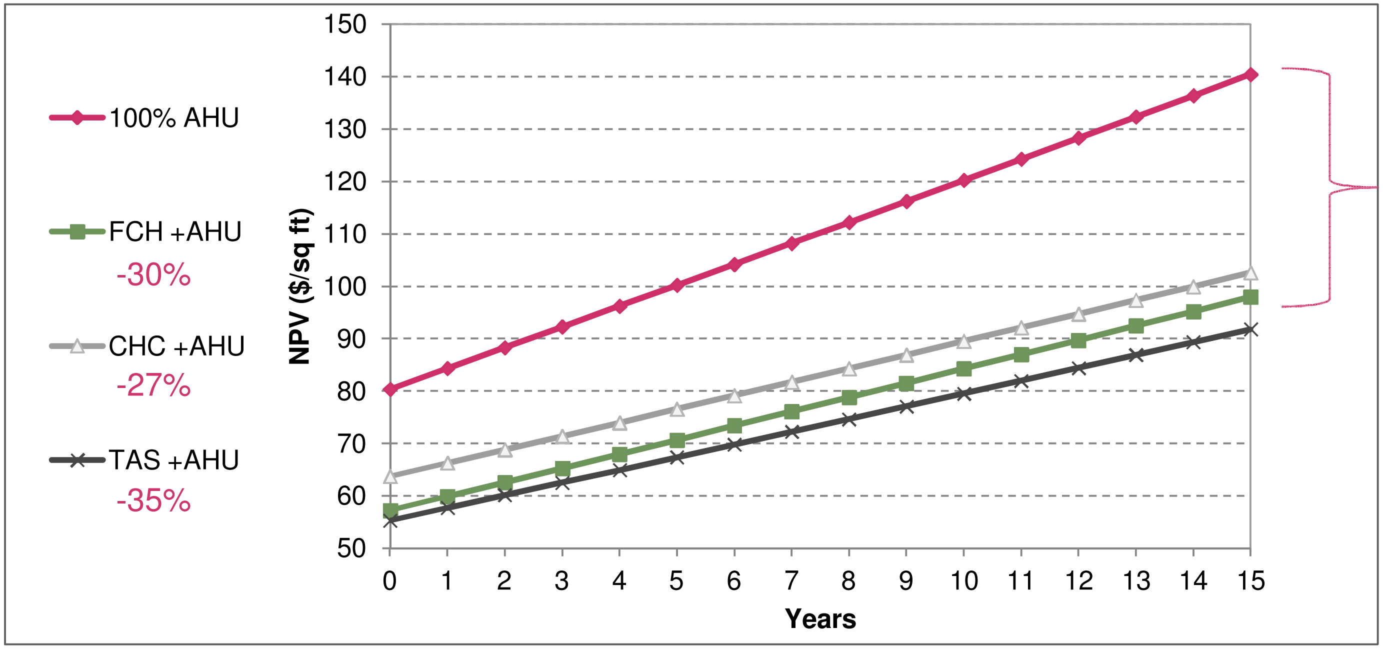
The comparison was made with the following assumptions:

- The rate of interest is calculated to be 3.8%
- The price increases for natural gas and for electricity are set to 4% annually
- The term of investment is 15 years, the estimated life of major components of the AHU system

NET PRESENT VALUE CALCULATION

RESULTS OF STUDY

NET PRESENT VALUE WITH CONVENTIONAL ENERGY SUPPLY



See legend on left for each system's savings at year 15

- High-cost components of an AHU are estimated to need major servicing after year 15
- This indicates that a system running for longer periods of time (e.g., 30 years) would illustrate huge advantages for the hybrid radiant systems if the NPV were extended to look at a building's life time

7. ADVANTAGES TO SPECIFIERS

OVERVIEW

The study compared the following parameters for the four systems:

1. Thermal comfort
2. Initial costs
3. Energy demand
4. Maintenance costs

The comparison lead to an overall score based on the following weighted values:

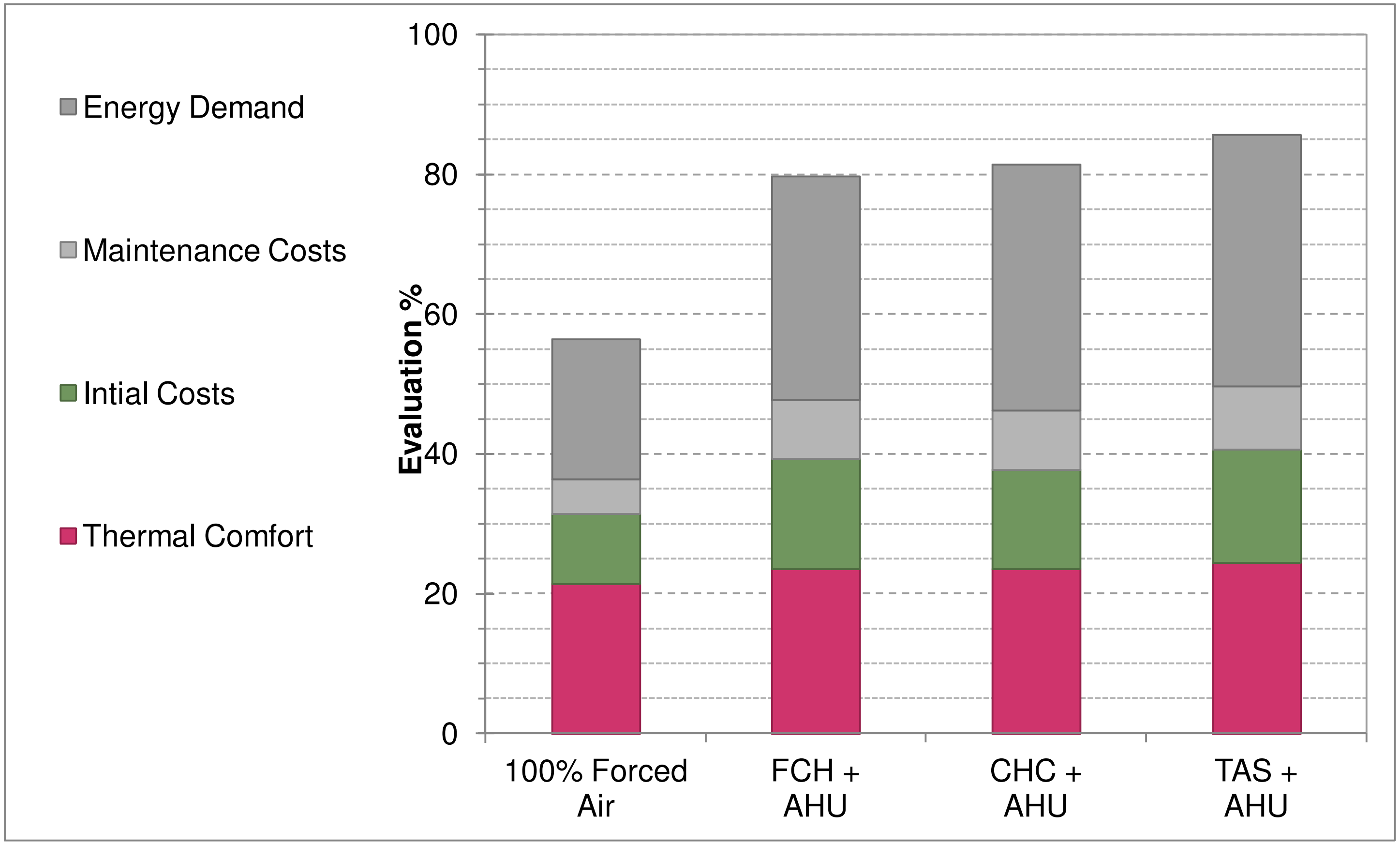
Category	Weighted Average
Thermal comfort	30%
Initial costs	20%
Energy demand	40%
Maintenance costs	10%
Total:	**100%**

ADVANTAGES TO SPECIFIERS

RESULTS OF STUDY

OVERALL EVALUATION

Systems scored on four main parameters



ADVANTAGES TO SPECIFIERS

FROM EXPERIENCE

The study and also the experience from hundreds of radiant cooling projects realized throughout the world prove the advantages of these systems.

Increased Thermal Comfort

- Radiant cooling optimizes the surface temperatures of the occupants' surroundings, providing a comfortable environment
- The human body feels most comfortable when it can regulate at least 45% of its heat emission via radiation achieved through a radiant system
- Comfortable cooling is provided with reduced ventilation air and little to no flow noises

ADVANTAGES TO SPECIFIERS

FROM EXPERIENCE

The study and also the experience from hundreds of radiant cooling projects realized throughout the world prove the advantages of these systems.

Reduced Investment Costs

- Radiant cooling can lead to a significant investment reduction in forced-air system components and ductwork
- Radiant cooling systems have lower operating costs due to the superior heat transfer properties of water compared to air
  - A 1 in. water pipe carries same thermal energy as 10 in. x 18 in. rectangular duct
  - A 60 watt circulator can deliver the same energy as a 1,500 watt air distribution fan
- Reduction in required maintenance of the radiant system compared to the 100% air system helps to augment operating incentives

ADVANTAGES TO SPECIFIERS

FROM EXPERIENCE

The study and also the experience from hundreds of radiant cooling projects realized throughout the world prove the advantages of these systems.

Reduced Operating Costs

- Radiant cooling allows a higher set-point temperature while still maintaining the same level of cooling comfort compared to a traditional AHU
- Operating with moderate supply water temperatures allows the integration of renewable systems such as geothermal heat pumps at maximum efficiencies
- Peak load can be reduced by thermal storage of the slab, making it possible to downsize cooling devices
- Flexible zoning is possible; areas can be separately controlled and balanced
- Lower energy usage may aid in LEED certification

ADVANTAGES TO SPECIFIERS

FROM EXPERIENCE

The study and also the experience from hundreds of radiant cooling projects realized throughout the world prove the advantages of these systems.

Architectural Flexibility

- Reduced mechanical equipment foot print yields more usable square footage
- Intrusive ductwork may be reduced
- Conditioning brought to space without the need for large ceiling plenum, leading to increased ceiling height, reduced building height or potential for additional levels

ADVANTAGES TO SPECIFIERS

SUMMARY

Architects, engineers and other specifiers note the following advice from experience:

- Radiant cooling is suitable for most commercial, industrial and institutional applications with careful engineering design of total HVAC solution
- Radiant cooling is not practical for most residential applications mainly due humidity control issues

Scenario where radiant cooling is most advantageous;

- Atriums with large glass exposures; counter solar gains directly with cooled floor
- Areas where reduced noise from ventilation is desired
- Buildings already being designed with radiant heating systems
- Buildings where peak electrical rates are favorable toward thermal storage

Coordination between all people involved in the building design and construction is mandatory for the success of the integration of radiant systems!

- Taking an integrated design process (IDP) approach has proven successful and is advocated by ASHRAE and AIA

RADIANT COOLING SYSTEMS

RADIANT FLOOR EXAMPLE APPLIED IN SHOWROOM
LIBERAL, KANSAS

- Project received award from the Radiant Professionals Alliance (RPA)

- Radiant system was combined with air system to meet customer’s need for:

    - Optimum thermal comfort
    - Reduced energy consumption

RADIANT COOLING SYSTEMS

THERMALLY ACTIVATED SLAB APPLIED IN A DORMITORY

TORONTO, ONTARIO

RADIANT COOLING SYSTEMS

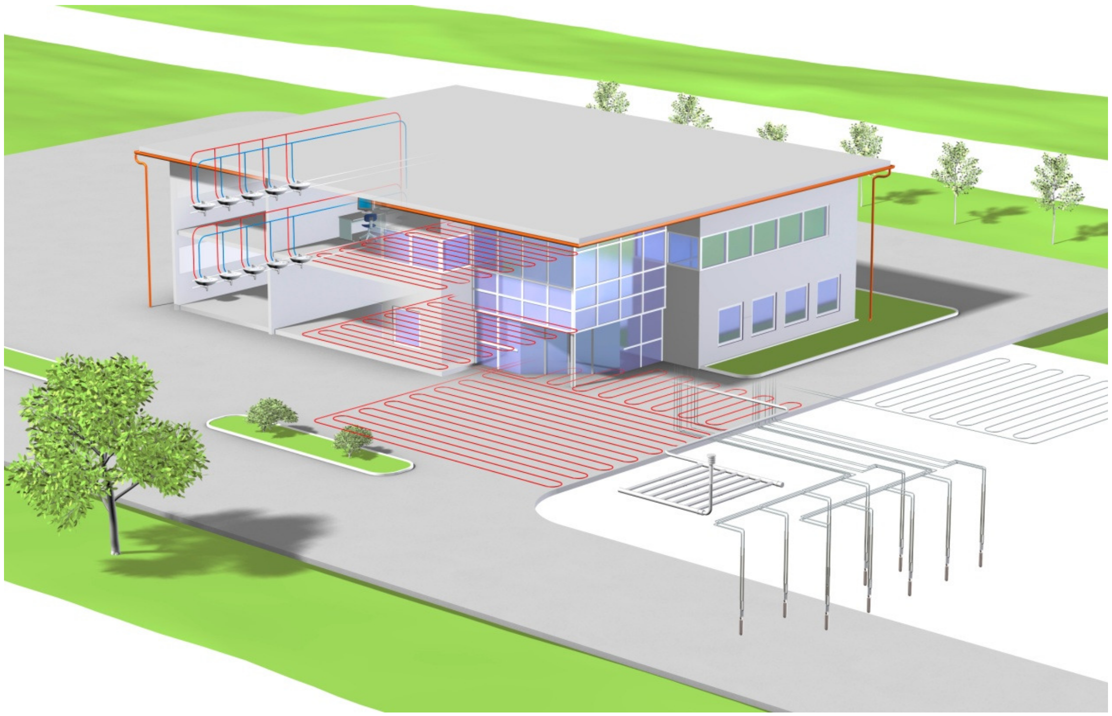
RADIANT CEILING EXAMPLE APPLIED IN A UNIVERSITY LIBRARY

CHICAGO, ILLINOIS

CONCLUSION

REVIEW LEARNING OBJECTIVES

1. Explain the basic principles of radiant cooling systems and the factors that affect the output capacities
2. Define the meaning of a “hybrid” HVAC system and how it can be optimized to address the concern of condensation
3. Discuss how a hybrid HVAC system using radiant cooling leads to improved building environment
4. Describe how a hybrid HVAC system using radiant cooling can reduce initial investment costs
5. Explain how a hybrid HVAC system using radiant cooling can reduce operating costs through reduced energy consumption and maintenance
6. Demonstrate how a hybrid HVAC system using radiant cooling can reduce the net present value of investment
7. Summarize the advantages of having a radiant system from a specifier’s perspective



THANK YOU FOR YOUR TIME
QUESTIONS?