Magnetic Fields of Green

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EXECUTIVE SUMMARY

- By incorporating even the basic elements of a more environmentally friendly, "green" construction and design in an MRI setting can create a safer, more pleasant space for the patients and staff, better images, and operational cost savings.
- Using building systems that have reduced amounts of steel can decrease construction time, increase thermal insulation, and reduce the weight of the structure meaning less energy required to transport and install. HVAC systems and lighting design can also play a major role in creating a "green" MRI suite.
- LEED certification places a focus on quality of the built environment, life cycle cost, and a productive indoor environment, as well as impact on the exterior environment. An LEED certified building considers costs and benefits for the lifetime of the building.

Thoughtful design of an imaging suite can result in a safer facility that creates a more pleasing environment for the patient, produces better images, and is less expensive to operate. Although there are specific benefits throughout all modalities, the focus for this discussion is on MRI.

Isn't "green" construction making buildings out of hay bales and old sneakers? How does "green" construction make a safer facility? How can "reduced carbon footprint" mean a more pleasing environment for the patients? How can any of this relate to better images and lower operational costs? Well, it all starts at the very beginning – which is a very good place to start. See Figure 1.

Building Structure

Any discussion of green building techniques should start with the "traditional" building of the building. The traditional materials and methods tend to utilize a fair amount of steel: structural steel columns and light gauge steel studs to frame the exterior walls; steel decking that supports the roofing is in turn held up by steel joists or steel beams. In addition to being a resource-intensive material, steel can interfere with good MR imaging, especially if it can move or vibrate. In many cases, the steel studs in the walls are increased in number, thickness, or both, in order to minimize any vibration that may be induced by proximity to such a large magnetic pull as from a MR bore. This, in turn, compounds the issue of having such a large amount of ferrous material within the fields of the magnet—again, potentially leading to decreased image quality.

By using building systems that have reduced amounts of steel—or, preferably, none at all—many issues are ameliorated. Instead of walls framed in steel with steel roof structures, the use of structural insulated panels (SIPs, which are "sandwich" panels of rigid foam insulation between sheets of plywood or oriented strand board) can decrease construction time, increase thermal insulation, and reduce the weight of the structure meaning less energy required to transport and install.[1] In one designed building scheduled to start construction very soon, the amount of structural steel was reduced by 16 tons for a 3800 square foot dual MRI suite. SIPs may qualify as using rapidly renewable materials, which makes them more sustainable. SIPs can also use low-emitting glues, which improve indoor air quality. Each of these features can help qualify for points if the facility is going for Leadership in Energy

Figure 1 • "Going green"—a tree made to look like an MRI scanner.

and Environmental Design (LEED) certification, the most popular sustainable building certification program.

In circumstances where wood may not be allowed as a building material, a great alternative is to use Insulting Concrete Forms (ICFs).[2] These are concrete walls made with cement poured into interlocking forms of expanded polystyrene (like foam coolers) that add thermal insulation as well as serving as permanent forms. There may be some ferrous steel in the walls in the form of reinforcing bars, but the amount is a significant reduction from a steel framed building.

Note that MRI shielding is its own unique element, and it is up to the individual manufacturers to create a more green product.

Beyond the Structure: Finish Materials

So now that an energy efficient building has been built with reduced amounts of steel, it's "green," right? It's well on the way, but this is only the beginning!

The finish materials used in the suite have an impact beyond simply being manufactured responsibly and using recycled products. Low Volatile Organic Compound (VOC) emitting paints and glues can be used to reduce irritating chemicals in the space. Using wall and floor finishes that can be maintained with minimal amounts of cleaners (ie, soap and water) further reduces the amount of chemicals required to be introduced into the environment as well as the equipment required to maintain the finishes.

Building a space that can be maintained with small, lightweight non-ferrous equipment such as a plastic squeeze mop makes a safer MRI environment. Ferrous metal equipment can be pulled into the magnet, even when the imaging machine is not performing a scan. The prime example of this is the unfortunately ubiquitous "floor-polisher-stuck-to-the-MRI." A heavy floor polisher can actually be picked up off the floor like a toy, and pulled into the bore of the MRI magnet, damaging the imaging machine and injuring anyone unlucky enough to be in its path.

Beyond the potential damage to the magnet (which quickly reaches six figures) it costs about $20,000 just to ramp down a magnet and get it ramped back up. There's also the lost imaging time (and revenues—a different type of "green" issue).

Lighting can play a major role in creating a space that is comfortable to be in —whether this is incorporating natural daylight into the space or using dimmable or colored light fixtures to create a pleasing environment. See Figures 2 and 3. Fluorescent lighting is efficient, but generates electrical noise that interferes with imaging. Since fluorescent lighting

Figure 2 • Bright, open areas may substantially increase patient comfort levels, as well as staff productivity.

Figure 3 • Large amounts of natural daylight in the imaging room can help reduce patient anxiety, as well as lighting costs.

is bad for MRI imaging, the predominant means of lighting in the scanner room has been incandescent bulbs, which also have the ability to be dimmed. Incandescent bulbs are not only inefficient (about 10% of energy use is made into light while the rest is heat) but have a relatively short life, which is made even shorter by the filament's exposure to the magnetic fields of the MRI room. The eventual "pop" when the filament breaks can also create distortions on any images being produced at the time. This short lifespan (as low as 700 hours) means that there is a more frequent need to have someone enter the room to replace the bulb. If a maintenance person walks into the MR room with a steel screwdriver or pair of pliers in his pocket, a serious accident could result, damaging the MR equipment, the individual, or someone else. The best way to avoid an accident in the magnet room is to not be in the magnet room. So with each bulb changing there is another potential for something to harm either the magnet or a person.

The use of light emitting diode (LED) lighting in MRI spaces has the advantage of using significantly less energy, creating far less heat, having no filament that can vibrate and create imaging artifacts, being dimmable, and coming in a multitude of colors. The life of an LED bulb is up to 50,000 hours, virtually eliminating the need to change the bulb for the effective lifespan of most MRI machines.

Heating, Ventilation, and Air Conditioning (HVAC) Systems

There are elements to built environments that are invisible and noticed only when people become too hot or cold. Heating, ventilation, and air conditioning (HVAC) systems are the silent, invisible 800-pound gorillas in the room.

For years, the standard in HVAC systems for hospital construction has been variable air volume (VAV) with a central air handler. VAV systems do save fan energy over the older constant volume systems that they replaced; however, they still waste significant fan energy. Conventional VAV is often coupled with direct expansion (DX) or water-cooled chillers. Ground source heat pump systems, sometimes referred to as "geothermal," can save significant cooling energy over these traditional cooling systems. In a more thermally efficient building, the equipment needed to heat and cool the space can be reduced in scope. Coupled with smaller unit equipment matched to the space, ground source heat pump systems can reduce fan energy and chilling energy by using the earth below. Rejecting heat into the soil, which remains at a constant 50 to 60 degrees fahrenheit in many areas, takes much less energy than rejecting energy into 90 degree air on a warm summer day. Ground source heat pumps can also provide heating energy as well as cooling energy, eliminating the need for a separate furnace, hot water boiler, or electric reheat.

So-called "one pipe" ground source heating systems utilize a loop between various small heat pump units distributed throughout the building and the ground source well. These allow simultaneous heating and cooling in different rooms or zones, utilizing the waste heat from cooling one space to heat another when loads vary from one side of the building to another.

Combined with additional wall insulation, high performance windows, solar shading and daylighting, energy cost savings of 15% to 20% (or more) are very reachable with such systems. Ground source heat pumps can be an important factor in creating an efficient, healthy building.

Just How Green Is It?

These are the basic building blocks of green design for MR suites, but the beauty of green design is in determining to what degree these approaches and philosophies may be utilized. Standard rating systems have been developed to measure and verify sustainability performance. One of the leading green performance standards is LEED.

LEED is a sustainable building certification program administered by the

United States Green Building Council (USGBC).[3] LEED is a system of credits that are awarded during the design and construction phases of a building project, that can be used to rate a building as to its sustainability or "green-ness." Most credits are optional, but there are certain minimum qualifications that must be met. A minimum score of 40 points out of a possible 110 are required to be LEED certified under LEED 2009 requirements, which are the current standard as of this writing.

What do building owners get if they qualify for LEED certification? Besides a shiny plaque, they are getting a building that is designed to work better, operates less expensively, has less impact on the local environment, and be more pleasant to work in. LEED places a focus on quality of the built environment, life cycle cost, and a productive indoor environment, as well as impact on the exterior environment. Instead of focusing on cost first as the only metric, an LEED certified building considers costs and benefits for the lifetime of the building. That has a bottom-line impact that building owners will like!

There are a number of LEED credits that would apply to a green MRI suite. Potentially any of the credits in the various categories that LEED 2009 allows could be used in building a green MRI suite. For this discussion, we are looking at LEED 2009 for Healthcare New Construction and Major Renovations. Some points in particular to look at are as follows.

Energy and Atmosphere Credit 1—Optimize Energy Performance

It would not be green without energy conservation, which is one of the most important measures in a sustainable building. Energy and Atmosphere Credit 1 requires a new building to be at least 12% more efficient than the minimums required in model energy codes. Additional points are given incrementally for higher rates of efficiency, and even more points are awarded if buildings are up to 48% better than the model energy codes. Creating a building 48% more efficient than the model codes is a lofty goal, but achievable. Attention to each facet of the energy using systems—heating, air conditioning, and lighting, is required to achieve this level of performance.

Indoor Environmental Quality—Low-Emitting Materials

As mentioned earlier, the selection of interior finishes for the suite needs to reflect both durability and ease of maintenance. In addition, materials can be selected to reduce or eliminate as much release of VOCs as possible—greatly increasing the air quality. This can be accomplished with selection of adhesives, sealants, flooring systems, and composite wood and agrifiber products.

Indoor Environmental Quality—Daylight and Views

Use of daylighting is another green idea that is important in MRI suites. Daylighting uses natural light instead of artificial lighting to save energy, but an important side benefit is a sense of well-being for the occupants of the space. Many studies have found increases in productivity, higher test scores in schools, or increased healing in patients exposed to daylighting.[4] Natural light in the scanning room may also help alleviate claustrophobic feelings that patients may have during the scanning process. Daylighting can have a significant impact on lighting energy costs, too.

Since MRIs need large access panels in exterior walls or ceilings to bring the equipment into the building, there is an opportunity for daylighting the clinical space. Translucent panels, instead of an opaque removable access panel, can be used to enhance the feel of the space, as well as increase lighting efficiency. Used in conjunction with daylighting controls, such panels can reduce the amount of energy used to light the space.

Daylighting in the control desk area also has benefits. Technologists are stationed in these areas daily, and using daylighting for this area can enhance their productivity. Large translucent panels, designed to eliminate glare and direct sunbeams falling in the workspace, can be used with reflective shelves or other light control devices to produce even light levels deep into the space. Higher levels of daylight (25–75 footcandles) in the control area, for example, can eliminate artificial light altogether.

An Example in Cost Savings

There are numerous variables involved in potential cost savings, so following is a look at one simple piece of the puzzle: lighting. In particular, using LED lighting versus incandescent bulbs.

How does an LED compare to a traditional light bulb? A high quality MRI rated LED fixture can achieve 42 lumens per watt efficiency, versus the 16 lumens per watt common in incandescent bulbs. That's like 42 miles per gallon versus 16 miles per gallon in comparing cars (like an SUV versus a hybrid). A typical MRI suite might use 16 individual 100 watt incandescent lamps. These 16 lamps would consume 1.6 kilowatts of electricity for each hour of use (or 1.6 KWHr). If the MRI were used for 260 days per year and 12 hours per day, and electricity costs 10 cents per KWHr, this cost adds up fast. For a typical MRI this would mean over $5000 in energy costs over the 10 year life of the MRI.

LED fixtures last longer than incandescent bulbs. A standard bulb only lasts 750 hours and can be significantly less in a magnetic environment. Over a 10 year lifespan, those 16 bulbs would require 665 bulb changes. The LED fixture has an expected life of 50,000 hours. If the MRI is used for 260 days a year, 12 hours a day, that is only 31,200 hours. The LED fixture may never be changed out in the 10 year life of the facility, eliminating bulb changes. At $4.69 labor per bulb change, that saves over $3000 in labor cost versus incandescents. In addition, with the new United States efficiency restrictions, incandescent bulbs are expected to grow both harder to obtain and more expensive.

How much energy will our "hybrid" LED lights save compared to the "SUV" 100 watt lamps? Using the same hours

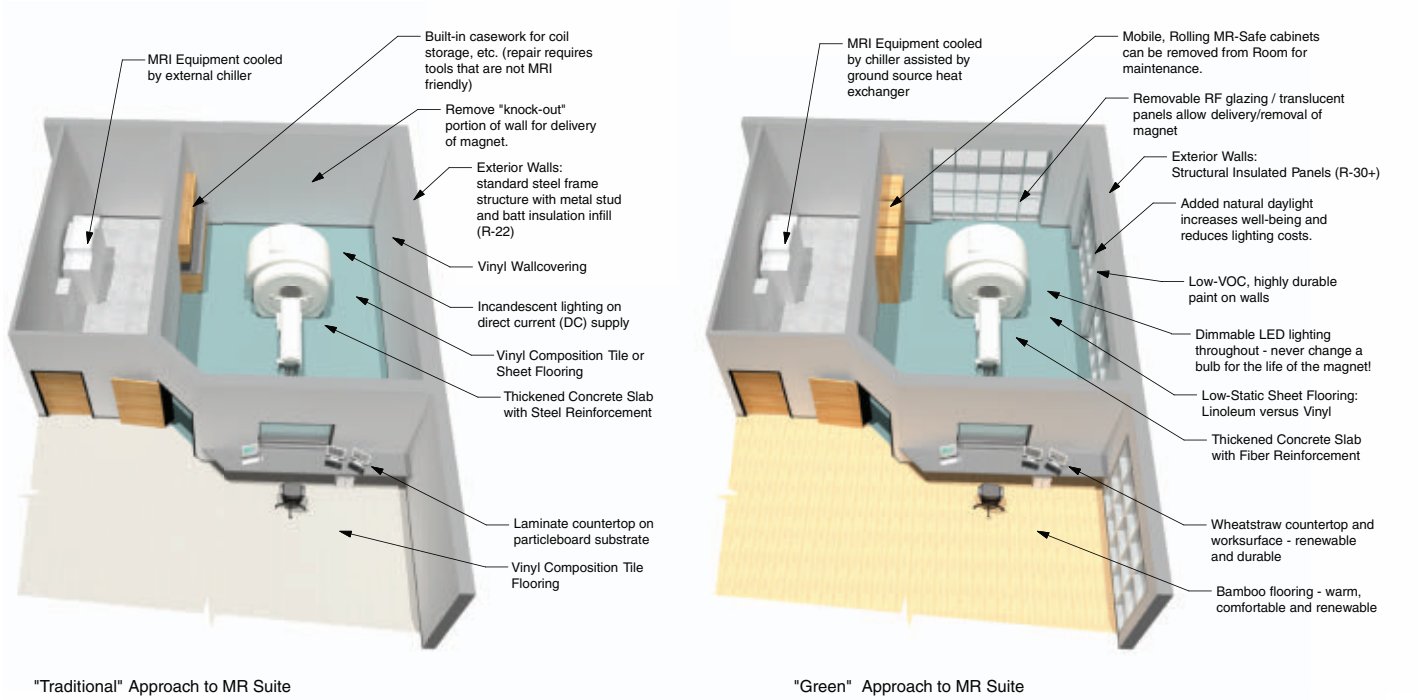

Figure 4 • Some key differences between a "traditional" design approach to an MR suite and a "green" approach.

as the previous examples, the savings for LEDs versus incandescents add up fast. Counting bulb changes, the incandescent lamps cost over $8000 in 10 years. But the energy-sipping LEDs cost only $1930 to operate, saving 76% of the cost for lighting the MRI space.

Want to save more? Add daylighting controls to the LED dimming system. Instead of running the LEDs full blast whenever the space is used, include translucent daylighting panels in the MRI suite design. Sensors determine the amount of daylight available and adjust the lighting in the space to achieve a constant level of light on bright sunny days, cloudy days, or at night. If these daylighting dimmers save half the energy, the LEDs would use a total of $965 worth of energy in 10 years, saving 88% over the incandescent.

Besides making employees feel better, daylighting can save energy. Generally, the lighting in the control room is standard fluorescents, which are efficient already, but the LED lights can easily be dimmed or turned off when daylight is available: significant energy savings is possible. In a typical control room, this could mean over $1000 in avoided energy and bulb change cost over a 10 year lifespan. Even more benefits of lowered energy use can be realized by potential tax deductions available for reduced power consumption in lighting systems.[5] Section 179D if the IRS Code allows deductions for energy efficient buildings, but since this is based off of total power consumption, the energy required to run the magnet typically throws the calculations out of the 50% savings range.

Conclusion

Figure 4 shows some key differences between a "traditional" design approach to an MR suite and a "green" approach. By incorporating even the basic elements of a green building structure that is magnet-friendly can create an environment that is safer and more pleasant for the patients and staff, produces better images, and costs less to operate. Durable interior finishes, lighting design, and proper heating and cooling of a facility are some of the foundational elements to pay attention to when considering a redesign or new construction project in an MRI setting.

References

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QUESTIONS

Instructions: Choose the answer that is most correct.

1. **Thoughtful design of an imaging suite can result in a safer facility that also:**
   a. Is less expensive to operate
   b. Produces better images
   c. Creates a more pleasing environment for the patient
   d. All of the above

2. **The use of Structural Insulated Panels (SIPs) can :**
   a. Decrease construction time
   b. Increase thermal insulation
   c. Reduce the weight of the structure
   d. All of the above

3. **In a designed building scheduled to start construction using SIPs, the amount of structural steel was reduced by:**
   a. 8 tons for a 2800 square foot dual MRI suite
   b. 16 tons for a 3800 square foot dual MRI suite
   c. 10 tons for a 1500 square foot single MRI suite
   d. 20 tons for a 4000 square foot dual MRI suite

4. **The most popular sustainable building certification program is:**
   a. Leadership in Energy and Environmental Design (LEED)
   b. Developing Energy and Efficient Buildings (DEEP)
   c. Construction of Sustainable Structures (CSS)
   d. Environmental Building of the Future (EBF)

5. **Using wall and floor finishes maintained with minimal amounts of cleaners:**
   a. Increases the amount of man hours required to maintain the surfaces
   b. Reduces the amount of chemicals and equipment required
   c. Reduces the amount of chemicals but increases the equipment required
   d. Increases the amount of chemicals and equipment required

6. **Ferrous metal equipment can be pulled into the magnet even when the imaging machine is not performing a scan.**
   a. True
   b. False