Radiant Air Conditioning Systems: Sustainable Energy Efficiency

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Radiant Air Conditioning Systems: Sustainable Energy Efficiency

Presented By: Termobuild Canada
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Description: Provides an overview of how sustainable radiant air conditioning technology leverages the scientific principle of thermal mass through the integrated use of hollow core slabs, night pre-cooling, and "smart floors." As well, the course addresses how radiant air conditioning systems can be utilized to help reduce/eliminate the need for heating and cooling energy from non-renewable sources and compares this technology with conventional systems.

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Learning Objectives

Upon completing this course, you will be able to:

- enhance the process you already may have in place and substantiate the value of integrated design in low- and zero-energy buildings
- discuss the concept of thermal storage and its relation to sustainable radiant air conditioning technology
- state the applications and components of a radiant air conditioning system and how they work together to capture, store and release low-grade energy on demand
- compare the features and environmental benefits of utilizing energy smart radiant air conditioning system vs. conventional systems, and
- discuss how to position your company for new developments with low energy or net zero/intelligent buildings critical in attaining enhanced market appeal and competitive advantage.

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Thermal Storage Concepts

Introduction

Renewable energy (RE) technologies have evolved dramatically over the past few years, and are rapidly becoming competitive through significant improvements in performance, reduced costs, and government incentives.

Thermal storage can further enhance the competitive advantage with proven tools and techniques to achieve impressive results.

This presentation reveals simple and rewarding sustainable initiatives that can be implemented to heat and cool buildings using basic off-the-shelf pre-cast products and HVAC equipment (referred to as radiant air conditioning systems).

This course begins with a discussion of some of the common terms and concepts related to thermal storage strategies, beginning with mass absorption and savings by integrated design.

Mass Absorption

Mass absorption refers to the process of storing energy in building materials for use at a later time.

Materials used in this application are commonly referred to as thermal mass.

In addition to absorbing solar energy, these materials also absorb internal heat gains derived from computers, lighting, ventilation, and body heat.

One of, if not most effective vehicle to supercharge the structure is pre-cast, hollow core, concrete planks.

Energy Source	Percentage
Sun	30%
Computers	20%
People & Lighting	25%
Ventilation	25%

High heat loads are developed through solar radiation, occupants and other electrical sources.

Anatomy of Body Heat

Note: The body heat generated by each student in a typical classroom equals a 100-watt light bulb. This energy source is used as a valuable component in radiant air conditioning technology. Surplus energy can be captured, stored, and released upon demand.

Thermal Mass Storage

Thermal mass storage utilizes the mass of the building to collect solar energy during the day and release it when temperatures drop later in the day or at night.

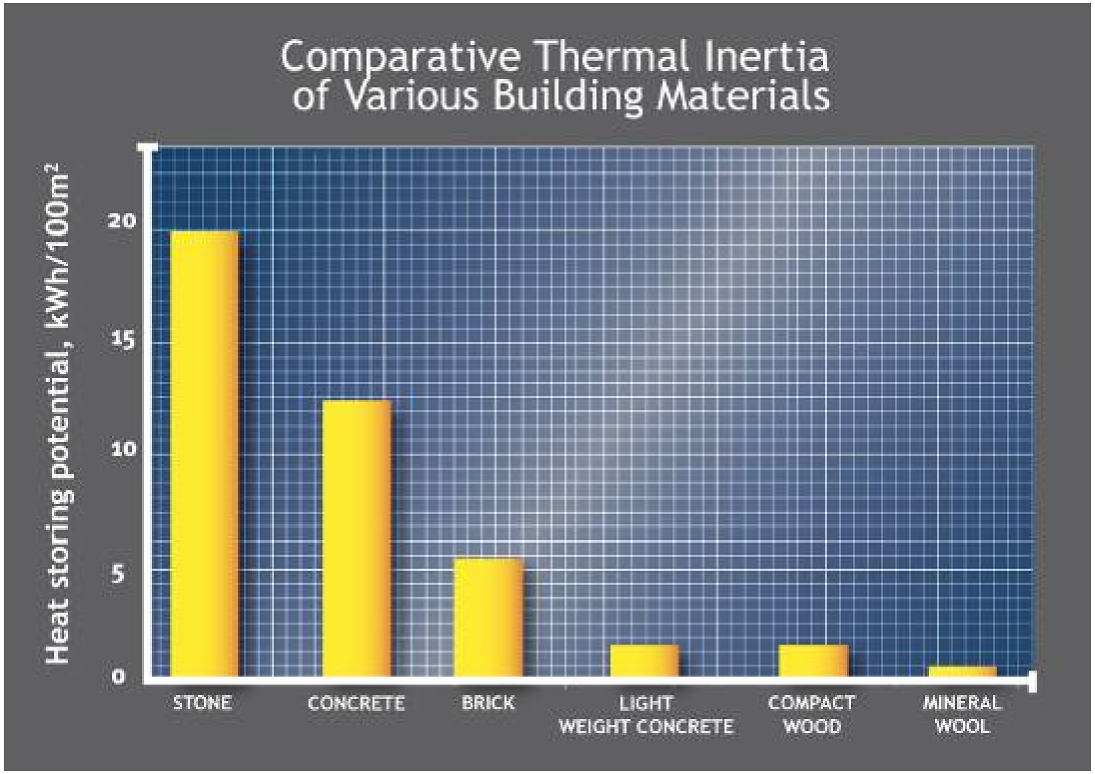
The slow release of stored heat in the mass prevents rapid temperature fluctuations in the building space.

One of the most classic examples of thermal mass storage is the adobe homes in the southwest of the United States.

The modern version of Adobe homes is amplified by linking natural energy that surrounds us with advanced computer logic to harvest that energy.

Thermal Inertia of Various Building Materials

Building construction of thermal storage systems is typically masonry and concrete and may be located in the floors, walls, or roofs.



Thermal Mass Combined with Ventilation

These surfaces are generally heated by direct sunlight through adjacent glazing.

When properly combined with a ventilation air system, thermal mass can significantly reduce or eliminate the need for bulky heating and cooling machinery, resulting in decreased energy consumption. At the same time, it can maintain environmental comfort in the building.

Note that the use of floors and ceilings as active thermal mass is less expensive when compared to the cost of conventional mechanical systems.

Radiant Air Conditioning Systems

Introduction

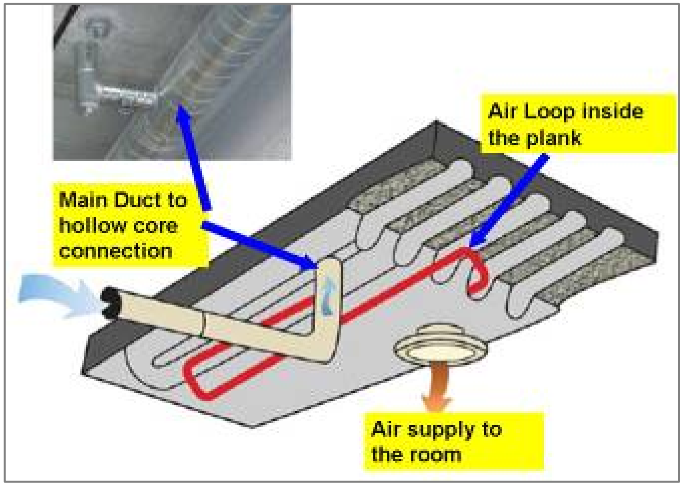
For the purposes of this course, slab-integrated radiant air conditioning systems with thermal mass (often referred to as thermo-active slabs) will be referred to as radiant air conditioning systems (RAIC). This method is based on two integrated and indivisible aspects – radiant heating/cooling + thermal storage.

RAIC leverages the scientific principle of thermal mass through the integrated use of hollow core slabs, night pre-cooling and "smart floors". As such, RAIC is as much of a product as it is the application of precision engineering strategies.

These RAIC systems have the ability to capture, store and release low-grade energy upon demands that reduces and/or eliminates the need for heating and cooling from non-renewable sources.

Thermo Active Slabs

Pre-cast, hollow core slabs form an integral part of radiant panels and thermal storage by activating the structure's dormant thermal properties.

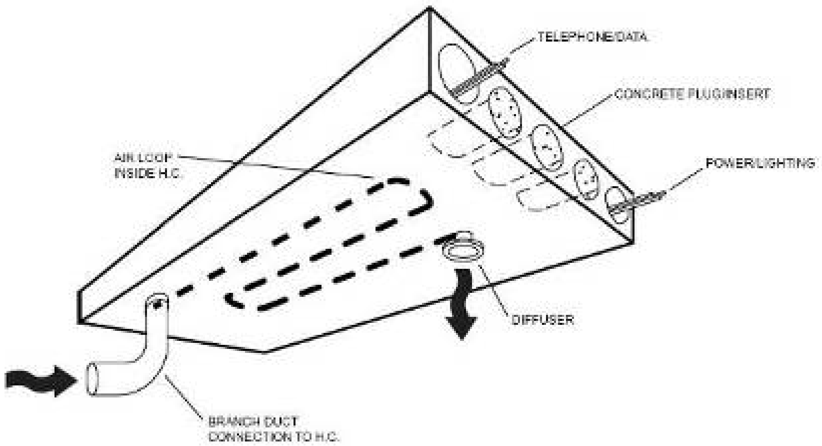


Placed within the structural, wall, ceiling and floor element, thermo-active slabs provide an economical resource for the distribution of air through their cores.

The surface area of the concrete thus becomes available for the energy exchange of heat and cool air.

Integrated Design

Linking pre-cast concrete planks with mechanical systems leads to an integrated design that is significantly more advanced and conscious of contemporary environmental concerns. When existing HVAC technologies are integrated with hollow core slabs and thermal mass principles, the need for such large and costly equipment is thereby reduced.



As air travels through the voids in each concrete slab (energy smart floor) energy is absorbed and naturally transferred into the structure. The result of such integrated design eliminates the need for prefabricated ceiling panels, chilled beams, pipes or tubes that are common in wet systems.

Unlike wet systems that are costly and in which comfort is never guaranteed due to their lack of integration with other building elements in the structure, integrated design outperforms not only in terms of overall comfort but in energy efficiency and overhead capital costs.

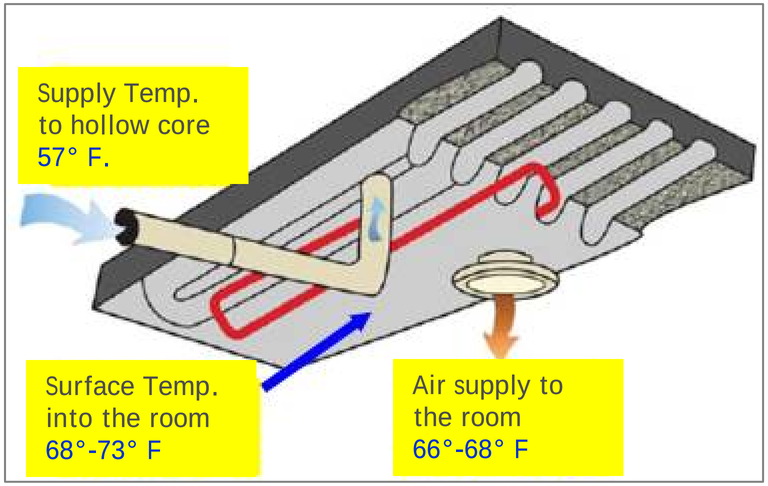
Radiant Air Conditioning Principles

Passing air through the concrete cores results in an improved heat and cool transfer between outside air and building's mass, as well as a controllable rate of energy transfer to and from the concrete.

The rise in temperature of 1 m^3 of concrete to 1°K absorbs 575 W-h.

In a radiant air conditioning system, the heat capacity of commonly-used hollow core slabs is estimated to be about 100 W-h m^2 °K.

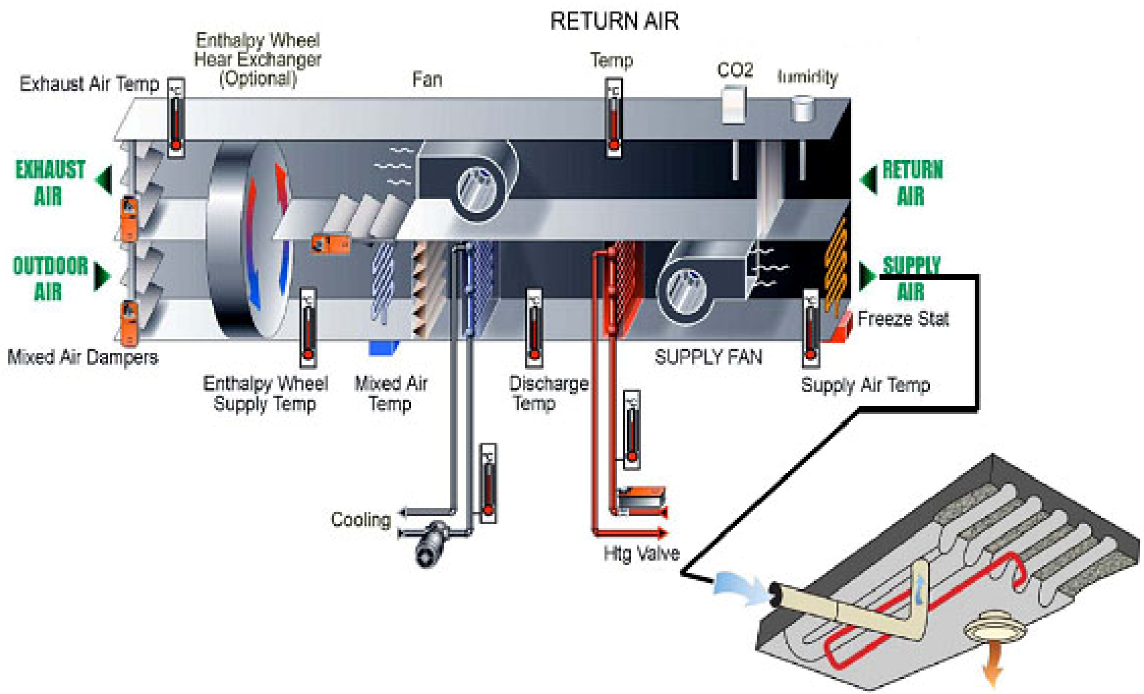
The thermal exchange between the room air and the walls has a heat transfer value of about 10% of the active floors or ceilings.



Activating dormant concrete of the floors and ceilings to act as "smart" rechargeable batteries provides added energy efficiency, improved indoor air quality, and radiant comfort.

Radiant Air Conditioning Principles

Radiant air conditioning is an efficient way to bring the heat capacity of structural concrete into a building's energy dynamics.

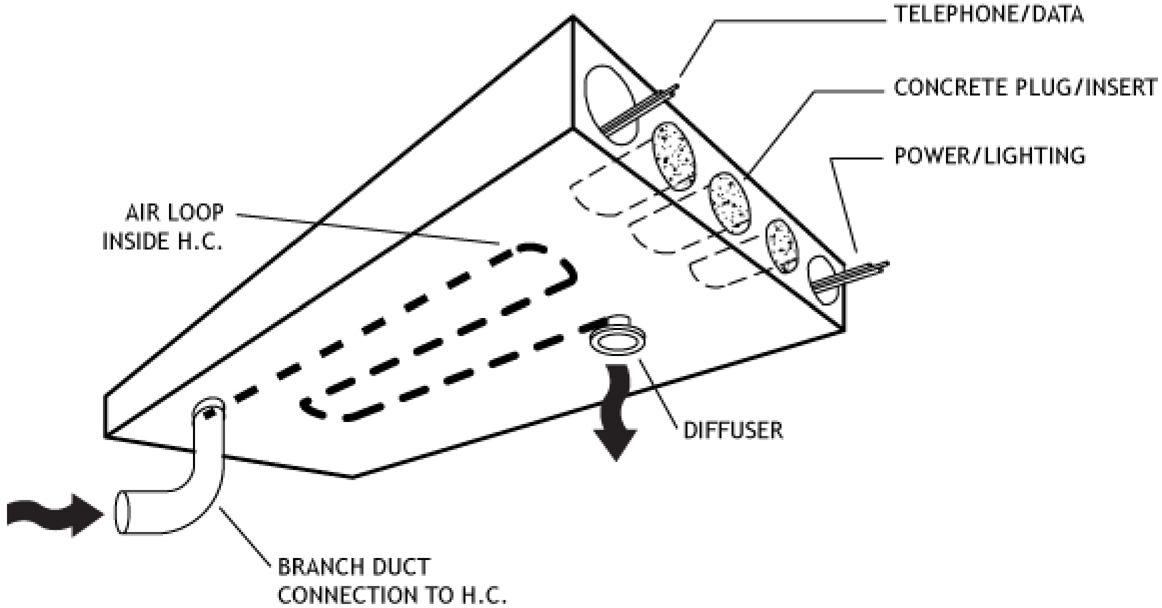


Thermal storage works intuitively with fan assisted ventilation system that pushes treated fresh air through a series of main ducts fed into branch ducts formed within the hollow core slabs of ceilings or floors. As air passes along the ducts the concrete warms or cools the fresh air before supplying it to the occupied space.

Image Courtesy of Setpoint Building Automation

Engineered Planks = Energy Smart Floors

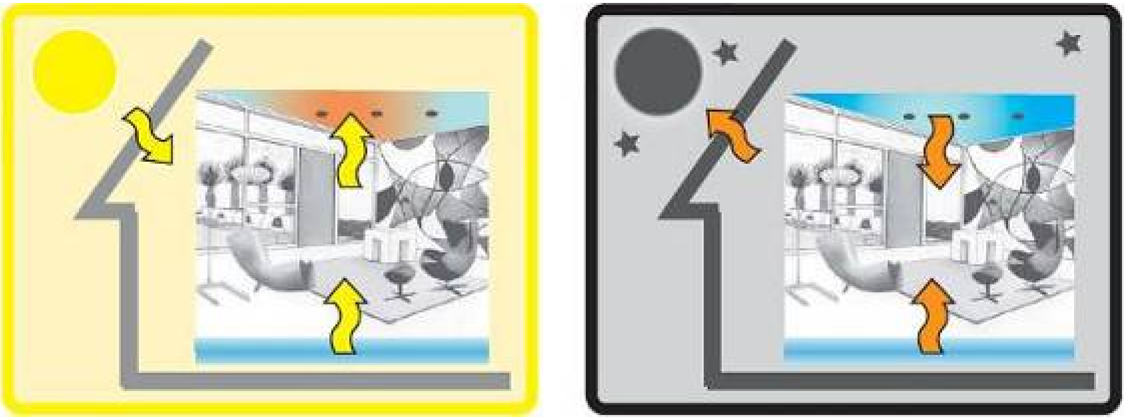
Radiant air conditioning begins with engineered plank. Standard pre-cast planks are modified in the factory and field. To avoid contamination, planks are hermetically sealed at the factory prior to shipping to site. Field drilling creates air inlet and air outlets, as well as air loops that connect three cores to work as a branch duct, terminating at the diffuser. Spare raceways may be custom drilled for electrical and communication requirements.



Cooling Season with Night Pre-Cooling

During occupied hours, heat from internal loads is absorbed by the concrete slabs. As long as the cooled surface is at a lower temperature than other surfaces in the room, heat will flow to it from all higher temperature surfaces.

Ventilation air, routed through the slab, absorbs heat and keeps the space in a comfortable range. During unoccupied hours, cool nighttime air is circulated through the slab to remove heat and pre-cools the space for the next day.

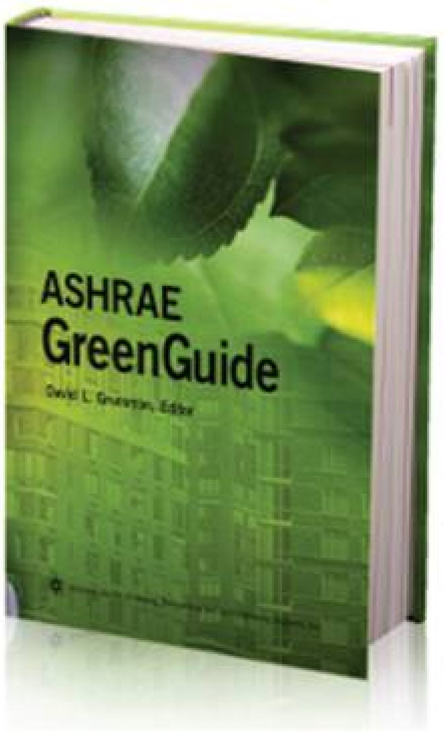


After a night cooling cycle, when stored energy in the thermal mass of the slab is sufficient to handle the space cooling load, the building will operate in a natural ventilation mode or supplementary cooling with operable windows.

ASHRAE

In 1995, ASHRAE (The American Society of Heating, Refrigerating and Air-Conditioning Engineers) recorded the significant value of a building's mass as a medium for thermal energy storage.

Its value was further highlighted in the ASHRAE Green Guide 2003 as Green Tip #1- the best method for reducing day time peak power loads and pollution.



Cooling Season

If your design took into account RAIC (Radiant Air Conditioning Systems) and local climate then the following mechanical options will do the following:

RAIC + EXHAUST AIR RECOVERY + DEMAND CONTROL VENTILATION + VARIABLE SPEED DRIVES

This equipment arrangement reduces or eliminates the need for cooling during occupied hours due to highly efficient thermal storage that absorbs the heat from lights, plug load and body heat for night time flushing.

Ventilation, required by building code, is a major energy consumer. Approximately 30% of the energy delivered to buildings is dissipated in the departing ventilation and ex-filtration air streams. In buildings constructed to very high standards of thermal insulation, the proportion of airborne energy loss can be much higher.

RAIC captures part of the daytime ventilation heat for night time flushing and with energy recovery, it can operate in 100% fresh air or demand controlled ventilation mode in extreme heat.

Cooling Season

In climatic zones, where free cooling is available, RAIC captures night time coolth for release on demand during the occupied period.

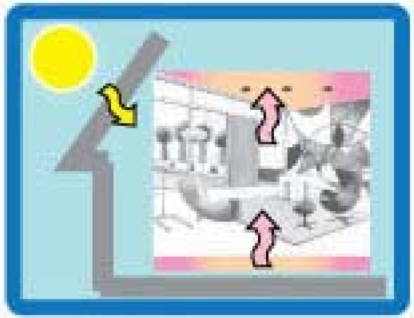
In these cases, the fan works like an energy amplifier. One Kw of fan power can draw in several Kw's of cooling. This reduces the need for occupied period cooling.

When conditions do not permit "free" cooling, super-charging takes place in recirculation mode with very low imposed loads, since lights, power, ventilation air, and solar heat gain are gone.

Off peak pre-cooling strategy cools the building prior to peak demand periods to reduce space cooling loads and electric demand during peak hours.

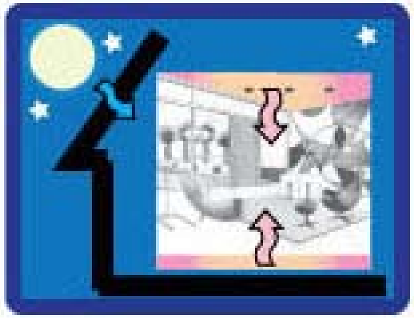
Heating Season

During occupied hours, heat from internal loads is transferred to the hollow core slabs through radiation.



The heat is either transferred to the supply air or stored in the slab.

During unoccupied hours, if the hollow core slab cools down below the setpoint, the air handling system is started in full re-circulated mode, providing warm air to raise the slab temperature and heat the space.



Heating Season

If your design took into account RAIC and local climate, the following mechanical option will do the following:

RAIC + EXHAUST AIR RECOVERY + DEMAND CONTROL VENTILATION + VARIABLE SPEED DRIVES

This equipment arrangement eliminates the need for heating during occupied hours due to highly efficient thermal storage that captures heat from lights, plug load and body heat*. Supplementary heat is required at night time (unoccupied) period.

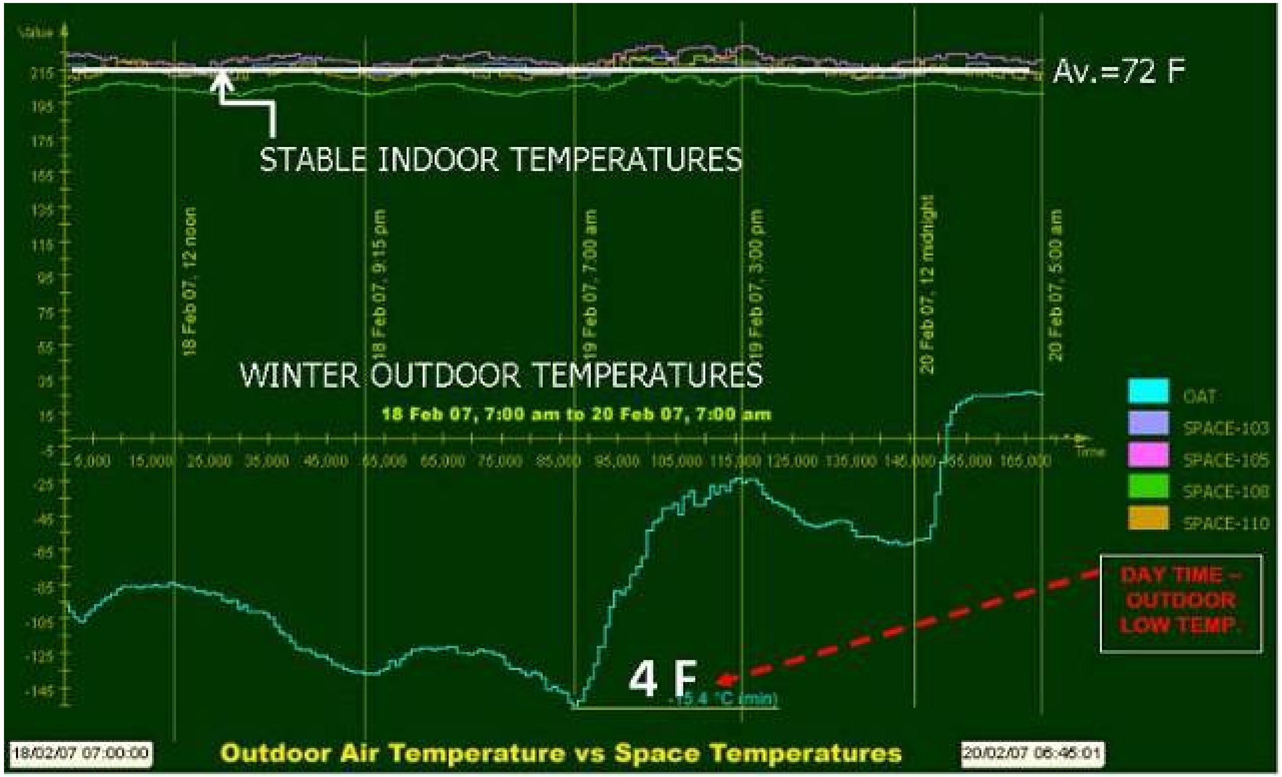
With heat recovery, it can operate in 100% fresh air or demand controlled ventilation mode in extreme cold.

Note: Use of solar thermal linked with RAIC can reduce or eliminate the need for heating. Cost and payback may vary from three to seven years.

**In educational buildings, body heat can reduce the need for heating by up to 50%.*

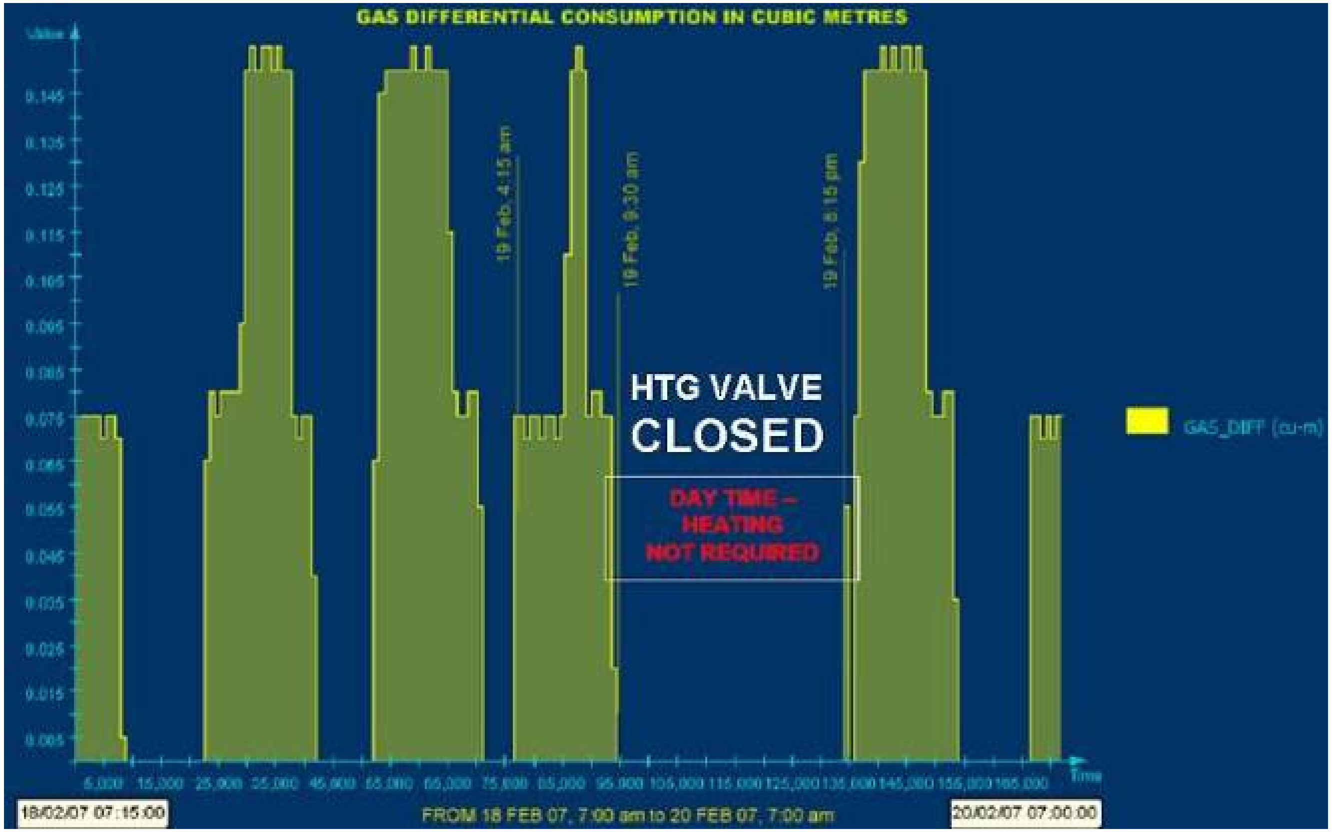
Winter Trend Log

Indoor temperatures are not affected by volatile outdoor temperatures due to the stable nature of thermal storage. In fact, there is even no need for supplementary heat during occupied hours as shown on the following slide.



Heating Valve Position

During occupied hours, from 9:30 am to 8:15 pm the heating valve is closed since there is sufficient energy available from thermal storage, body heat, and lights.



Exhaust Air-Recirculation

Generally, in buildings with RAIC, air re-circulation is only used overnight, during non-occupied hours.

It is used in winter when heating is needed and in hot climates when night pre-cooling is required.

Note: Rooms with highly variable loads may require a booster system to compensate for extreme conditions or variable occupancy.

Radiant Floors

The advantages of energy efficiency provided through comfortable heat sources have made radiant floors (radiant air) increasingly popular in many parts of the country. Often referred to as “hydronic” radiant heated and cooled floors, these types of systems have been popular in Europe for many years.

However, radiant air conditioning systems with thermal slabs delivers a more stable low temperature through open loop hollow core slabs.

Most conventional carpet is suitable for use over radiant heated floors, however it is advisable to confirm with the manufacturer prior to specifying.

Benefits of Radiant Air Conditioning Systems

Advantages of a Radiant Air Conditioning Solution

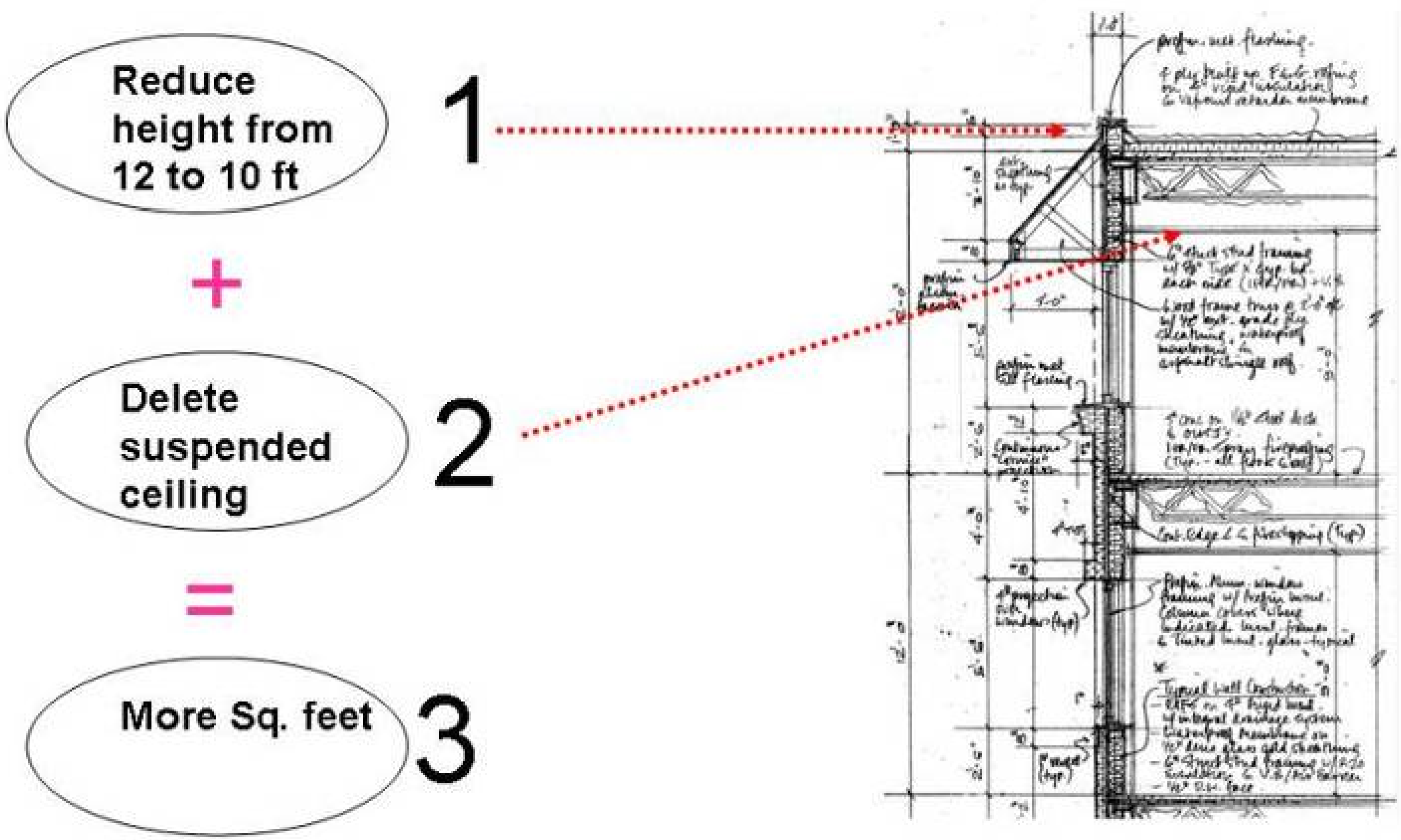
Compared to wet systems, radiant air conditioning systems have more than a few advantages related to zoning, flexibility, responsiveness, intuitive controls, and better coupling with the thermal mass of the building structure. As well, these systems use 100% fresh air, whereas conventional systems can use as little as 10 to 15%.

Radiant air conditioning systems reduce fossil fuel consumption, in turn, eliminating carbon and green gas emissions. The benefits of reduced operating costs, decreased local environmental impacts, and potential government offsets add to the incentives of this green technology. This building method entails integrated design that is significantly more advanced in the way we combine radiant comfort with thermal storage by activating dormant concrete floors that exist in a building anyway. Radiant air conditioning systems also use less building materials that lead to lower cost per sq. ft. of active surface. (Refer to next slide).

Note that radiant air conditioning systems work with variable power sources, such as solar, wind, wave, and geothermal and contribute to improved ROI due to reduced cost and payback period. (Refer to slides 32 and 33)

Cost Reduction Areas in Building Envelope

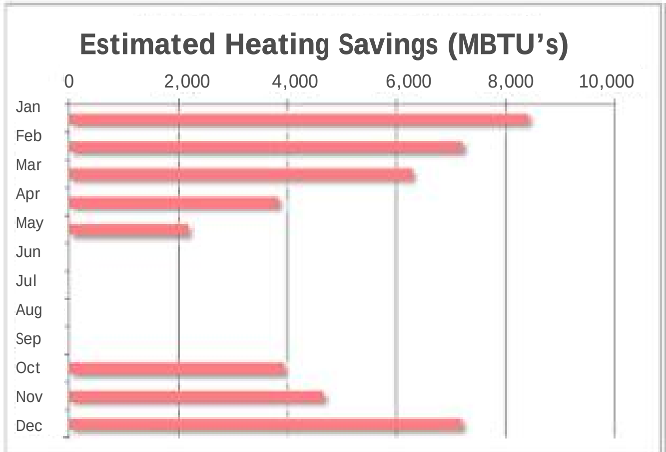
Cost reduction areas in mechanical equipment are shown on the following slide.

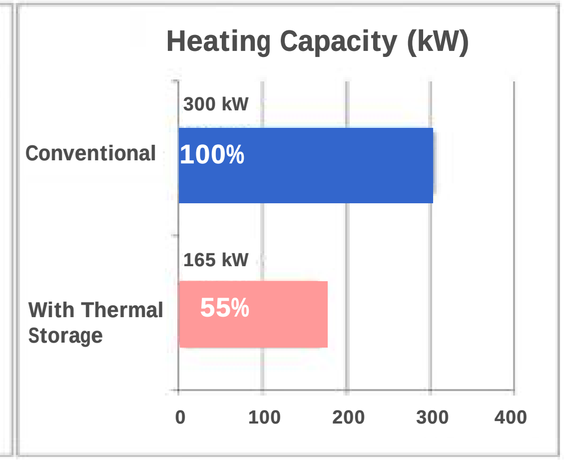


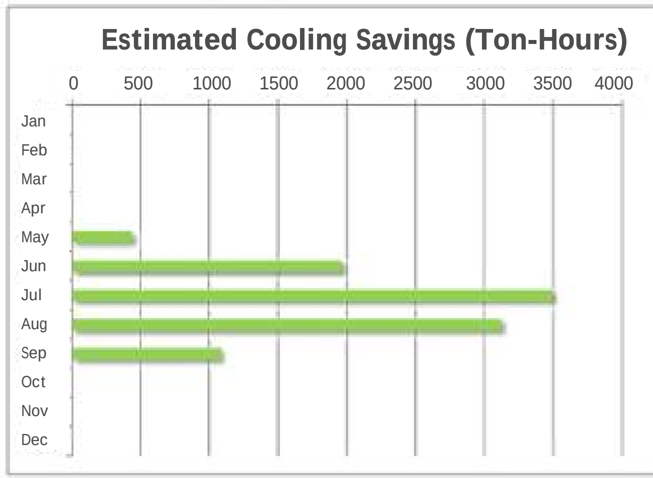
Mechanical Cost Reduction & Energy Savings

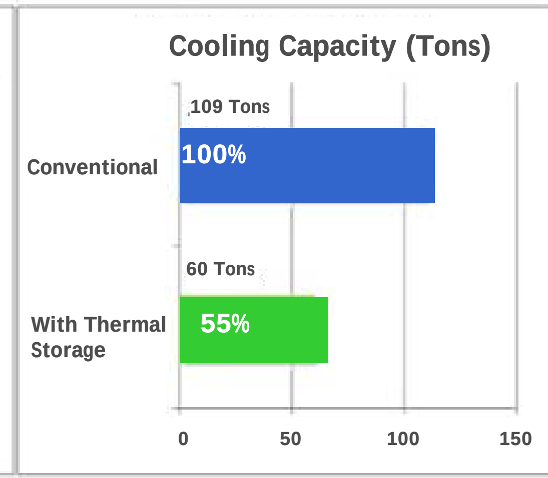
On-site power generation capacity can be reduced by up to 35% when HVAC is linked with thermal storage.

These graphs indicate capacity comparisons with and without thermal storage to heat and cool a building.









Improved Indoor Air Quality

"Sick building syndrome" is a modern phenomenon that impacts the quality of life in buildings globally.

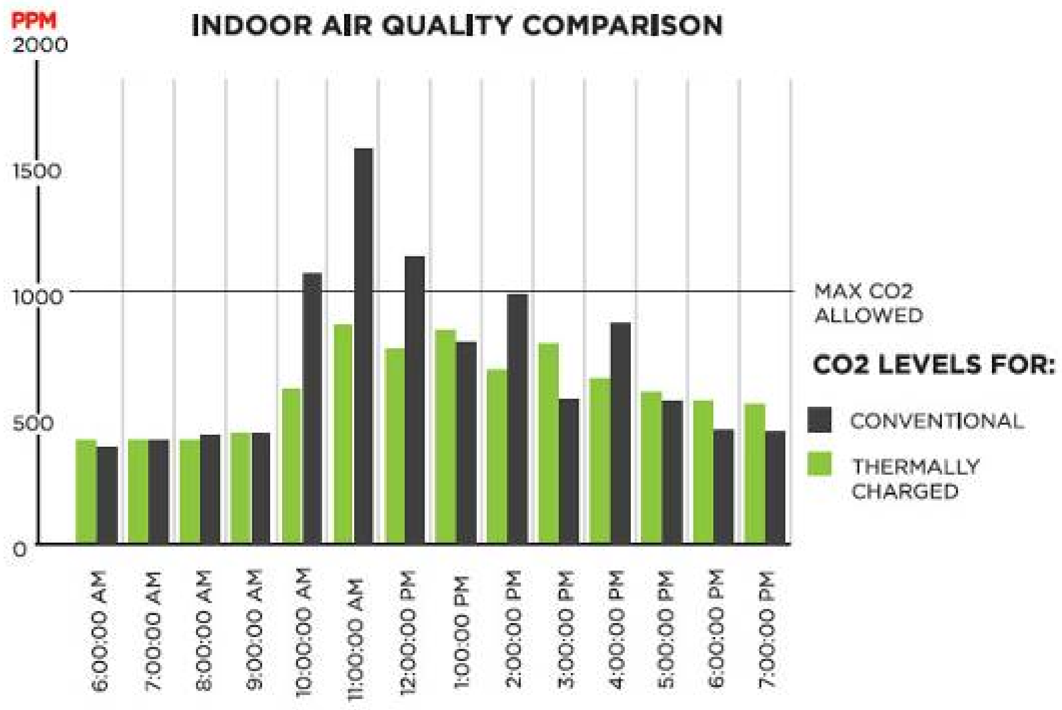
For example, some establishments employ a system of closed air circulation to lock in HVAC temperature controls. Consequently, while hot and cool energy cannot escape the building, neither can the stuffy indoor air that re-circulates around the premises. This, in turn, compromises the standard of comfort of the occupants. More critically, the spread of bacteria around the facility increases health risks for the occupants, since bacteria manifests through recycled air.

Conversely, with a radiant air conditioning system, fresh air fully penetrates each corner of the building, regardless if windows are open because these systems rely upon a constant influx of fresh air to stimulate building temperatures.

Presented on the following slide is an Indoor Air Quality comparison of conventional vs. radiant air conditioning (thermally charged) systems.

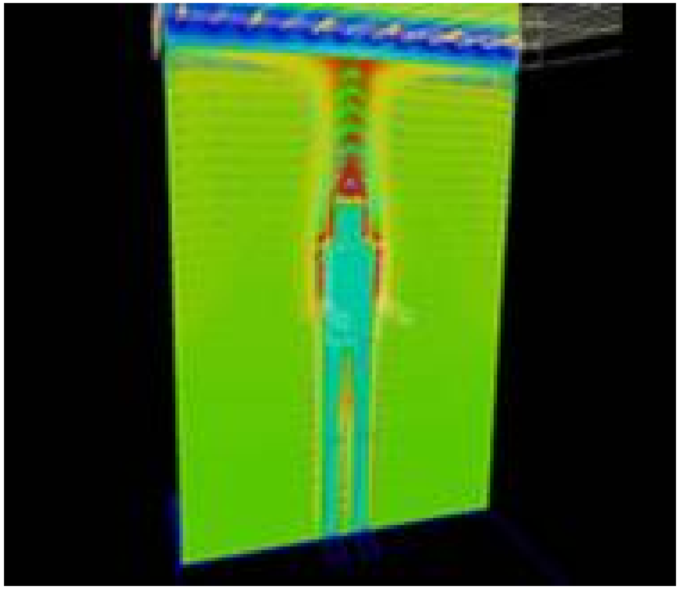
Improved Indoor Air Quality

The chart shows Indoor Air Quality in a typical 24 hour day. The Indoor Air Quality (IAQ) Chart represents a side by side comparison of an existing school in Ontario, Canada (shown in black), whereas the new school addition constructed two years after is highlighted in green meets and exceeds ASHRAE 62.0 ventilation requirements.



Human Comfort

With radiant systems people are cooled by radiant heat transfer from their bodies to adjacent surfaces and ceilings whose temperatures are held a few degrees cooler than ambient.



LEED®

Points within the Leadership in Energy and Environmental Design (LEED) Credit system can be achieved by reducing the design energy cost of a building compared to that of an ASHRAE/IESNA 90.1-1999 reference building.

The percentage reduction determines the number of points achieved. Whole building energy simulation, as indicated on slide 43, is used to determine the percentage energy cost reduction.

Current acceptable modeling software used for these calculations, like DOE-2, Energy Plus and E Quest, are not able to capture the value of thermal mass, critical to the radiant air conditioning system. For that reason, the full benefit of radiant air conditioning cannot be quantified within a simulation.

Some specialists in thermal mass and energy storage have developed proprietary software that is able to measure radiant air conditioning's contribution to lowered energy costs.

LEED®

A number of low energy HVAC systems are able to consistently earn a specific number of points within the LEED credits. For instance the dedicated outdoor air systems (DOAS) VAV system which typically can earn 7-8 points. These systems have excellent exhaust air heat recovery performance, excellent temperature control and relatively low fan power.

When hollow core slabs are linked to a simple mechanical system with ERV (energy recovery ventilators) they deliver the same or better performance than a DOAS VAV system. LEED scoring with the combined system should be same or better since it is doing more with less.

When compared to DOAS distributed air systems the radiant air conditioning will eliminate the need for a lot of mechanical equipment, for instance, the fan coils in the DOAS distributed system. Simple ventilation fans can deliver radiant comfort (in both heating and cooling modes) for most of the year in a moderate climate. Its night pre-cooling is extremely efficient in hot climates since it is much easier to cool the building structure at night to 70 or 71°F and allow it to absorb energy during the day to 78°F while maintaining 74 to 76°F space temperature.

LEED®

The radiant air air-conditioning system is ideal for use with dedicated outdoor air systems (DOAS), which typically capture 7-8 points in Credit EA 1.

A solution combining these two systems should score even higher in this category, due to reduced need for mechanical equipment and carbon footprint reduction.

One of the trade offs encountered within the LEED credit system is balancing the need for increased outside air ventilation within EQp1 And EQc2, and the energy costs associated with these increased ventilation rates. This situation is less of a trade-off when using radiant air conditioning. By over ventilating the building, valuable low grade energy (exergy) can be captured and supercharged at same time for release on demand.

Note: The ENERGY STAR® rating system is based on statistical data gathered by EPA and Department of Energy. The rating system indicates how the actual building is performing relative to its peers. This rating method eliminated reliance of software predictions and reveals the true value and performance of any building systems, including the one described in this presentation.

LEED®

Experts have said that by using integrated design and designing for low temperatures, low energy comfort systems can be created. These types of systems often require larger heating/cooling devices for a given load and better enclosures. However, with the radiant air conditioning system the concrete floor is, in fact, the larger device. By acting as both structure and heating/cooling equipment, it is able to reduce the building's carbon footprint.

Like the low temperature designs, the radiant heating and cooling system is also ideal for use with renewable energy sources.

There remain a number of benefits of the radiant air conditioning system that can not be measured in a LEED simulation; the ability of the system to act as both structure and HVAC delivery system, the ability to provide both radiant heat/cooling, ventilation and air cooling or heating, and the value of the thermal mass.

Summary of Benefits

To summarize, radiant air condition systems' benefits include:

- more comfort, lower cost
- increased energy efficiency due to the multitasking fan power and advanced energy harvesting
- demand peak load reduction
- easy to maintain
- improved indoor air quality
- dedicated outdoor air system with 100% fresh air
- future proofing property values
- a contribution to LEED accreditation, and
- improved building ranking based on ENERGY STAR that correlates best with environmental impact and energy cost.

Design and Installation Considerations

Introduction

An efficient building envelope will limit energy exchange across the entire building. This is necessary for the structural mass to work well as a thermal storage medium.

Consequently, coordination between architectural, structural, and HVAC design professionals is required from the conceptual stage through to the construction phase.

Good design of a radiant air conditioning system starts with standard ASHRAE principals to translate the value of thermal storage into supply airflows.

Energy Modeling

Energy modeling, or simulation, is the practice of using computer-based programs to model the energy performance of an entire building or the systems within a building. It provides valuable information about the building and system energy use, as well as operating costs.

Whole-building simulation is typically performed for an entire year using typical meteorological-year weather data.

An important aspect of whole-building modeling is that it accounts for the interaction between different elements of the building, such as the impact of lighting on space conditioning loads or the impact of daylighting on electrical lighting loads.

The impact of different building uses and occupancy patterns is also accounted for due to the natural symbiosis of thermal mass and radiant comfort. Contemporary energy modeling through DOE-2, Energy-10, and E-Quest fails to capture the full value of integrated design. While the radiant part can be established, this alone can be sufficient to qualify for LEED points, government incentives, and determine ROI.

Support Services

Manufacturers of Radiant Air Conditioning systems typically offer support services to aid in the design and engineering of an integrated system in early design stage that will meet your project’s requirements.

A radiant air conditioning system is usually simple in design, has few, if any, moving parts, and requires minimal to no maintenance.

However, it does need precision engineering that goes beyond the commercially available software. Precision engineering allows the optimizing of building systems and improves the integration with the overall building design, right from the very start.

Planning and Design of Radiant HVAC System

HVAC:

Any conventional HVAC equipment can be integrated with the building structure to deliver radiant comfort. It can address the choice of variable occupancy, daytime load schedules, and super-charging during off-peak hours. Local electrical utilities should be able to advise on discount electricity rates during off-peak hours, as well as grants for demand peak load shading (reduction).

AC Plant for low and Zero Energy buildings:

Performance parameters of integrated approach to design provide persistent benefits in terms of efficiency and performance with smaller on site power generation capacities, without compromising the building’s architectural statement. Refer to slide 33. This in turn opens up the possibility for better ROI by using low grade energy (below 120°F) from solar, wind, geothermal, or fuel cell cogeneration.

Special Design Considerations:

Spaces located along the perimeter, corner rooms, conference rooms, internal rooms, rooms with special requirements, or simply speculative offices should be designed to a mutually agreeable range of possible loads and use.

Recommended Building Envelope Design Standards

Target R-values for wall, roof, floor and glazing should be 10% to 15% higher than basic buildings. Note that the extra cost will be offset from significant heating and cooling plant reductions.

Building Fabric Criteria:

Recommended minimum standard for active thermal storage and building design are as follows:

Walls	R24 to R28
Roof	R28 to R32
Windows	R3.5 to R5.0
Solar shading coefficient	0.3
Solar Heat Gain	0.3

Internal partitions:

Lightweight, insulated, removable partitions are acceptable, although heavyweight wall construction is preferred in order to increase thermal lag.

Zoning Considerations

HVAC zoning in thermally active systems follow the same design considerations as any traditional ventilation system.

Considerations include:

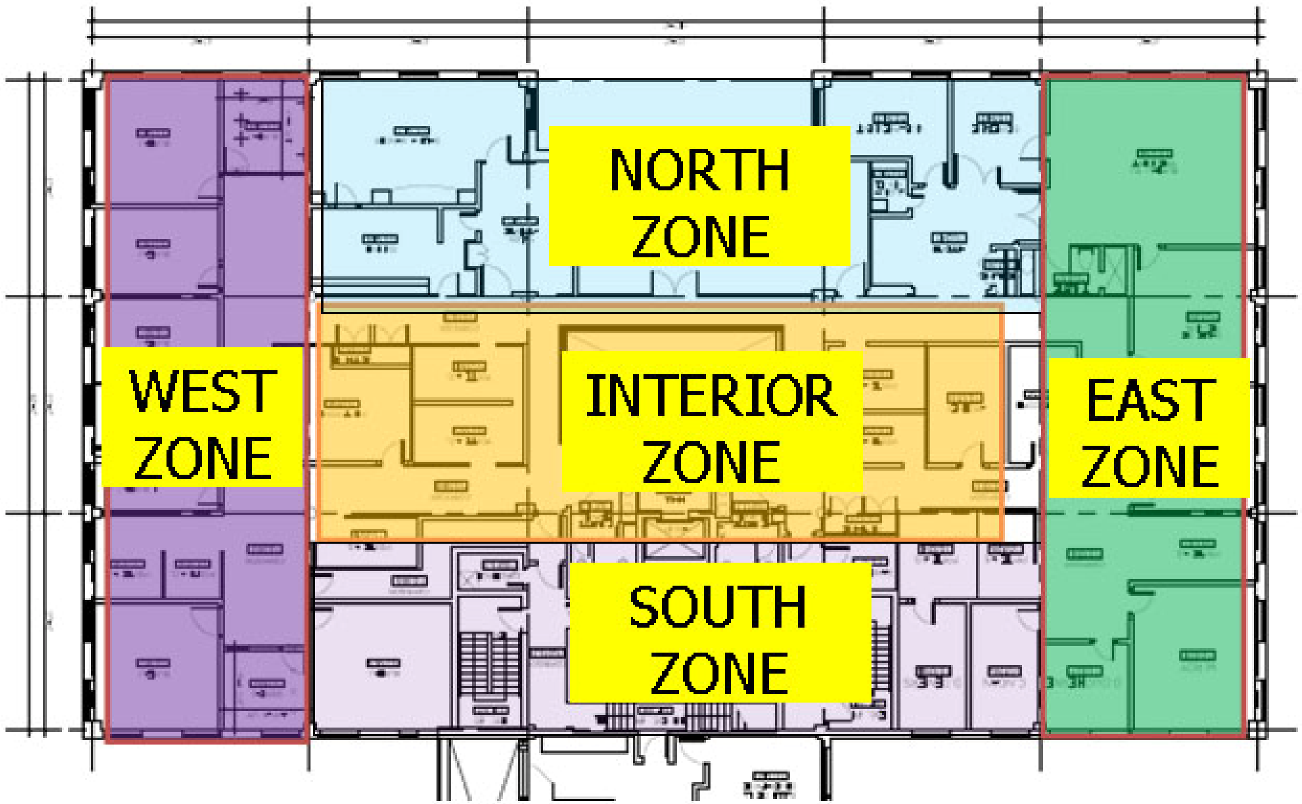
- the variation of heating and cooling loads and the ability to heat/cool the interior and/or exterior of a building at any time
- the separation of exterior and interior zones, and
- the flexibility to meet occupancy schedules and operating costs.

Depending on internal loads and orientation, different zones in a building have varying needs for heating and cooling.

An example of HVAC zoning is shown on the next slide.

Example of HVAC Zoning

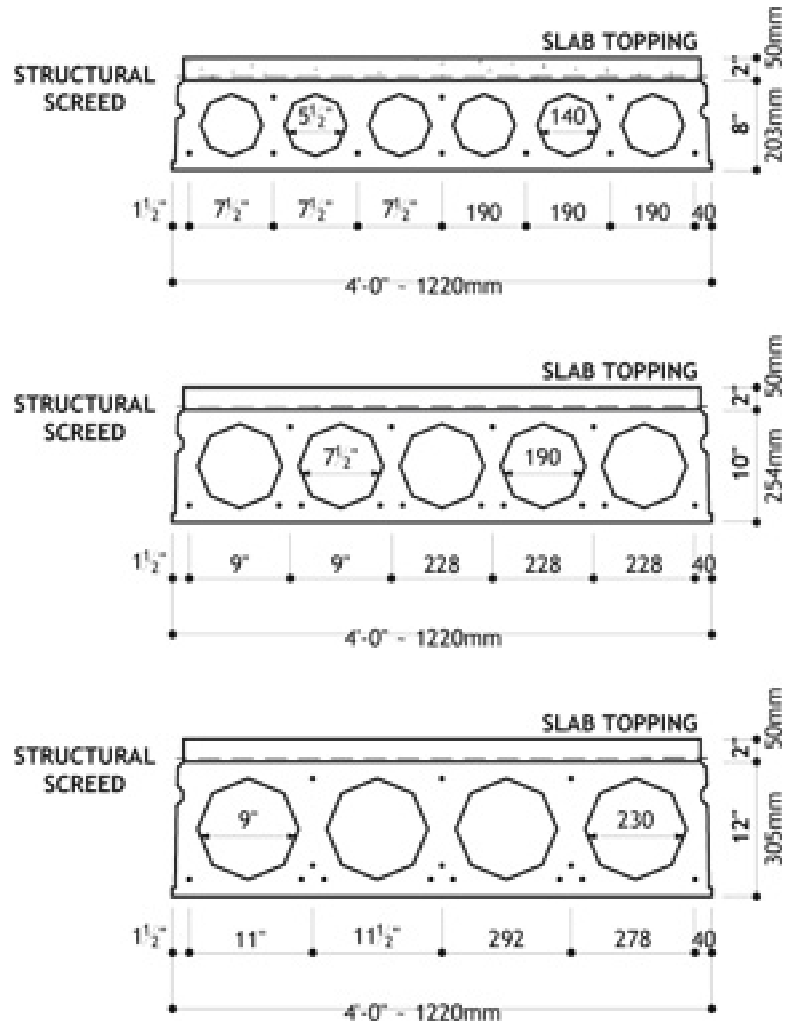
In radiantly air conditioned buildings, the zoning follows the same principals as in any conventional design.



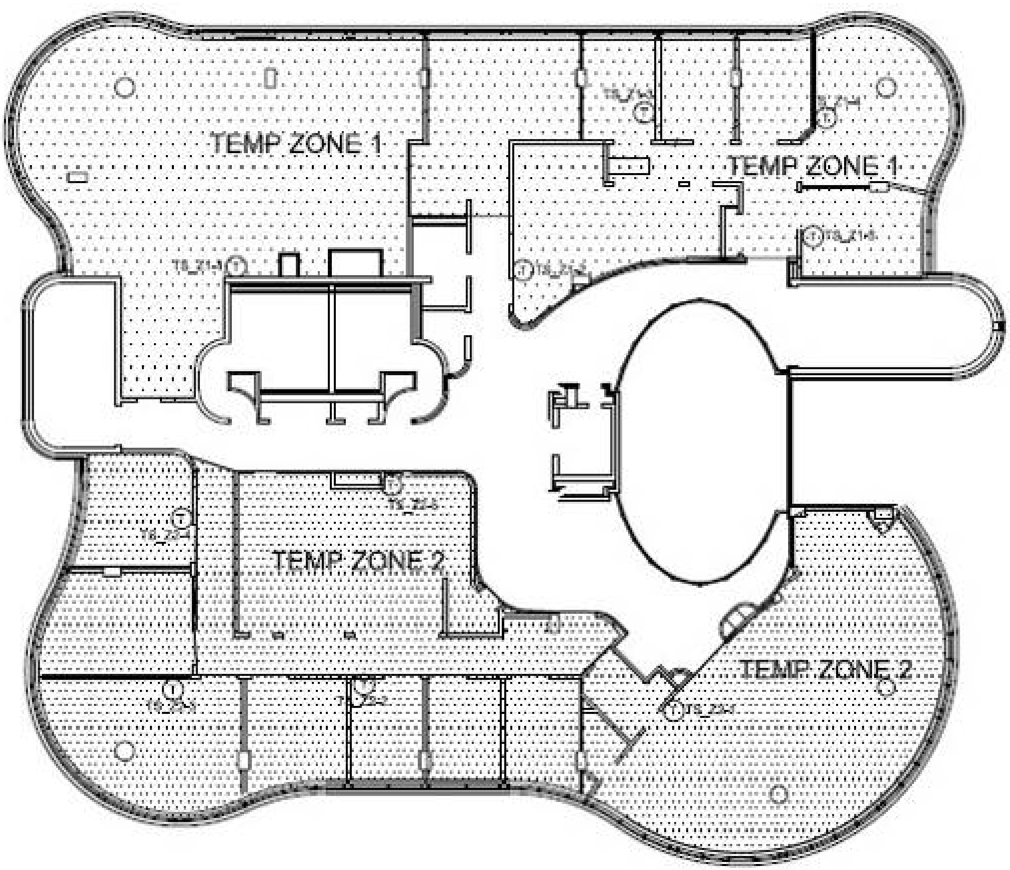
Illustrations of Slabs

Illustrated at right are typical 8", 10" and 12" standard hollow core slab profiles that are used in a integrated radiant air conditioning system.

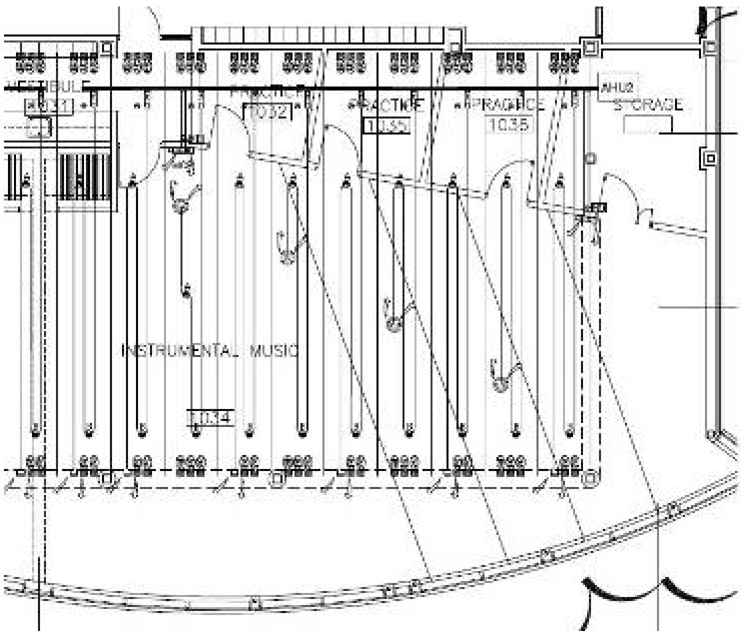
All standard planks are 4'-0" wide with custom length cut to suit architectural design. Clear span is subject to application type, as well as live and dead load considerations and shall be subject to structural engineers' design recommendations.

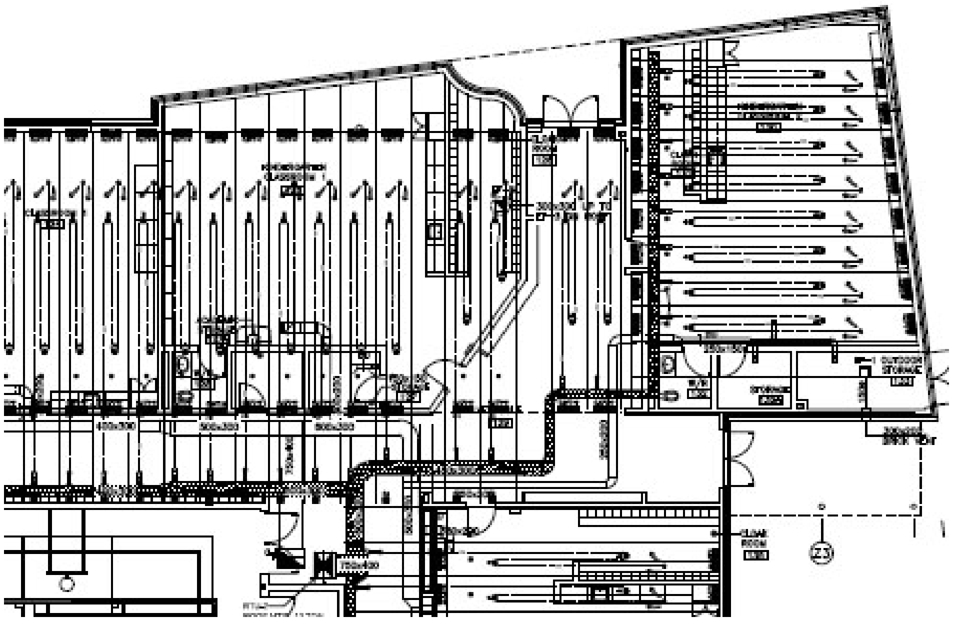


Building Shapes



Building Shapes





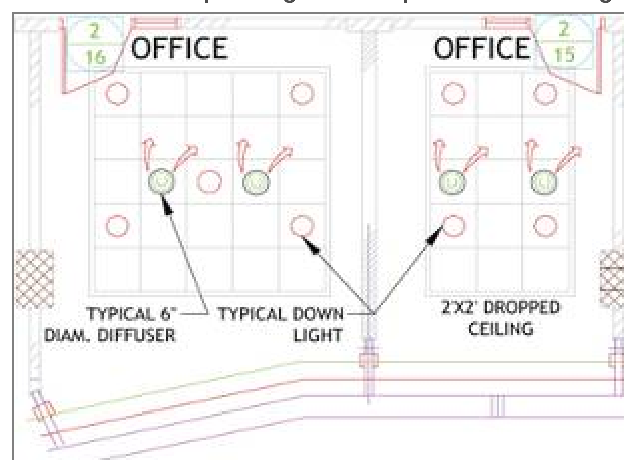
False Ceilings and Sound Absorbents

To enable the accumulation of internal surplus heat in the building frame, the surfaces must be accessible.

Suspended ceilings and acoustical treatment should be placed so that the energy transfer between slabs and room air is efficient. The recommended opening of the ceiling should be 40% or more.

A variety of typical and custom solutions work well with radiant air conditioning systems. Most system manufacturers take into account various ceiling types and can offer suitable heat exchange solutions between the space and thermal storage.

40% Openings In Suspended Ceilings



Office Application

Ducts

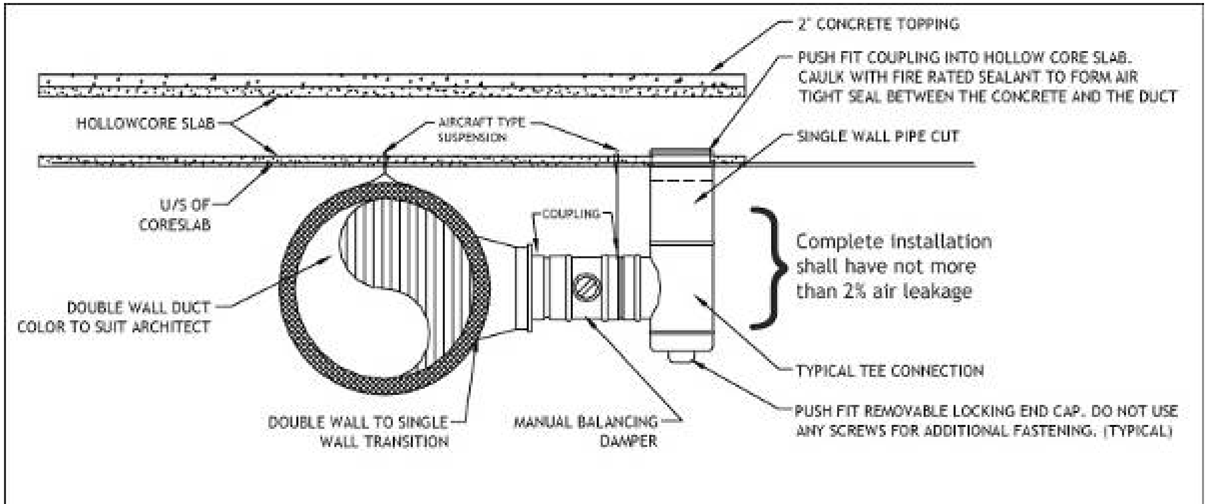
The ductwork in a radiant air conditioning system does not differ from a traditional system.

From the mechanical room, supply air ducts run through vertical shafts in the center parts of the building.

Distribution ducts run perpendicular to the length axle of the hollow core slabs above the suspended ceiling in the corridor area.

Duct Connection

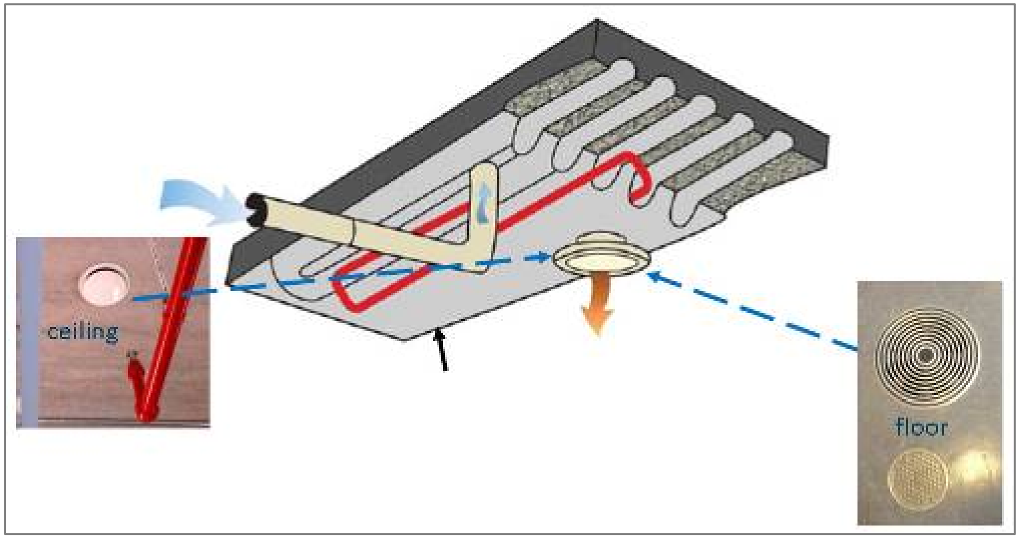
The position of main ducts is similar to a conventional system when supplying air through diffusers in a corridor wall. The difference is that air distribution branch ducts are connected to the system of cores in the slabs instead of directly to the diffusers. This results in an extension of the duct, giving greater flexibility for placement of the diffusers.



TYPICAL CEILING BRANCH DUCT CONNECTION TO H.C. SLAB (N.T.S.)

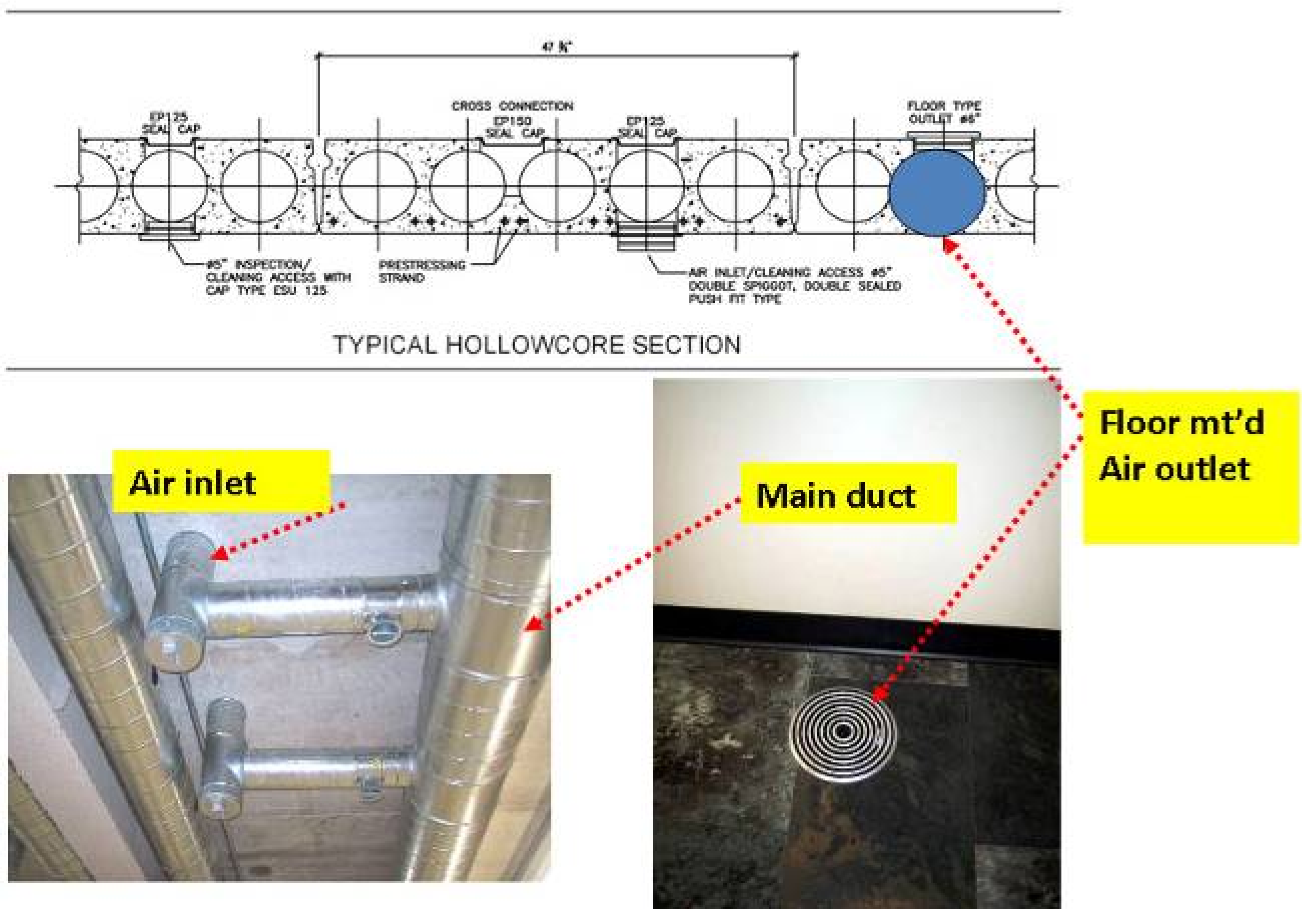
Diffusers

Using a radiant air conditioning system offers flexibility regarding choice of room supply air system and diffusers. Almost any of the diffusers produced in North America can be assembled in a radiant air conditioning system.



Any standard ceiling or floor air diffusers can be used.

Connections and Diffusers



Typical Connections

Connection to the Slab

Balancing Damper (Typical)

Code Compliance

Radiant air conditioning systems with properly installed ductwork are building code compliant, meet structurally sound practices, as well as life safety and fire safety requirements. Listed below some of the typical values and performances of RAIC systems.

Fire rating: Typical hollow core slabs have two hour fire rating.

Ventilation rates: Generally exceed ASHRAE's minimum 62.0 fresh air requirements. The systems works for most of the year as a Dedicated Outdoor System (DOAS). It can be used in 100% fresh air mode in buildings where such need exists and spread of communicable decease minimized through ventilation systems. (Refer to slide 35)

Acoustics: Sound treatment should be considered in any design and it is subject to proposed floor, wall and ceiling finishes. It may require design inputs and recommendations from acoustical consultants.

Systems Comparison

Radiant Wet Systems vs. Radiant Air System

RADIANT WET SYSTEMS:

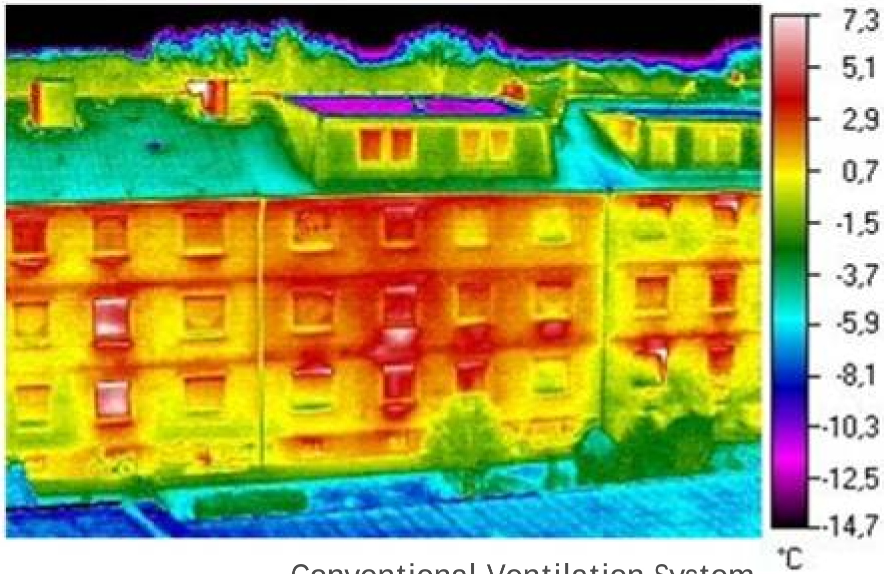
- Low intensity radiation with limited total cooling capacity
- Strictly temperature control. Sometimes difficult to control condensation and temperatures in multi-story buildings
- Separate ventilation and space temperature control
- Renovations require careful planning and x-raying floors to avoid puncturing wet tubing

RADIANT AIR SYSTEM USING VENTILATION AIR AND HOLLOW CORE PLANKS:

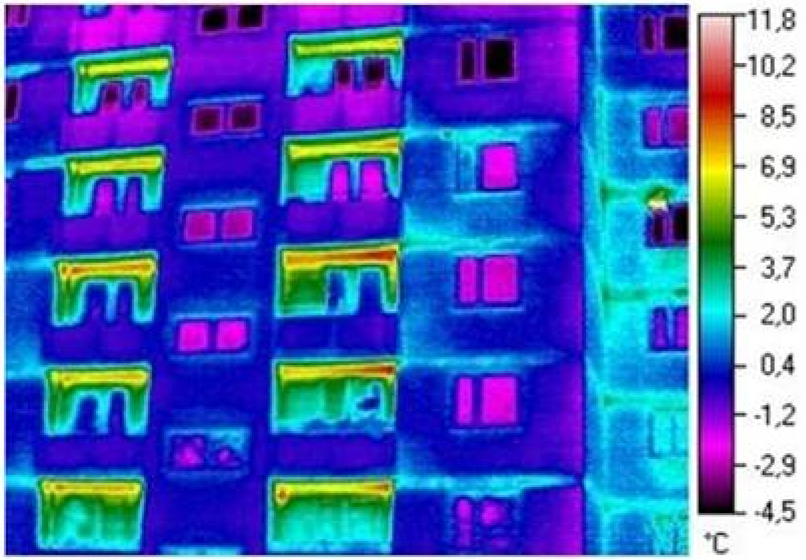
- User-adjustable space temperature control
- Combined radiant comfort and ventilation air delivery is designed for multi-tasking
- Efficient super-charging of the building structure during off-peak hours
- “Smart” metering ready - highly efficient in night pre-cooling mode
- Low intensity radiation capable of addressing present and future variable heating and cooling loads
- Easy to renovate with built-in flexibility. Often involves rebalancing of ventilation air only

Comparison of Systems

The performance of conventional vs. radiant air conditioning systems is compared below.



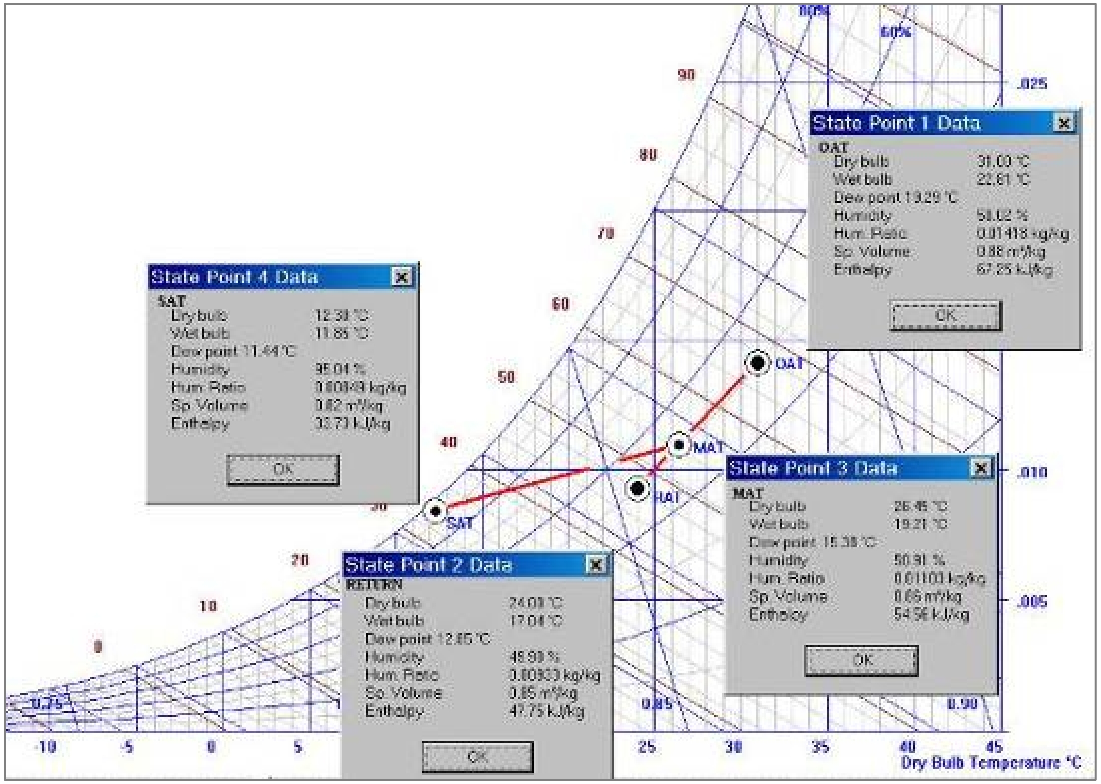
Conventional Ventilation System



Radiant Air Conditioning System

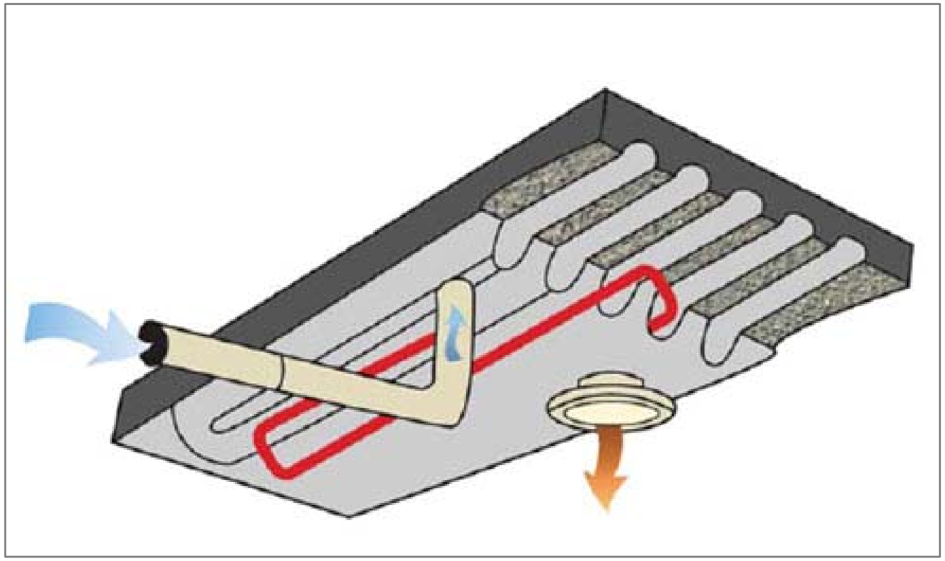
Comparison of Systems: Humidity, Condensation and Mold

Additionally, with radiant wet cooling, control of humidity within the space is critical, unlike air driven radiant cooling that does not attract condensation in a way the wet systems do.



Comparison of Systems: Storage

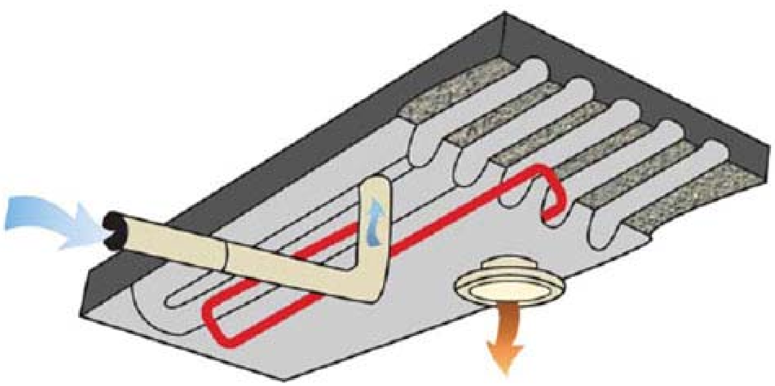
Ice Storage or Exhausted Format



vs. Radiant Air Conditioning System

Comparison of Systems: Simplicity

Compared to wet systems, radiant air conditioning technology eliminates inflexible and wasteful routines.



Comparison of Systems: Power Demand

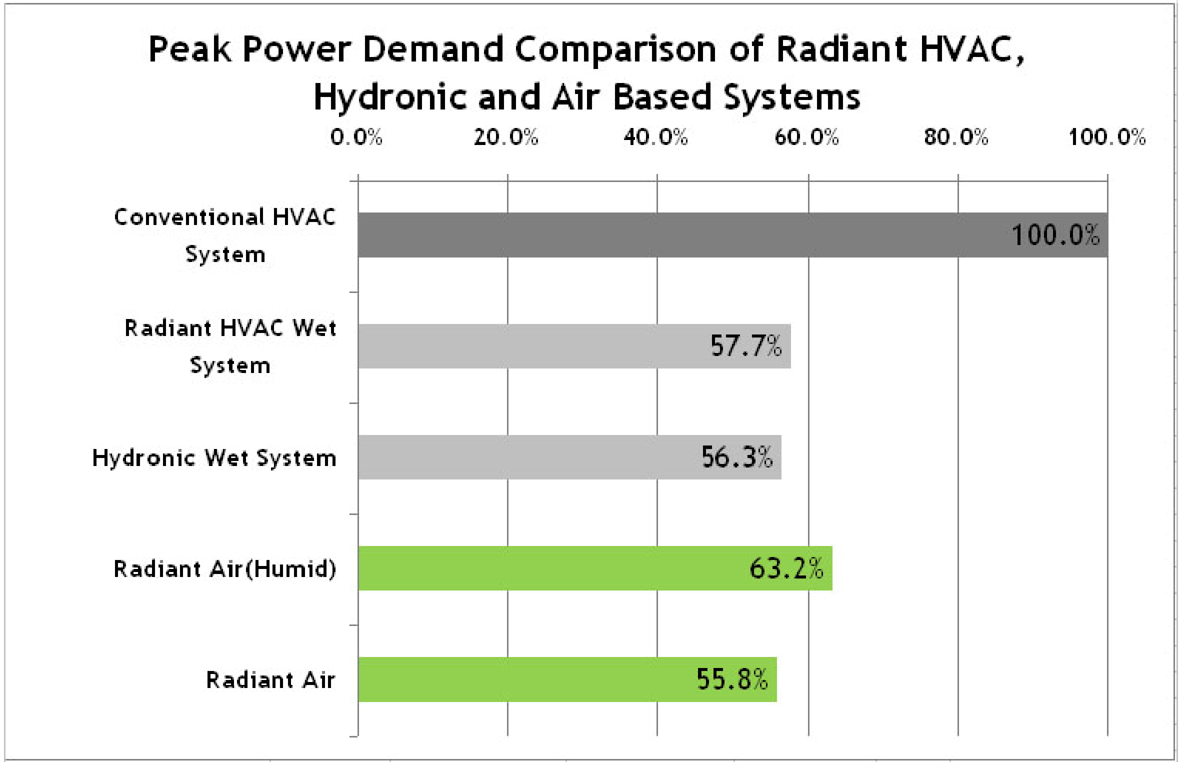
Thermal storage and "smart" floors further enhance the business case of greener strategies by smoothing day and night time peaks and valleys in power demand.

Design Considerations:

When opting for radiant comfort, it's important to consider that water has 3,500 times the energy transport capacity of air.

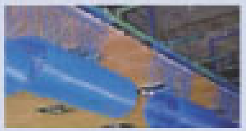
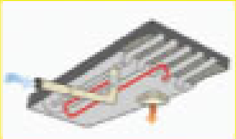
The bar chart on the following slide demonstrates how the total power consumption for both radiant wet and radiant air cooling is remarkably similar. By comparison, first cost analysis and the carbon footprint for radiant air conditioning is significantly less.

Comparison of Systems: Power Demand



	Other Loads	Air Transport Load	Load From Lights	Fan and Motor	Pumps	Total Power including Fan Power
Conventional HVAC System	34.4%	9.3%	18.8%	37.5%	0.0%	100.0%
Radiant HVAC Wet System	34.4%	4.9%	9.4%	7.5%	1.5%	57.7%
Hydronic Wet System	25.8%	0.0%	9.4%	20.6%	0.5%	56.3%
Radiant Air(Humid)	27.5%	0.0%	9.4%	26.3%	0.0%	63.2%
Radiant Air	25.8%	0.0%	9.4%	20.6%	0.0%	55.8%

Temperature and Response Comparison

DESCRIPTION	TEMPERATURE RANGE	INERTIA	REPONSE TIME	
Radiant wet Suspended metal panels	6 to 10 Deg. C (43 to 50 Deg. F)	LOW	FAST	
Radiant wet Plastic capillary mats	3 to 8 Deg. C (37 to 46 Deg. F)	MEDIUM	SLOWER	
Radiant wet Cast-in-placing slab plastic tubing	3 to 6 Deg. C (37 to 43 Deg. F)	HI	SLOW	
Radiant air conditioning	3 to 3.5 Deg. C (37 to 38 Deg. F)	HI	INTUITIVE *	

* Intuitive controls have built in flexibility for highly customized experience in comfort and space control. Comfort settings are adjustable to evolving needs.

Radiant Wet System vs. Radiant Air Conditioning System

Description	Radiant wet	Radiant air
UNDERSTANDING SYSTEM BEHAVIOR & CONTROLS	Difficult	Simple
COOLING CAPACITY	Can be limited	Designed to suit
MAINTENANCE	Distributed*	Simple
DEMAND CONTROL VENTILATION	Very good	Very good
Latent cooling	Limited	Very good
Peak cooling control	Add on**	Built-in
Multi-tasking	Not available	Built-in
* Extensive and expensive with many fans, filters and condensate drains		
** Refer to comparison slide 64		

Radiant Wet System vs. Radiant Air Conditioning System

Description	Radiant wet	Radiant air
Initial capital cost building compared to conventional budget	Must pay a premium, generates more waste	No premium for building
Small ductwork	Yes	Yes, no branch duct required
Space temperature and condensation control	Good, may be expensive	Intuitive and simple
Vertical temperature control	Fair to poor, may require insulation of exposed slabs	Intuitive and simple
Indoor air quality	Very good	Very good
Reheat	Maybe required	Not required
Total energy consumption	Very good	Excellent. Built in energy harvesting feature is free
Ease of renovation	Complexity varies, floor x-ray maybe required	Simple and cost effective

Applications / Case Studies

Introduction

During the last 25 years, hundreds of commercial and institutional buildings in Scandinavia, the United Kingdom, Saudi Arabia, and more recently in Canada have been using the radiant air conditioning method.

Applications include:

- educational
- commercial
- institutional
- health care
- multi-use
- hospitality, and
- residential.

Case Study: Mundy Bay Elementary School, LEED Gold, Midland Ontario

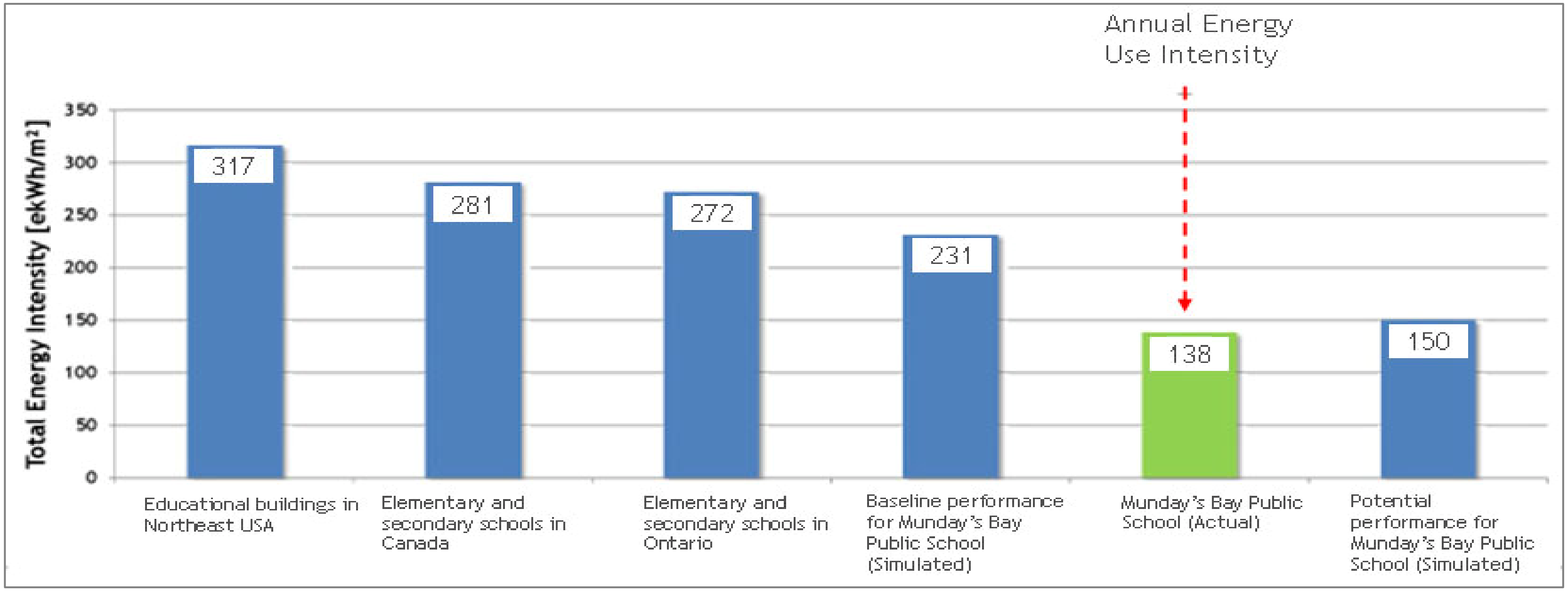
Presented in subsequent slides is a case study of the LEED Gold-Certified Elementary School located in Midland, Ontario that utilizes a radiant air conditioning system.

Exterior

Classroom

Case Study: Mundy Bay Elementary School, LEED Gold, Midland Ontario

Based on a gross floor area of 4,792 m^2, the annualized energy intensity (ekWh/m^2) for the school is 138 ekWh2 or 12.8 ekWh/sq.ft, which is approximately 40% lower than comparable educational buildings in Ontario.

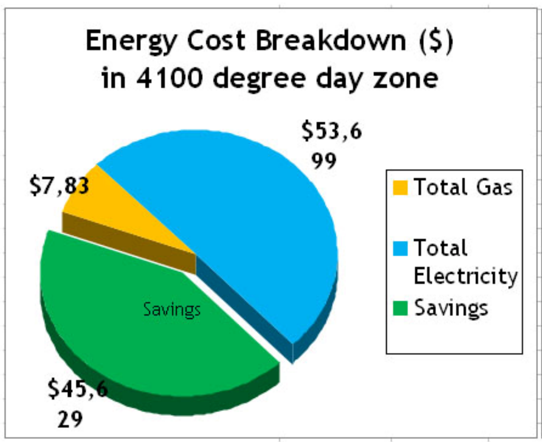


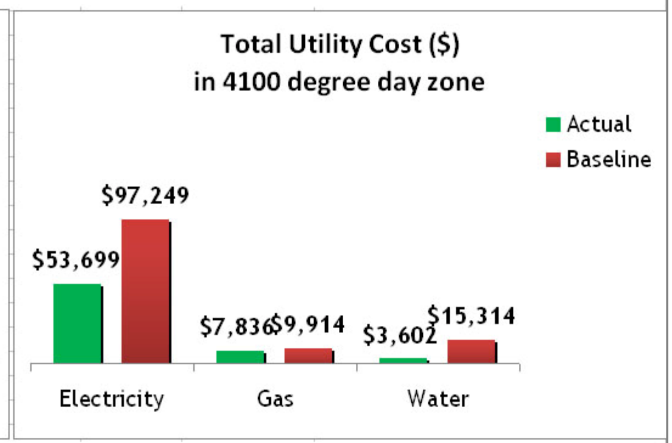
When compared to the potential performance obtained from the calibrated simulation, the Midland Elementary School is performing as expected. Energy consumption data for entire facility was retrieved from utility invoices (gas and electrical) and analyzed for full 12 month. (Refer to next slide for itemized breakdown)

Case Study: Mundy Bay Elementary School, LEED Gold, Midland Ontario

This report summarizes the energy consumption and utility cost savings for the Midland 6th Street Elementary School from September 1, 2008 through November 30, 2008.

Savings Statistics			
Energy Cost Savings	43% $45,629	Energy Savings	40% 445,827 ekWh





Utility Cost and Energy Intensity						
	Actual Cost		Baseline Cost		Cost Savings	Energy Intensity
	[$]	[$/m²]	[$]	[$/m²]	[%]	
Water	$ 3,602	$ 0.75	$ 15,314	$ 3.20	76%	138 ekWh/m² or 12.8 ekWh/ft²
Electricity	$53,699	$11.21	$ 97,249	$20.29	45%	
Gas	$ 7,836	$ 1.64	$ 9,914	$ 2.07	21%	
Total utility	$65,136	$13.59	$122,478	$25.56	47%	

Case Study: Mundy Bay Elementary School, LEED Gold, Midland Ontario

To expand of the report, the information compares the actual building consumption with the baseline building consumption.

The School's energy consumption is comprised of electricity (lights, HVAC system, ground source heat pump and plug loads) and natural gas (boilers and domestic hot water).

The utility costs averaged $0.10/kWh, gas was $0.54/ m³ and water was $3.57/ m³ .

Interior

Note:

- $/m2 indicates dollars per square meter (m^2) of floor area
- $/m³ indicates dollars per cubic meter (m^3) of gas or water used

Case Study: Mundy Bay Elementary School, LEED Gold, Midland Ontario

Building energy performance of the Midland Elementary School is better than comparable buildings due to the significant energy conservation design features, including:

- an energy efficient envelope
- high-performance windows
- a heat recovery system
- a ground source heat pump system
- an efficient lighting design with occupancy sensors and photocells, and
- proper operation as intended.

Central Court

Please remember the **exam password** [STORAGE]. You will be required to enter it in order to proceed with the online examination.

Case Study: Humber College, Toronto, Ontario

The next case study, the construction of a new academic building, presented several challenges. Built on an incredibly low budget, the structure was constructed mostly during harsh winter conditions with a tight schedule that allowed less than two weeks between floors.

This schedule was met by manufacturing the hollow core slabs off-site, ready to be delivered precisely when the floor and roof slabs were required, thereby keeping disruptions at the job site to a minimum.

Approximately 6,970 sq m (75,000 sq ft) of 254 mm (10 in) and 305 mm (12 in) hollow core slabs were utilized for the three levels of this new facility.

Case Study: Humber College, Toronto, Ontario

The building is a mix of classrooms and office space, with classrooms comprising the second floor.

The HVAC system of this building utilizes a radiant heating and cooling system that uses hollow core concrete slabs to distribute air that takes advantage of the thermal mass of the building.

Up to 70% of the heating or cooling of rooms is accomplished by radiation, directly heating or cooling the occupants with the stored thermal mass, rather than conditioning the air around them.

Case Study: Humber College, Toronto, Ontario

In the winter, the hollow core slabs can store the energy generated by the lighting, equipment, and building occupants.

This strategy is especially effective in educational environments, where many students may be located in rooms for an hour or more at a time.

These factors were among the incentives that convinced the designers of Toronto's Humber College to select a radiant air conditioning system for the new three-storey academic building.

References and Resources

- ASHARE GREENGUIDE 2003, Green Tip#1
- ASHRAE 1995 HANDBOOK. Thermal storage section
- World Building Council, Washington, DC. Zero Energy Buildings, 2008
- Commercial and Institutional Building Energy use Survey 2000, Office of Energy Efficiency, Natural Resources Canada
- Commercial Building Energy Consumption Survey (CBECS) 2003. Published by Energy Information Administration, USA, December 2004
- Termobuild Canada, www.termobuild.com
  (date accessed: March 15, 2010)

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