9

Ergonomics in Design

Ethics and the Carbon Choice: Speeding the adoption of new energy methods.
By Susan Farist Butler 9.12.13

In 1992, twenty-one years ago, 1700 scientists led by Henry Kendall, Chair of the Union of Concerned Scientists Board, issued The World Scientists' Warning to Humanity, a statement of intense concern about the damage being wrought upon Earth by human behavior. In 2003, Nickerson (p.46) wrote, "Delays in dealing with [environmental] problems will ensure both amplification of the magnitude of effects and their extension in time; beyond some point of deterioration or depletion, full recovery may not be possible...As difficult as preventing or slowing some types of environmental changes may be, reversing them after they have occurred will be much more difficult and, in some instances, perhaps not possible at all." The urgency is only escalating. We must break out of immobilization.

Delay, seeking optimal return, in an economy that omits the costs of degradation from the economic calculus, is erroneous. We must speed the transition off carbon: innovate, implement, evaluate and revise. The efficacy must be evaluated in vivo, measuring the actual function. Demonstration of functioning methods allows for

both evaluation and teaching.

In what follows, I describe an in vivo experiment, the goal of which is to retrofit two urban, historic – 150-plus year old – buildings, so utility requirements are met in a form that is either carbon neutral or carbon negative. More specifically, when electricity is obtained from the grid, it is balanced or exceeded by surplus energy generated within the boundaries of the property. Other energy will be extracted by heat pumps, from ground water or from air.

Conservation efforts should be first; they are most economical, and result in smaller demands for energy, electricity, and water. If the demand is lower, the systems installed are smaller, costing less to buy and less to run. To conserve electricity, first and best, turn things off. When necessary, for lighting, use LED's, light emitting diode light bulbs. They use little electricity and give beautiful light. Motion detectors have been useful in common areas, and tenants are involved in deciding the application of motion detectors within their apartments. One tenant with epilepsy was able to create a balance of CFL's and LED's that did not provoke seizures. The overall response from tenants has been positive and enthusiastic.

Potable water contains a great deal of embodied energy

from the costs of pumping and of purification. Water conservation offers great opportunity for energy savings. The water systems in the five-unit building are separated per apartment so tenants pay their own water bills, to motivate conservation. Water efficiency measures were maximized as Massachusetts state law requires when billing is individual.

In the transition to geothermal, old hot water heaters were not immediately replaced. The purchase of new heat pump domestic hot water heaters was temporarily postponed. Each apartment's domestic hot water was simply piggy backed onto one 40 gallon gas fired hot water heater. As a result, approximately 14 people in 5 apartments now use one 40 gallon hot water heater. None of the occupants were informed of the change, so behavioral change was unlikely. In four years following implementation, there was one complaint that between 7:30 and 8AM, the hot water had not seemed as hot as usual. This unusual circumstance demonstrates the power of water efficiency.

To conserve heat in winter and cool in summer, air-sealing, weatherization, and insulation were implemented using energy audits and state funded energy saving efforts. Specifics have included blown in cellulose (up to R-70 in the attic), good storm windows, weather-stripping, and lots of caulking. Attic insulation,

reducing the stack effect, is the best first step to heating conservation. ASHRAE standards for air quality and temperature were followed for both conservation and renewable projects. Information from state, federal, and non-profit programs was central to decision making. Funding, rebates, and investment tax credits made the efforts affordable and influenced decision-making. These conservation efforts reduced the heating load in the large building (9755 sq ft) by 25% from a 20 ton system to a 15 ton system, reducing the costs of both installation and ongoing use.

Beyond conservation, implementation of renewable energy sources made it possible to fuel the energy needs of the building within the lot. Photovoltaics on one roof fuel the lights, appliances and pumps for the heating systems. The photovoltaic system is 5kW, and will be expanded to meet the demand of the geothermal system. The photovoltaic system is battery backed-up and grid tied, with a net time-of-use meter. Generated electricity is used in the building, stored in the batteries, or sold to the grid. Electricity is sold at peak (9AM to 6PM) prices when the sun is out. In turn, grid-sourced electricity is obtained during evening and night when appliances (dishwasher, clothes washer) are set to run at 2AM when there is a surplus. The battery covers multiple systems in the building. The building's heating systems and the sump pump are

on battery back-up. The kitchen circuit is on batteries, so the freezer never thaws. The office is on the batteries. These changes improve quality of life, a good reason to adopt this innovation, gaining economy, comfort, and security.

Finally, for heat, air-conditioning, and domestic hot water, we can use the photovoltaic electricity to run the geothermal system. Whenever geo heat or air-conditioning is functioning, the de-superheater heats the domestic hot water, simultaneously dehumidifying the building, an important added function in an old building that has been air-sealed. Air based heat pump domestic hot water heaters also dehumidify the building, preventing mold in a building that was not originally designed to be so thoroughly air-sealed. Geothermal systems are so efficient their coefficients of performance (COP) are now over 5, when powered by photovoltaic electricity. The best, efficient gas system has an overall COP of approximately 0.8 to 0.9. That huge difference in efficiency makes it possible to heat and air-condition a building using geothermal to move heat from groundwater to a living space, using available electricity from rooftop photovoltaics. Without combustion, there is no carbon monoxide risk, and nothing inside the building is consuming the oxygen, except the occupants. By using heat pumps powered by photovoltaics, energy is obtained without

combustion. No chemical bonds are broken; no nuclei disturbed. This elegant minimalism enables extraordinary efficiency.

Geothermal in the city, is it doable? Yes. One 800' open standing column well is now fueling two apartments, totaling 2500 square feet, half a block from City Hall in Cambridge Massachusetts. Geo compressors take heat from water pulled in a small pipe (1.5" diameter) from the bottom of the 800' well. The temperature is between 48 and 55 degrees Fahrenheit. Compressors remove 5 degrees from the water before it returns to the well. Over the 800' descent, the water exchanges heat directly with the entire length of the well where it will be used again to deliver heat to the compressor and the building. The depth of the well is directly proportional to the heating load of the building (Egg, et al., 2013). Water has enough heat capacity to heat the building even when the outside temperature is below 0 Fahrenheit the entire winter for six years now. Open loop wells have performed well for decades. Air based heat pumps cannot pull enough heat from air when the temperature is below 32 Fahrenheit because the heat capacity of air is lower. Open loop wells have shown optimal long term performance.

With the wells underground and all connections trenched 5

feet below grade, and the equipment inside the building, the garden is more pleasant. There are no ugly noises. There is no unsightly equipment needing to be screened. Quality of life has been improved by this technology, as residents have remarked anecdotally.

In a multi-unit building, two compressors share one well, without complication. For air conditioning, compressors run in the other direction, putting heat into the well, sending cool refrigerant to the blower system for distribution throughout the building. As a renewable resource the well will provide heating and cooling indefinitely. The investment in digging the well yields a future pre-paid fuel source. The compressor's cost is roughly equivalent to an efficient gas furnace. The electricity to power the compressor and blower is generated by photovoltaics. All the energy for heating, air-conditioning, and household electric use comes from within the lot.

Recent visitors reviewed this approach to retrofitting existing building stock for appropriate energy conservation and engineering. When Les Norford, Professor of Building Technology at MIT toured the building and reviewed the measures taken, he said, "Yep, this is it. I am inspired. I hope in the future to visit an entire neighborhood of houses like yours." Jerry

Gabreilse, Levrett Professor of Physics at Harvard reviewed the installations and remarked, "This is just not that radical a change." Retrofit to zero carbon, with simple, elegant solutions can become familiar. It is time to take responsibility and make the leap into new methods, and a new, pleasing aesthetic for our energy use. "100% Now" must be the new standard for all buildings, homes, business, industry, and government buildings.

Kendall, Henry, Union of Concerned Scientists (1992). The World Scientists' Warning to Humanity. http://www.ucsusa.org/about/1992-world-scientists.html

Nickerson, Raymond S. (2003). Psychology and Environmental Change. Mahwah, NJ: Lawrence Erlbaum Associates.

Egg, Jay, Cunniff, Greg, Orio, Carl (2013). Modern Geothermal HVAC Engineering and Control Applications. New York, New York: McGraw Hill.