WHITE PAPER

Net Zero Buildings: Moving from Theory to Reality

The role of radiant heating and cooling in net zero building progress

Overview of Net Zero Building

The concept of "net zero building," a building which produces as much energy as it uses over the course of a year, in recent years is becoming more of a reality than simply theory. Although currently there are only a small number of highly efficient buildings that meet the criteria to be considered a net zero building, creating net zero buildings is becoming more and more feasible.

One of the biggest hurdles is education. Architects, engineers and contractors need to realize that net zero buildings are achievable—and they don't need to be limited to high-profile, showcase buildings. The net zero concept can and should be considered for ordinary office buildings and commercial spaces, as well as residential.

Industry Goals

The industry is steering its participants to net zero goals. California, a frontrunner the industry, is aiming to be net zero for commercial buildings by 2030. The Center for the Built Environment (CBE), one of the organizations leading and supporting this initiative, has been collecting and sharing data from a few hundred buildings (many of them LEED certified) that they are monitoring, both in North America and globally.

Cutting-edge contractors are embracing the movement and educating themselves to adapt.

Radiant Heating and Cooling and its Role for Net Zero Building

How can radiant heating and cooling figure into a net zero building design? The main strategy a building can take to achieve net zero is simply by reducing the amount of energy that is spent on conditioning the space. Traditionally, there is a lot of energy expended when using air to regulate temperature in spaces. Radiant allows for reducing air systems enough to meet fresh air requirements and to ensure the space keeps from getting too humid. The remaining heating and cooling can be accomplished by conditioning the mass of the building—the floor below and the ceiling above—in order to keep the space comfortable for occupants.

The People Factor

People experience temperature in multiple ways (47.5 percent radiantly, 27.5 percent convectively and the remainder exhalation and other processes). Most HVAC systems only address one of those, which is the temperature of the air surrounding people, and typically ignore almost half of what makes a person comfortable. But another very significant way people experience thermal comfort is through the temperature of the surfaces around them. For an example, the heat from a fireplace makes you feel feels comfortable even though the air around you may be very cold.

With radiant, the concept is similar. Comfort cannot be defined, as it is a perception from person to person. Radiant tends to make more people comfortable due to an individual's body reacting with a tempered surface. If there is a high temperature difference, the person feels the work being done by the surface to pull heat away and restore it to them. The greater the difference, the more work a person can feel, and a greater number of people can feel more comfortable in the same place.

The Basics

Radiant allows for cooling and heating a space by pumping water at one-third the energy of blowing air for identical loads, an enormous energy savings. Radiant heating is efficient primarily because of the heat-carrying capacity of water. On an equal volume basis, water carries over 3,000 times more energy than air. This energy density allows for smaller distribution channels, lower flow rates, and less energy intensity overall. As almost 25 percent of commercial building energy usage is used for heating and 10 percent for cooling (combined for ~2.4 quadrillion BTUs in the U.S. in 2012), anything that can be done to reduce this large consumption should be considered.

Radiant heating and cooling is also effective due to the large surface area that is conditioned. Being exposed to the entire floor or entire ceiling provides a large amount of heat transfer with moderate temperatures that are easily and efficiently reconditioned by mechanical room equipment (boilers and chillers). The actual air temperature in a room can be up to five degrees cooler with no decrease in comfort from occupants.

Design and Control Strategies

Benefits can be magnified with good design and proper installation practices coupled with other energy efficiency measures such as quality insulation. A quality design might include selecting proper spacing of tubing, tubing depth within a poured concrete slab, or flow and temperature control of the water. Another very important consideration is the control strategies being used.

Control strategies in a radiant building are a great way to pre-cool a building before the peak demand in the day. If the building is pre-cooled a few degrees by cooling off the furniture, the ceiling, the floors and the windows, that building will not need as much instantaneous conditioning at the peak of the day when it reaches 100 degrees and a conventional system would need to run at full power.

Thermal Building Battery

A radiant-cooled, net zero building can have a lower peak demand and need less instantaneous electricity to run it. This advantage is beneficial to building what is considered to be net zero energy because it helps balance peaks and lows. In a sense, the building becomes a thermal battery, which allows for a smaller, less expensive cooling system.

The cooling (or heating) is stored in the building's thermal mass, enabling radiant to make net zero energy more affordable than without radiant, because less equipment is needed with the use of the thermal battery. Air duct work can shrink from 20 inches to six inches to supply only the air needed by code for air exchange. Other typical equipment reductions include reducing the size of the chiller by one half, the number of VAV units (variable air volume) units by one fifth, and the size of the air handling units by one fourth. A real-world example is described below.

Integrating Radiant with Acoustical Design

Instead of the whole ceiling being covered with drop ceiling tiles, a drop ceiling of acoustic "clouds" permits isolated sections without drop ceilings, exposing concrete surfaces needed for radiant and interweaving thermal comfort with acoustic comfort. These gaps that exist below a radiantly cooled slab and with fans installed, generate the same amount of heating and cooling as if there is no drop ceiling at all. Acoustically, this helps to manage the noise and when combined with thin carpeting, it creates a very good acoustical strategy that is imperative for occupant comfort.

How Radiant Impacts Net Zero Requirements

With over 80 percent of net zero buildings with radiant in the equation, clearly radiant heating and cooling is an integral aspect of the net zero building goal.

Radiant buildings (and radiant in general) are perceived as being a premium, luxury comfort. When construction costs are considered, radiant is always an additional element—there is a heating and cooling system AND there is a radiant system that provides heating or cooling in an area. When a radiant strategy is used as the primary source for heating and cooling and everything else is simplified, it can actually be more cost competitive than conventional designs.

With buy-in from architects, engineers and contractors, and by incorporating the proper engineering design, it is possible to creatively make a solution palatable and affordable. Recent radiant buildings have shown a decrease in upfront costs when designed to factor in smaller air systems and lower ceiling heights, but it is also the cost of the life of the building that needs to be factored. The basic premise is to install a radiant system and remove other unnecessary equipment in order to make it affordable. It's a very delicate design challenge to create a system that provides fresh air, manages moisture in the building, and yet is simple enough and small enough that it only brings in the right amount of ventilation air—and no more than that. Cost savings can be achieved in several ways: by reducing the size of the ducts, the number of control points, and the shafts that run through every floor and take up space that could actually be used for additional offices or conference rooms.

Case Study: San Francisco Airport Office

Innovative firms are encouraging clients to achieve net zero buildings – and not necessarily on "showcase" buildings. Integral Group, one of the leading Zero Energy MEP design firms in North America, is leading this charge. Having completed more than 30 LEED Platinum buildings, the firm is always pushing to get its clients to net zero energy on their projects.

The firm recently completed a 130,000-square-foot net zero building for San Francisco International Airport, consisting of an engineering office and museum curatorial space. With everything working together towards a goal of reducing and eliminating, the building boasts exemplary numbers from an affordability standpoint.

The building reaches net zero energy using radiant tubing for heating and cooling in the concrete structural slabs. Ceiling fans empower radiant around the acoustical cloud, that provides great acoustical performance and allows for high radiant capacity, while increasing occupant comfort and control. Thin carpet tile adds to the acoustical strategy to allow enough radiant capacity. An exposed, five-foot-wide strip of ceiling that is free of acoustic clouds and the carpet, allows radiant to powerfully handle the building envelope loads. Automated interior blinds reduce direct solar gain to help encourage radiant success as well as visual and thermal comfort. Sun shades reduce the effect of solar enabling self-cooling by radiant and eliminate the need for supplementary fan coils. VAV boxes were installed only for ventilation allowing the VAVs to serve larger areas, and in the process, reducing the number of them needed by one third. Fresh air supplied at a neutral temperature provides both thermal comfort and energy savings.

The end result was that Integral Group was able to reduce the number of air handlers that traditionally provide air conditioning for buildings to one-fourth of the size that there would have been, ultimately translating into more floor space. Smaller duct work allowed for raised ceiling height, which is aesthetically pleasing and provides more daylight and a better occupant experience.

Had the building been a high-rise, an additional floor could have been added in the same amount of space, translating to an invaluable amount of cost savings. Overall, when the building was inhabited, building occupants were comfortable and happy.

Viega's Role in Radiant for Net Zero Buildings

Viega provides assistance with radiant systems as early as the first contemplation of building a structure. The sales team has access to tools that help determine if radiant is a viable solution for a particular building. Discussions early in the process can help significantly in determining a good fit. Once radiant is accepted as a viable alternative, a floor plan is given to the Viega design team who works to ensure loads can be met and then supplies the tubing layouts to the contractors.

Components to a radiant solution include PEX tubing, manifolds and controls, and the labor that is required to install them.

PEX tubing is used to carry tempered water throughout a building, emitting or absorbing heat as it travels underfoot or overhead. An oxygen barrier is very important in radiant systems to protect from corrosion in ferrous components.

Manifolds are prefabricated units used to distribute water to the tubing in the floor or ceiling. Water is heated or cooled in a central plant and then pumped to each manifold. The manifold ensures the appropriate amount of water is flowing to each section of a room so that "hot-spots" do not occur.

By far the biggest cost for radiant cooling and heating is the labor—therefore any way labor can be reduced, the cost can be reduced. Viega offers pre-fabricated roll-out mats that considerably lower labor time and installed costs for large projects. Viega Climate Mat comes labeled and numbered in conjunction with drawings so that each is literally rolled out and connected faster than concrete can be poured. Viega's design team also ensures that each mat is hydronically balanced to reduce commissioning time.

So, Why the Resistance?

While there are plenty of contractors doing radiant installs and proving that it is working, there is still resistance from some, especially those contractors not as progressive.

Scheduling: Contractors usually work in silos, completing a project and moving on to the next building. With radiant, the general contractor begins by setting up the building frame using steel and concrete, then the mechanical contractor arrives on the project site to install the tubing, and then the general contractor returns to the site to pour concrete over the tubing. The fact that the mechanical contractor is involved in the middle of the project and requires scheduling and cooperation is sometimes a challenge.

The construction process needs to address questions from contractors and their trades who need to know when and what the order is for installing tubing into the floor, returning to pour concrete over the tubes, and then running air duct work underneath the floor.

Condensation: One of the biggest fears is condensation. If the system isn't properly controlled, condensation can be a problem, causing floors to become slippery surfaces. However, when designed and installed properly, condensation can be avoided. Simply providing code-minimum ventilation typically lowers the dew point below where condensation can occur.

When radiant projects first came to the U.S., copper tubing was installed, which didn't last in the concrete, and was an unfortunate lesson learned. Also, in that era, the systems traditionally used really cold water that made the slab too cold and formed condensation. It's simply not done that way anymore. PEX tubing and warmer water temperatures ensure that the surface doesn't promote condensation. But there is a fear in many contractors that is a result of these past experiences. Contractors might quell their fears by looking at overseas contractors that install incredibly high rates of radiant– more than 80 percent in Germany and more than 95 percent in Korea.

Mechanical engineers are generally concerned with the capacity that radiant can provide, as well as its limitations. The issue of ventilation and conditioning outside air so it doesn't get too humid and the requirement of a separate system to remove the moisture from the outside air is also a concern. However, the formula for relationships of temperature-controlled surface areas in the building versus heating or cooling sources to provide enough conditioning are slowly trickling into the engineering design community to help alleviate these concerns.

Perceived Cost: Perceived cost of radiant is another concern that creates resistance. Purchasing additional materials—manifolds, PEX tubing, controls—and the installation costs that go along with it can cloud the judgement. To combat this perception, it's important to remember the equipment that will not be needed when a radiant system is installed. If it's not brought up, radiant simply becomes a line item that is an additional expense. Also, the back-end energy savings from implementing a radiant-dominant system that uses less energy contributes to combating the perception.

Acoustical Challenges: Because radiant heat involves radiant heat transfer, the formula of occupants' exposure to the majority of the floor and ceiling surface area is critical to its success. If radiant heating and cooling is the primary strategy in a building, traditional drop ceilings and full carpeting may not work. Often, building owners are very resistant, and insistent upon having drop ceilings and thick, plush carpeting in every room. Concern with reducing acoustics from hallway foot steps to conference room chatter creates a resistance to the need for exposed hard surfaces that are needed to make a radiant system viable. There are definitely ways to accomplish it and compromises that can be made to keep the building owner and tenants happy, but it's important to realize that these discussions and decisions need to be addressed early in the project rather than at the end.

Collaboration and Communication: The Key to Net Zero Radiant Success

Education and collaboration is the key to achieving the goal of net zero buildings. Years ago, solar had a similar battle for acceptance. While there hasn't been much innovation in solar technology, there has been incredible education and adoption in solar installations, and costs for solar have dropped drastically over the years, making solar much more achievable and commonplace.

The radiant solution is a package system with the acoustical strategy. The architect designs the ceiling and works with the engineering team for the location of the fans in the ceilings if needed, which are installed by the contractor, creating a solution that everyone is happy with. The design team, building owner and contractor need to be in collaboration from the beginning. If that doesn't happen, the project outcome is likely to be less successful, as with any project.

The name of the game is collaboration. Collaboration is needed between architects, contractors, developers, trade partners and allies. This way, everyone can leverage the knowledge, apply it in practice and into product selection to create the most affordable and comfortable system needed.

By identifying the challenges and working together to address them, the industry can discover solutions. The end goal is to meet a timeline to design and build the lowest energy building that costs the least to construct.

About the Author:
Adam Botts is product engineer, heating and cooling, at Viega. He is responsible for product testing and measurement, developing technical specifications and instructions and resolving product-related issues. Bringing more than seven years of engineering experience to the position, Botts earned his bachelor's degree in engineering physics and master's degree in mechanical engineering from Colorado School of Mines, Golden, Colorado.