Viridiant Lecture Series

energy efficient retrofits: lessons learned and best practices

The most resource efficient form of construction is renovation. There are problems associated with changing the way an existing home operates and these problems can be disastrous. In this bulletin, we discuss strategies and systems that take the ‘what if’ out of renovation and provide helpful insights from Viridiant partners and clients about lessons learned and appropriate first steps in any energy retrofit.

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homeowner habits

Energy efficiency and conservation begins with how we live in our homes. Day-to-day resident operation can have a significant impact on both comfort and utility expenses. There are many habits that can be adjusted, often slightly, which can lead to significant savings in energy and dollars spent.

- Adjust refrigerator settings to 40° and water heater settings no higher than 120°
- Change your HVAC filters regularly (frequency varies, typically every 60 days)
- Use a programmable thermostat: 68° in the winter, 78° in the summer
- Change to efficient lighting and unplug your electronics when not in use

basic energy retrofits

In all homes, there are items that can be easily and affordably upgraded. These items are typically referred to as the 'low hanging fruit.' Attics, crawlspaces and basements are typically accessible and often contain mechanical equipment. Air sealing in these spaces tends to dramatically reduce the overall envelope leakage in the home. Other considerations include lighting upgrades and low-flow water fixtures.

- Air seal duct connections, plumbing penetrations, and electrical outlets
- Insulate hot water pipes and install a hot water heater blanket
- Install an attic access cover and chimney balloons
- Replace incandescent light bulbs with LEDs or compact florescent light bulbs (CFLs)
- Install sink aerators, efficient showerheads, and low-flow faucets

deep energy retrofits

Deep energy retrofits, retrofits that achieve approximately 50% reduction in energy usage, are more intrusive than the low hanging fruit options, but these improvements can be performed with minimal demolition to the existing structures. Existing wall systems can be addressed from the interior and/or exterior. Renewables can also be added to offset energy use. Renewable energy systems are more effective if the basic energy retrofit items have already been addressed. For instance, if the air sealing, insulation, lighting, and operation of the home have been addressed, reduced energy usage allows for installation of a smaller solar array to offset energy needs.

- Insulate attic kneewalls
- Bring HVAC equipment into conditioned space
- Insulate, pressurize, and condition your crawlspace/basement

energy efficient retrofits

In the U.S., buildings account for 41% of the energy we consume.[1] Replacing aging mechanical equipment and appliances with newer more efficient equipment can help save energy, water, and money. This bulletin identifies measures that can be taken to improve the performance of homes with regard to both occupant behavior and building operation. While this bulletin focuses primarily on single family homes, many of the overriding principals can be applied to multifamily and commercial buildings as well.

The first step toward improving a home's energy performance is addressing occupant behavior. Homeowner education in conjunction with a home energy assessment can help ensure any measures taken to improve the operation of the home are as effective as possible.

The second step toward a more efficient home is a detailed evaluation of the existing conditions. A home energy inspection begins with a visual evaluation of the exterior of the home, focusing on site drainage: the effectiveness of the existing grade, waterproofing, and ability of the home to shed water away from the building assembly. Blocked gutters and downspouts, inadequate site grade, and poor site drainage can have significant adverse consequences with regard to durability and indoor air quality. Drainage issues can even preclude some measures, such as enclosing crawlspaces, from being taken to improve the overall operation of the home. Once moisture and drainage has been addressed, steps can be taken to improve the operation of the building components and systems.

The ceiling or roof, walls, and floors of the home make up the building envelope. Typically, the building envelope includes:

- Air barriers:

  Exterior sheet material in newer housing such as Oriented Strand Board (OSB) or asphalt impregnated sheathing, slat 1"x6" sheathing or similar in older homes

  Drywall or plaster on the interior
- Weather resistant barriers:

  House wrap in modern housing, tar paper in many older homes
- Thermal barriers:

  Fiberglass, mineral wool (e.g. Rockwool), or cellulose insulation
- Structural elements such as wood or steel

In many existing buildings, one or more of these components may be missing, if materials and processes were unavailable, or damaged. HVAC systems or other mechanical components may have been added to the home or replaced during

previous renovations. Many of these issues can be identified through a visual inspection, but further analysis is often necessary through thermal imaging and diagnostic testing.

Thermal imaging, using an infrared camera, can help energy professionals detect thermal issues without intrusive demolition. Additionally, performing diagnostic testing such as duct and envelope leakage tests or pressure and flow testing identifies baseline conditions of a home, thereby providing a yardstick against which future improvements can be measured. This helps both the homeowner and contractor understand a home's normal operating condition and make educated retrofit decisions. After energy improvement opportunities have been selected and completed, diagnostic testing should be performed again to gauge the efficacy of the measures taken.

Once the home has been thoroughly evaluated, the combination of selected energy improvement opportunities will be determined based on homeowner goals, budget, and contractor input. These improvements will make up the retrofit work scope. The following items represent typical, highly effective, retrofit scope items.

Air infiltration occurs as outdoor air enters the home, often moving through crawlspaces, garages, and attics, which are typically nasty places. Having regular air exchange with such places can have negative impacts on indoor air quality and occupant health. Air leakage accounts for 25-40 percent of the energy used to heat and cool homes in the U.S.[2] Sealing air leakages reduces the load on the mechanical equipment which can help cut energy use, reduce utility bills, extend the lifespan of the equipment, and improve resident comfort.

There are several ways to increase the tightness of the envelope in a home. Because stack effect, or the want of warm buoyant air to rise up through the building, is constantly working on all buildings, it is often beneficial to start with the ceiling plane. The ceiling plane frequently separates unconditioned attic from the interior space and is typically riddled with penetrations for lighting, exhaust, and ductwork. Electrical and plumbing penetrations through the top plates of interior partition walls and the top plates themselves should all be sealed to ensure air from the conditioned environment is not escaping into the attic. Identifying and sealing as many air leakage pathways as possible makes added insulation more effective.

When mechanical equipment is located outside of the thermal envelope, the equipment must work to overcome ambient conditions, which could lead to a shorter equipment lifespan, higher energy bills, and indoor air quality issues. The same principal applies to mechanical equipment located in unconditioned basements and vented crawlspaces. Average duct systems in the U.S. leak close to 20 percent of the air they are supposed to be delivering to the space.[3] Any steps that can be taken to bring these systems inside the thermal envelope and reduce duct leakage can help improve comfort and curb energy costs.

Home foundations can be a concrete slab, crawlspace, basement, or some combination. When both a crawlspace and basement exist, it is important to identify the thermal envelope boundaries before moving forward. Most commonly, insulation is installed between the floor and foundation, or along the ceiling of the crawlspace/ basement. When the later condition exists, the insulation has a tendency to droop or fall as it is fighting gravity thus its effectiveness is compromised. In many instances, the footprint of the home has a dramatically larger area than the walls of the crawl or basement, and it

Insulating the roofline (as above, netted cellulose) brings mechanical equipment inside conditioned space


crawlspace before


crawlspace after
vapor barrier installed and foundation walls insulated

may be more economical to relocate the thermal barrier to the interior surface of the foundation walls. If not prone to flooding or extreme moisture, enclosing the crawlspace can mitigate moisture, enhance the home's durability, and increase resident comfort. A vapor barrier, such as a 6 Mil Polyethylene (Poly) on the floor, sealed to the walls and piers of the crawl with all seams sealed with tape or mastic, helps ensure that moisture from the ground does not enter the space. In addition to the insulation and vapor barrier, some pressurization applied to the crawlspace drives pollutants out. This can be done with mechanical equipment, if it exists in the crawlspace, or using a low wattage in-line continuously running fan. Enclosing a crawlspace brings the volume of the space into the envelope and can help prevent moisture and other pollutants from entering the space. The U.S. Department of Energy in conjunction with the National Renewable Energy Laboratory provides helpful guidance with regard to the amount of pressurization needed in the crawl, based on square footage and volume, as well as helpful architectural details.[4]

When pursuing air sealing in a building, there are certain health and safety precautions that must be taken into account. Atmospherically vented HVAC and water heating equipment can be prone to back-drafting depending on the pressures working on the home. When the envelope is significantly sealed, large exhaust fans such as range hoods will have a greater effect on home pressurization. It is important that a professional perform combustion appliance zone (CAZ) testing when these appliances exist and the building's operation is being altered. When certain tightness levels are achieved, mechanical ventilation may need to be added to the scope as well. The Building Performance Institute program uses 0.35 natural Air Changes per Hour (ACHnat) as the threshold. For any home as tight as or tighter than this level, mechanical fresh air ventilation is recommended.

There are viable ways to address the thermal performance of the exterior wall assemblies as well. Shy of removing drywall or exterior sheathing to insulate exterior walls, a process commonly referred to as 'drill and fill' can be done from either the interior or the exterior of the building. The contractor will use a hole-saw to access the uninsulated or poorly insulated wall cavity, and strategically remove small pieces of either drywall or exterior siding/ sheathing. They will then fill the cavity as uniformly as possible with an insulation product such as cellulose, blown fiberglass, and foam. It is advisable to use a product that allows some drying potential, but also cuts down on air flow. Large savings can be realized when pursuing this application.

Finally, the addition of renewable energy sources, such as wind, geothermal and solar can be added to offset a home's energy use. The price of solar has decreased significantly in recent years and the added benefit of a 30% Federal Tax Credit can help make the addition of solar more economical. By incorporating the strategies discussed previously in this document, the home's overall energy usage can be reduced, allowing renewables to have a greater impact.

[1] IEA, www.iea.org/publications/freepublications/publication/NAM_Building_Stock.pdf
[2] ENERGY STAR, www.energystar.gov/ia/home_improvement/home_sealing/AirSealingFS_2005.pdf
[3] ENERGY STAR, www.energystar.gov/index.cfm?c=home_improvement.hm_improvement_ducts
[4] NREL, www.nrel.gov/docs/fy13osti/54859.pdf

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For more information or guidance on your next renovation project, contact Viridiant at (804) 225-9843 or admin@viridiant.org.

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