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ch 6 True cost acounting for buildings.pdf

David A Bainbridge

Chapter 6. True Cost Accounting for Buildings *w/o tables or endnotes*

We spend more and more of our lives inside buildings. Their construction and operation have involved enormous impacts on our health, ecosystems, and the global climate. External costs from buildings arise from energy use (nitrogen pollution, CCGs, and acid rain from fossil fuel burning), toxic runoff, waste water, disruption of hydrologic flows, bird mortality, and much more. Poorly designed, built, and maintained buildings are a common cause of human suffering, illness, and death.

Building design and well-planned land use matter even more in countries where there is no power grid. Good design and careful choice of materials enable the simplest buildings to perform better. They can be warmer in winter, cooler in summer, safer in earthquakes, fires, or typhoons, and they pose less risk for mold and asthma.

Estimating true costs begins with design and construction, then operation and maintenance, and finally demolition or deconstruction. Site acquisition, clearing (logging), and ground-shaping with heavy equipment lead to habitat destruction, soil compaction, and erosion. Studies have demonstrated erosion loss may be near zero up to 100 tons per square mile in native cover, but with road building, utility trenches, cutting trees, grading and other activities soil loss can increase to 100,000 tons per square mile. This has catastrophic effects on streams, lakes, and waterways.

External costs of buildings can be shaped by custom, design standards (if any), rules, and regulations. These have neglected environmental and social costs, such as comfort, health and productivity, while focusing on energy savings. The Center for the Built Environment database reveals that throughout the 897 buildings surveyed, occupants reported air quality problems (25%), temperature control problems (39%), noise (34%), and poor lighting (14%). The building codes have made it much less likely buildings will collapse, but have clearly missed the mark on comfort.

Building Energy Use

In 2020, the combined end-use energy consumption by residential and commercial sector buildings was about one-third of the US total. Energy also costs energy, and if we add the losses that occur in the electrical production and distribution networks, the residential and commercial buildings may rise to 40 percent of total US energy consumption. Buildings are energy guzzlers that harm the environment and people especially because fossil fuel energy has been heavily subsidized. These direct subsidies enable the enormous costs that are transferred to the environment, the poor, and future generations to be ignored. Energy has been so cheap that there has been little incentive for innovation or change in how buildings are designed, built, and operated. Buildings have also grown because we have ignored true costs. Home sizes grew—from 1,000 square feet in 1950 to 1,500 in 1970, 2,349 in 2004, and 2,261 square feet in 2020. All the while, family sizes have been decreasing.

Buildings have not improved much because building science research has been underfunded. Many of the basic flows and impacts of buildings are still not well understood. Environmental costs have not been studied carefully either, and may well exceed health costs. Indeed, the external costs of buildings have been almost completely ignored. Solar pioneers and energy specialists have demonstrated that windows, thermal mass, and insulation can be used to meet most if not all heating, cooling, and ventilation needs. But architectural schools have rarely selected professors who understand and study these proven strategies. The notion of the architect as an artist first and foremost still holds sway in many programs. As a result, many students graduate with little exposure to cost-effective designs and material choices.

The Department of Energy reports the average annual energy use for a commercial building is about 22.5 kWh per square foot. This includes 8 kWh/sq. ft. for refrigeration and equipment, 7 for lighting, 3 for cooling, 2 for heating, 2 for ventilation, and 0.5 for hot water heating. The average energy use for a 150-square foot office would be about 3,375 kWh per year, costing $338 at 10¢ kwh. The external cost of climate change emissions at a gas-fired power plant to meet that need would be about $456 at 13.5¢ per kWh. The true energy cost would then be $338 plus $456, or $794. For electricity from a coal-fired power plant with an external cost of 40¢ per kWh, the true cost would be $1,320 for a total energy cost of $1,658.

Life cycle costs are important for buildings that may be in use for 50 to 100 years or more. In the US, most commercial and residential buildings are designed and built on speculation, and future occupants have little say in design, energy use, material choices, comfort, lighting, or health issues. In Europe, where buildings are more often owned by occupants, the incentives are different. Long-term costs and health impacts are more often considered. In Switzerland, mortgages of between 50 and 100 years are common, so the quality of materials and skill of labor are critical.

Construction of homes, offices, and industrial buildings is important. Retrofitting for energy efficiency is generally more expensive and less effective than getting it right in new construction. External impact cost recovery will often double the price, suggesting the level of hidden subsidy we all benefit from—which many will fight to retain. But change is coming.

Office buildings are similar to residential buildings, but typically are used more during the day. The higher occupational load along with computers, printers, and other equipment often makes cooling more important than heating. Institutional buildings vary widely, but usually require the same services as commercial and residential buildings. Some, like churches, have more unusual patterns of energy demand.

True Costs of Building Materials

The external costs of construction materials are also important. Cement production may account for 8 percent of global climate change gas emissions. Stefan Brincrezu and coworkers computed the resource intensity of the fifty-eight sectors of the German economy and concluded that buildings and dwellings consumed between 25 and 30 percent of the total nonrenewable material flow. The Dutch National Environmental Database (Nationale Milieudatabase) contains product environmental profiles in the Netherlands. It was created to develop a uniform calculation of the environmental performance of buildings and civil engineering works. Similar work should be done in other nations and states.

Homes and commercial buildings shed or leak toxic materials from roofing, paints, and other components. We need to look at the inflow and outflow of these materials. Copper and zinc ions in runoff from roofs and architectural elements cause ecosystem disruption even at very low levels. Asphalt and composite shingles use copper, arsenic, and other biocides to minimize growth of moss and algae—these leach into the runoff. A study in Washington State found cadmium in runoff from one-third of the sampled roofs, arsenic in 90 percent, lead in 99 percent—and copper and zinc in all water samples. Cleaners, detergent, solvents, hormones, antidepressants, antibiotics, viruses, bacteria, chemicals and other compounds enter the sewage from homes and offices.

Environmental costs throughout the life of a building and perhaps long after that if waste materials, hazardous materials, and pollutants remain. Most attention has been placed on energy, but this is rarely the primary cost. Health, lost productivity, and environmental costs may exceed energy costs by a factor of five, ten, or more. As with most true cost considerations, the impact depends very much on the skill and intent of the people along the value chain. Wood, for one, can be sourced from a well-trained sustainable logging operation or from a "scorched-earth" logger pushing their crew to go faster and faster with no concern for environmental damage or risk of injury.

The cost of building materials also includes the energy used in mining, processing, and transportation. All of these have global climate change emissions as well. Information may be found on CO2e costs, but much information is more available in energy units. Investing in better materials may cost more up front, but will save money over the lifetime. By one estimate, the energy used by a well designed and built conventional home wouldn't match the construction energy for eighteen years. The energy required to make a product is called its embodied energy. Lower energy-use materials like straw bales can cut building energy and impact. Using more wood sequesters carbon. Using recycled materials can offer dramatic savings, compare aluminum roofing in the following table.

EMBODIED ENERGY OF BUILDING MATERIALS —tables

Lower Price Materials at Higher True Cost

Historically, the developer's goal has usually been to seek the lowest first cost, ignoring life cycle problems and future costs. Most houses are designed and built by developers who leave after the homes are sold. In one neighborhood where I lived, the developer was known as a least-cost champion. He saved a couple of dollars with each water fitting to the main line. These were not durable, and within thirty years, almost every one was replaced—at a cost of more than $1,000 each, some as high as $4,000. He saved a few hundred dollars and cost homeowners and taxpayers $100,000.

The high costs of using lower-cost materials have been clear in many cases. Between 2004 and 2007, an estimated 100,000 homes in more than twenty states were built with toxic drywall imported from China. Emissions from the drywall corroded plumbing and electrical systems. Homeowners also blamed it for illness, headaches, and respiratory ailments. Many homeowners have paid $40,000 or more to have all of the drywall replaced, as well as damaged wiring, A/C, and other hardware. Others simply walked away from their homes. The estimated total cost for replacing the Chinese drywall in the United States was more than $25 billion. In part, this material was imported to meet the demand for sheetrock to repair buildings damaged by Hurricane Katrina. Some builders stepped forward and replaced the defective drywall, but thousands of homeowners were forced to wait until 2020 for a settlement. Ultimately, many victims got nothing, and others will recover pennies on the dollar for the damage to their homes and possibly to their health. The emotional strain of a decade lost will not be compensated.

In the 1960s, builders tried using aluminum wiring because it was cheaper and more available than copper wire. A national survey conducted by the Franklin Research Institute for the Consumer Product Safety Commission found that homes wired with aluminum before 1972 were fifty-five times more likely to have one or more wire connections at outlets reach “fire hazard conditions” than homes wired with copper. Replacing the wire can cost more than $10,000.

The quest for lower costs has also led to the use of different types of plastic pipe instead of copper. The low costs of these materials have earned them the moniker of “the pipe of the future” and led to their widespread use. Unfortunately, when water with high levels of chlorine flows through polypropylene pipe, the protective antioxidants are stripped off the inside surface. Once that protection is gone, the surface layer becomes degraded and brittle. Cracks form and pipes fail. The newest plastic pipe, PEX, is more stable but has an estimated lifetime of only 30-40 years—maybe half the life of copper. On the upside, PEX is considerably cheaper and more resistant to freeze damage. But millions of homes may need to be repiped by the year 2050.

Construction Worker External Costs

There are external costs for construction labor as well. These include energy for food, miles of commuting to the site for many days, weeks, or months, and travel for medical care. The US relies on undocumented workers for much of its construction labor. In Texas, more than a quarter of construction workers are undocumented. They operate dangerous equipment, often with no training, and work in extreme weather conditions, from heat to freezing snow or rain. Safety rules and regulations to prevent falls and injuries are often ignored. The undocumented can’t afford to complain. As a result, many construction workers are killed each year. In 2019, the recorded construction-related deaths in Texas reached 123, with more than 11,000 injuries and illnesses. Costs are often paid by the government, which is to say, the taxpayers. In California, 330,000 construction workers rely on government safety nets at a cost of more than $300 billion a year. These are significant external costs.

TRANSPORTATION COSTS Table

Operational Energy Use

The embodied energy is just the first energy cost. Operational costs are high as well. Energy for heating, cooling, cooking, hot water, lighting, and other uses can be found on your monthly bill for electricity, gas, solar, and/or propane. This can be done for home, apartment, condo, office, or workshop. Compare this with the EIA report for the average American home that uses 11,000 kWh a year. A super-insulated passive solar design may use less than 2,000 kWh. Maintenance energy use is relatively minor, but can have health and environment impacts.

End of life Energy Use

At the end of the life of a building's life, more energy costs are added. This involves heavy equipment, transporting wastes, and the energy used in the landfill operation. The embodied energy of lost materials for a light frame wood building may be 3,000 BTU/sq. ft. For a masonry/concrete building it may be five times as much.

In 2009, the Construction Materials Recycling Association estimated that about 350 million tons of construction and demolition material is generated in the US every year, considerably more than the total amount of municipal solid waste. When buildings must be removed to make way for new development, many types of buildings can be deconstructed instead, with much of the material saved, reused, or recycled rather than buried. When true costs are considered, it will be preferable to unbuild almost every kind of building instead of having them demolished and sent to landfills. Taking a house or building apart piece by piece creates jobs and saves reusable materials such as metals, windows, doors, and wood. Old wood is often much higher quality than that available today, but an old true 2"×4" may need to be processed to match today's lumber that is 1.5"×3.5".

When I helped deconstruct the dilapidated ranch buildings on my parents' place in Colorado, the discoveries included beautiful clear 18-inch-wide pine planks from the late 1800s. My parents recycled almost all of the wood, pipes, insulation, and other materials into their new home. My father organized all the wood by size and length and was able to minimize waste. My mother helped straighten the larger nails in the evenings.

There are a number of programs that can help. In 2014 Vancouver, British Columbia, enacted a deconstruction bylaw that required all pre-1910 and heritage-registered buildings to be deconstructed, as the Canadian law says, " . . . systematically dismantled, typically in the opposite order to which it was constructed." This was later extended to houses built before 1950, recycling 75 percent of materials by weight and 90 percent for homes built before 1950 and deemed character houses. The ReBuild Hub in Vancouver provides assistance in this area, and the organization used salvaged material to build their office.

The Hub has the resources to guide building owners through the assessment process and tax benefits. A study in metro Vancouver suggested the potential volume of salvageable wood a year with this new law would be worth approximately $340 million. Many other cities as well as Habitat for Humanity help to recycle and repurpose building materials.

When a building's life ends in a fire or flood, the external costs are very high. A burning building creates both toxic air and water pollution. The ash that remains often includes heavy metals including antimony, arsenic, cadmium, copper, selenium, lead, and zinc. Building materials found in older houses, including stucco, sheetrock and joint compound, cement pipe, exterior home siding and shingles, often contain asbestos that remains on site to be blown in the wind.

A burning building also creates polycyclic aromatic hydrocarbons (PAHs), chlorinated polycyclic aromatic hydrocarbons, and other harmful compounds. If heavy rains or winds come after the fire, these nasty materials can spread far and wide to contaminate fields, streams, and lakes. Benzene and other volatile organic compounds were found in the water distribution networks of areas hit by the Tubbs and Camp wildfires in 2017 and 2018.

Getting rid of this wildfire debris is very costly. In California's 2017 fires, the cleanup cost per parcel at the Valley Fire was $77,000 when done by the state, and a staggering $280,000 for the North Bay fires done under contracts from the Army Corps of Engineers. In 2017, two million tons of fire debris were removed from 4,500 parcels—more than 400 tons each.

Floods can create equally hazardous and difficult-to-manage debris. Flood waters pick up sewage, manure, gas, oil, cleaners, pesticides, chemicals, fertilizer, drugs, paints, and other pollutants as they enter, damage, and destroy buildings. Flooding also increases medical costs. Wounds, gastrointestinal diseases, and skin or soft tissue infections (primarily staph and strep) occur after floods. Anxiety and stress also take a costly toll. Flood-damaged and contaminated personal belongings, fixtures, appliances, furniture, and other material are piled up on the streets to be carted off and buried.

Hurricane Katrina destroyed or damaged more than 850,000 homes, more than 300,000 vehicles, and 2,400 ships and vessels. Fifty levees and floodwalls failed. The cleanup took more than a year and cost more than 2 billion taxpayer dollars. More than 23,000 homes were demolished and cleared in the New Orleans area. Hurricanes Harvey and Irma also left millions of tons of debris. Houston officials expected the cleanup costs would reach $200 million to dispose of 8 million cubic yards of storm debris. Hurricane Harvey also damaged about 1 million vehicles; many could not be repaired. In 2022 Hurricane Ian devastated parts of Florida with damage estimates as high as $50 billion.

In 2021, flash floods in Germany and Belgium left hundreds of thousands of tons of debris. The tsunami of trash was so large that the main priority was getting rid of the stuff before it posed a worse risk to human health. It couldn't be recycled and reused as called for by EU guidelines. In addition, between 40,000 and 50,000 vehicles were damaged.

Other Energy Costs

Other external costs of building energy use include the emission of climate change gases, ecosystem damage from dams built for hydroelectric generation, and disruption of ecosystems from constructing power lines, pipelines, generation plants, substations, and other facilities. As noted in Chapter 1, wildfires have become the critical external cost of energy in some areas. Because many of the external costs of energy production are known and power plant generation data is available, the true costs can be estimated.

The tragedy of this energy misuse is that much of it could be eliminated at little or no cost with better design, more skilled craftsmen, and more judicious choice of building materials. Buildings using low-impact design strategies (natural heating using window placement and thermal mass, cooling with microclimate resources, and ventilation by wind flow) have demonstrated energy use reductions of 90 percent with noticeably improved comfort. When true costs are counted, these design principles will be used in almost every new building and building renovation. Today, most "net-zero energy use" buildings follow the same old designs but add large arrays of PV panels. These are more costly and less sustainable.

Health Costs in Buildings

Energy use is often considered the most important external cost of buildings, but this is rarely the case. The value of human health impacts and loss in productivity can be five to ten times higher than the cost of energy. A worker earning $70,000 a year in a 150 square foot office with poor air quality and mold may experience a 7 percent cut in productivity. The external cost from the loss in productivity would be $4,900. Treatment for building-induced asthma could easily add another $3,000 a year for a true cost of $7,900—ten times the cost of energy.

In many cases, the health costs and productivity loss will be even higher. Outgassing from building materials, furniture, and other components also add external costs. Chemicals used for cleaning, painting, and pest control can add to health risks. We have known this for decades, we know how to avoid these problems, but it hasn't been done. The benefits have been demonstrated in field studies. In controlled environment tests, the cleanest air with lower CO2 and volatile organic compounds led to a performance increase of 101 percent. It also improved decision-making.

One office complex I worked in for several years had mold problems from poor roof design, least-cost construction, inadequate repairs, and minimal drainage maintenance. One of the seven workers in this complex was more afflicted and had serious breathing problems with repeated lost work days, medical care, and misery. This may have degraded her performance by 20 percent for the year. Three of the others, including myself, suffered to some extent. I would say it cut my productivity by 5-10 percent. Saving a few thousand dollars on construction and maintenance cost tens of thousands of dollars in healthcare and productivity loss.

True cost accounting for buildings can provide health benefits for everyone—whether you own or rent, whether you work at home, in a factory, or commute to an office. The commercial and residential building stock in America ranges from health-giving to deadly. Too often, people are hot in summer, cold in winter, and face real danger if and when the power goes off. More people die of heat stroke than from storms or tornadoes. People also die in the cold—both from freezing and, more commonly, from carbon monoxide generated by improvised heaters.

One and a half million people were without power in Louisiana, many for weeks, after Hurricane Ida roared ashore in 2021. Puerto Rico's energy system was shattered by hurricane Maria in 2017, when people went for days, weeks, and months without electricity. This can be catastrophic for people who rely on energy to provide water or medical support.

Power outages also stop sump pumps in basements, leading to flooding and water damage. Power failure from ice storms can lead to frozen pipes and water damage. Heat waves can create power demands in excess of capacity, leading to rolling blackouts, brownouts, and equipment failures. Every climate disaster reveals the vulnerability of current building designs.

Many people—especially the poor, but from all segments of society—suffer at work or at home from poor air quality. Sealed buildings, inadequate ventilation, flawed building materials that off-gas, and poor design leads to leaks and mold. In 1998, World Health Organization research suggested that 30 percent of all new and remodeled buildings in the world were afflicted with sick building syndrome (SBS). The symptoms are mainly allergy-like, including nasal, eye, and mucous membrane irritation, dry skin, respiratory distress, fatigue, lethargy, headaches, and fever. Chronic or cumulative exposure to the microbiota (molds and other organisms) that thrive in damp indoor air can make SBS potentially life-threatening and leads to irreversible dampness and mold hypersensitivity syndrome (DMHS). This results from dysregulation of the immune system, leading to hypersensitivities and reduced immunity that increases susceptibility to infections. This has happened in my family, and it is a terrible burden with a very high external cost!

The CDC estimates that from 2008-2013 the annual economic cost of asthma was $81.9 billion, much from buildings. US adults miss about 14 million workdays per year as a result of asthma, often from moldy buildings at home or at work. Students miss an estimated 14 million days of school from asthma, often caused by mold, mites, or other allergens in their home or school. The annual medical cost per person with asthma in the US is over $3,000. Of that, more than half is for prescriptions, with about equal amounts for office visits and hospitalizations, and some for outpatient visits and emergency room care. Asthma triggered by bad buildings can become a lifelong challenge, costing as much as $100,000 over a lifetime.

The annual cost of poor indoor air quality in the US has been estimated at as high as $168 billion—several times the cost of energy and more than the gross national product of most countries. In a survey of 215 office buildings with 34,000 responses, only a quarter of the office workers expressed satisfaction with the air quality, and a tenth for thermal comfort. Improving indoor air quality could bring substantial economic benefits.

The COVID-19 pandemic has highlighted the need for better ventilation. Some buildings can be cured, others need to be replaced. Older buildings that have been modernized and sealed can often be returned to more natural space conditioning, ventilation, and daylighting. Better design and material use can return large dividends in human comfort and health while improving productivity. The value of productivity gains alone is often 100 times greater than the energy savings.

Climate Change, Extreme Storms, and Extreme Temperatures

Global climate change will lead to more frequent and intense storms. The changes in hydrology from impervious surfaces around buildings will combine with storm surge and sea level rise to make it even worse. More and more buildings will suffer flood damage and increased mold. The longer a building is flooded, the worse the problem becomes. When Hurricane Harvey flooded 150,000 homes in Texas, cleanup took months in many cases.

Mold exposure can be hazardous during cleanup and often will persist for the life of the building. Repairing mold damage is difficult and expensive. Treatment may require stripping out all wall board and insulation, then cleaning, drying down the building, blasting with dry ice, spraying with anti-mold coating, and finally sealing with impermeable paint. Some buildings have materials that are hard to treat or areas that are impossible to reach.

The cost of a professional cleaning can be $10,000-30,000 for a house. After a major hurricane and flood event, cleaners may be booked for months or years, and the longer buildings sit untreated, the more expensive remediation becomes. If all the homes flooded in Harvey had been professionally cleaned, it would have cost three billion dollars. Mold remediation is rarely done well when homeowners try to do it themselves. Even professional treatment may prove inadequate, and homeowners or workers may suffer from asthma and allergy for decades.

Increasing carbon dioxide levels in the atmosphere have been found to cause subtle changes in many aspects of the environment. One of the many surprises was the large impact this increase has had in stimulating fungal spore production. Mold grown in current carbon dioxide levels produced 8.5 times as much allergenic protein as those grown in pre-industrial carbon dioxide levels. The extra carbon dioxide induces changes in the bacteria's respiration and growth processes. This provides a very important warning, and suggests that there will be more unexpected impacts of global climate change that cause severe and costly problems.

Record-high temperatures also harm residents, degrade building materials, and increase energy use intensity. Overheating in buildings without air conditioners in Europe has led to thousands of deaths. The European heat wave of 2003 was blamed for more than 70,000 deaths. Subsequent heat waves in 2006, 2010, 2015, 2018, 2019, 2020, 2021, and 2022 have killed thousands more. Some experts think global deaths from heat exposure now may reach one half million people a year. Several cities, including Phoenix Arizona, have established Heat Response & Mitigation Offices to address this risk.

Demand for air conditioning will increase the environmental cost of manufacturing and operation. New energy demand for cooling will further stress energy grids—with the potential for more frequent and longer-lasting power outages. Extreme high temperatures also increase the risk of wildfire and degrade building materials. When buildings burn, a wide range of toxic materials are released. Climate change gases are also emitted.

Along with extreme highs, we can expect more extreme lows as a result of meridional flow from the more erratic jet stream. Extreme cold events threaten people. They also damage buildings as frozen pipes rupture and lead to water damage to building materials with the potential for mold. Widespread low temperatures can also over-tax fragile energy grids, leading to cold-related deaths and suffering.

Disruption of the Hydrologic Cycle

Streets, parking lots, sidewalks, and roofs dramatically increase the percentage of the soil surface that can no longer absorb water. In industrial areas, these impervious surfaces can cover 75 percent of the area and malls can cover 95 percent. Residential areas may still have 65 percent impermeable surfaces. Instead of filtering into the ground, a high proportion of rain water runs off quickly into streets and streams, causing much more frequent and higher peak flows than exist in the natural watershed. Scientists found that not only are floods more likely to be severe in the future, but that they've become more intense. Mean flood heights have increased by nearly four feet over the past 1,200 years. Flooding from the more intense floods of a new, more intense "100-year rainfall event" today can be catastrophic and will reach far beyond the historic 100-year flood plain maps calculated and drawn before urbanization and climate change.

Climate change has increased flooding in many areas. The area of West Houston called Memorial City was outside of Houston's calculated 500-year floodplain, but has flooded three times in the past decade. With climate change, we may see flooding at levels never seen before. For example, heavy flooding occurred on June 26, 2022 after more than 12 inches of rain fell in 8 hours from Hawk Point to St. Peters, Missouri.

High stream flows destabilize stream beds, mobilizing sediment, which in turn can destabilize lower stream reaches and cause additional problems. Bridges and roads can be damaged or washed out, power may be knocked out, sewers can break, and transportation can be interrupted by damage to railroads and highways. Sediment and debris can block drains and pumps, causing even more extensive flood damage. Sediment can also fill ponds and reservoirs, reducing storage capacity. Water quality is degraded as stormwater collects pollutants from streets, homes, farms, and industry, even before it gets mixed with overflow from treatment plants in high rainfall events. People are sickened by exposure to this toxic stormwater. Recreational use of streams and beaches may be curtailed for months, at high economic cost to the tourism industry. Fishing may be banned as well until water quality improves.

The solution is to minimize or eliminate runoff by incorporating stormwater management in the design of every home, facility, city, region, and transportation infrastructure. Porous pavement, infiltration wells, and surge storage ponds all can help. Homes, schools, and commercial buildings should include cisterns to capture rainwater. These tanks can also provide needed drinking water in emergencies after storms or earthquakes damage water supply systems.

Stormwater management techniques are proven and inexpensive. Some areas now mandate a net-zero increase in runoff. Developers can actually save money by doing the right thing. The innovative 220-unit solar subdivision known as Village Homes in Davis, California, minimized impervious surfaces and used above ground water collection and retention basins instead of storm sewers. My own research enabled the development to use streets as narrow as 20 feet. These features all saved money. The city engineers fought these features, but the development has performed very well. Village Homes did not flood after a major storm just after the features were installed—while much of the city did. After this success, other developers found it easier to adopt stormwater management design. One developer in San Diego told me that he saved $1 million by moving from a storm drain and pipe solution to aboveground drains, swales, and infiltration basins in one of his developments.

In Texas, rainwater has been captured in large cisterns at schools where water resources are limited. The Roy Lee Walker school in Texas, built in 2000, has 68,000 gallons of storage. The Wimberley Blue Hole primary school in Texas approached design and construction of the primary campus using a "One Water" concept, which looks at drinking water, wastewater, stormwater, and greywater as a single resource. The campus collects and stores up to 200,000 gallons of rainwater. In addition 600 to 1,300 gallons of air conditioning condensate is collected per day. This water is used for toilet flushing and landscape irrigation through an advanced reuse system. The system reduces the campus water consumption footprint by 90 percent. The University of California in Davis installed rainwater harvesting in their new viticulture building complex, where the 36,000 square foot roof will collect and store 250,000 gallons of water for use in the teaching and research winery. General Electric Power and Water donated the reverse-osmosis system and key instrumentation.

True cost accounting will reduce stormwater runoff and pollution. Charging impact fees based on runoff water quantity and quality can limit flooding while funding stormwater retrofits and more resilient natural stream and river channels. Stormwater impact fees can also support educational programs to help landowners understand how to minimize stormwater runoff and reduce their fees. (More on stormwater and external cost recovery at www.truecostalways.com).

Environmental Impact from Building Runoff

Runoff from building roofs is often laced with copper, zinc, lead, arsenic, and cadmium. The concentrations in water are not high enough to pose much of a risk for people, but can be very damaging to aquatic ecosystems. Very low concentrations can be biomagnified hundreds of times to levels that sicken or kill organisms higher on the food chain. For example, if the concentration of a pollutant is 2 ppm in lake water, then it might be 5 ppm in phytoplankton, 200 ppm in fish, and 1600 ppm in a fish-eating loon or merganser. Biomagnification is often suggested to be about ten to twenty times for each step up the food chain, but has been found as high as 2,000 for one step.

Copper is considered a pollutant of concern by the Environmental Protection Agency because of its widespread occurrence and impact on the environment. Copper roofing, gutters, and downspouts are good examples of seemingly sustainable products with a very long service life, but they have a hidden cost in the shedding of copper ions. Roofing may release 1.3 pounds per thousand square feet. Concentrations of copper in runoff from buildings has been measured at 3 parts per million. Levels as low as 1.5-10 parts per billion, 1,000 times less, can be detrimental or lethal to aquatic organisms. Trout are particularly sensitive. Biofilters on downspouts using peat or crushed crab shells can capture most of the copper ions, but these are rarely used. They could be very helpful if installed when new roofing or copper flashing and gutters are installed.

Zinc ions from galvanized roofing are another common pollutant from buildings. Zinc is used in many other applications to reduce corrosion of pipes, railings, fixtures, and other elements. It is effective but does have external costs. Roof runoff may approach 1 pound of zinc per 1,000 square feet of galvanized roofing per year. Zinc runoff is very toxic in aquatic ecosystems. *Daphnia magna*, a common bioassay test organism, started dying within 24 hours with 0.5 ppm zinc in soft water, reaching 100 percent mortality in 72 hours. Coatings such as urethanes, epoxies, and acrylics can be used to seal roofs and limit release of harmful material. They should be carefully selected as they may have problems of their own.

Other roofing materials may also leach arsenic, copper and other harmful compounds. These are applied to reduce growth of moss, mold and other unsightly stains or damaging growths. Wood shakes treated with copper arsenate released arsenic (692 to 4,690 ppb) and copper (601 to 3,190 ppb). Tests showed one type of asphalt shingles also leached copper 30 ppb, zinc 6.4 ppb, arsenic 0.21 ppb, cadmium 0.005 ppb, and lead 0.05 ppb.

Other types of infrastructure, like parking lots, roads, and utilities, also add to pollution loads and ecosystem disruption. Pavement is usually identified as the most significant source of metals above natural background levels. In addition to metals from car brake pads (copper, zinc, nickel, lead, and more), runoff may include antifreeze, lead from the weights used to balance tires (in older cars), oils, and other compounds. Tires also contain zinc, which is released onto highway surfaces as the tire wears down.

Copper, zinc, and other pollutants enter streams and lakes where they kill or disrupt a wide range of organisms. Every step up the food chain can increase concentrations by ten times or more, easily reaching a thousand times the base level in high-order predators. Even low levels can be harmful. Pacific salmon are particularly susceptible to copper-induced olfactory injuries that inhibit behaviors critical to their survival. In general, insects are more tolerant than fish and shellfish to copper, zinc and other pollutants.

Water Use in Buildings

Buildings use water inside and out. Single-family homes may use more water for landscaping, while multiunit dwellings, commercial and industrial buildings, use more water inside. Public supply withdrawals account for about 14 percent of the total freshwater used in the US. Almost 300 million people on public water supplies use 39 billion gallons per day. External costs are involved in water extraction, transport, supply, treatment, and disposal.

Buildings also cause very significant environmental damage related to water. The building site is stripped and converted to hardscapes of roofs, concrete sidewalks, asphalt roads and parking lots with no water infiltration. This leads to fast runoff with quick and much higher flood peaks.

Water diversion leads to the deterioration of ecosystem services. Streams and rivers may run dry. The price we pay for water ignores most external costs, but when true costs are determined, water use in buildings can often be reduced with relatively simple changes in equipment and habits. Rainwater capture can reduce imported water use. Some cities have approved rainwater for non-potable uses like flushing toilets—some even encourage the widespread use of rainwater. Pliny Fisk and the Center for Maximum Potential Building Systems started Austin and Texas on the path to capturing and using more rainwater back in 1996. Since then, Texas has supported rainwater harvesting, and the Texas Commission on Environmental Quality doesn't regulate the use of rainwater for indoor uses in private homes if it is their sole source of water supply (i.e., homes that are not connected to a public water system). Filtration, disinfection, and testing are required for homes on public water systems as well as for schools and commercial buildings.

Nutrient Pollution

Building design and land use planning affects energy and fossil fuel use, which in turn determines nitrogen pollution. Development design choices can minimize transportation impacts and encourage bicycling, e-bikes, walking, and public transit. Nitrogen deposition can be reduced by making better choices for building design, land use planning, and choices of electric rather than gas-powered garden tools. Nitrous oxides from burning fossil fuels that generate electricity and provide space heating and hot water in buildings contribute to the problem. So do cars, gas-powered tools, trucks, and power plants. The nitrogen falls back to earth as dry particulates and in rain. Deposition rates in auto-dominated areas like Southern California are considerably higher than the world average application of nitrogen fertilizer to farmland. Decreasing the emissions from cars, trucks, and other vehicles is critical.

Phosphorus pollution can cause similar problems. In aquatic systems, it can compound the effects of nitrogen pollution and create super blooms of algae. Phosphorus is a common constituent of home and agricultural fertilizers, manure, and organic wastes. About half of the total input of phosphorus coming in to the city of Gothenburg, Sweden, was in food and beverages. Detergents made up 6 percent of the total phosphorus input and pet food 4 percent, while goods for agriculture made up only 2 percent. Wastewater and solid waste represent the main flows and sinks for phosphorus. Sewage sludge and incineration residues each contained 40 percent of the total output of phosphorus. Ten tons of pet feces-related phosphorus was estimated to have been dropped in the environment. Only 4 percent of the phosphorus input was recycled to agriculture as manure and 0.3 percent as certified sludge. These phosphorus flows are very out of balance, and levels in soil and water will continue to increase.

Bird Kills from Windows and Reflective Walls

We often see information about birds killed by windmills, but we should remember that buildings are more deadly. Glass can be invisible to birds in many situations, and conservative estimates suggest that 100 million birds die as a result of hitting glass in the US every year. Nearly half of all window strikes are thought to occur at residential houses (44%), and over half at low-rise buildings (56%). Fewer than 1 percent occur at high-rise buildings.

The bird kill risk of buildings can be reduced by simple steps. Move plants away from windows because interior landscaping by windows can increase the risk. A leafy plant inside a building can be seen as a refuge, and a panicked bird will smack into a window as it attempts to hide. Designs with glass on both sides of a room or building can create the illusion of an unobstructed corridor. Tilting glass out at the top to give a ground reflection helps (and keeps glass cleaner), as do shades and shutters (best when installed to the exterior) and markers on the glass. Bird strike prevention tape is readily available, and has worked very well on my own patio doors.

Additional sources of bird kill are affected by design and planning decisions. Longer commutes or many long-haul truck loads lead to vehicle collision bird kills. These are estimated to be as high as 100 million per year. Birds also die in collisions with towers, guy wires, and transmission lines. Mine and industrial operations can also kill birds. Solar concentrating mirrors at “power tower” electricity generating plants create extremely high temperatures in the area around the collector that vaporize birds. They appear as little puffs of steam.

Light Pollution

Buildings and development also create more complex ecological problems. Many organisms rely on light polarization to determine locations for migration, nesting, breeding, or feeding. Pavement, dark cars, glass, and other shiny building materials can polarize light and confuse this behavior. Birds that cannot take flight unless they are on water have been known to land on asphalt at night because it can have a polarized light signal similar to water. Insects that lay eggs near ponds may lay eggs near parking lots for the same reason.

Light has such a strong biological impact that artificial lights at night can adversely affect foraging, sleep, migration, immune response, cortisol, testosterone, and melatonin levels. It can affect glucose metabolism in birds, animals, and other organisms. The impact of light differs by species. Lights rich in short-wavelength blue and green light (metal halide, mercury vapor, fluorescent, and LED) tend to be more disruptive than those emitting long-wave length pure yellow-orange light (high or low-pressure sodium).

Lights contribute to the death of millions of birds a year. Many migratory bird species fly at night and they are confused by or attracted to artificial lights. Light pollution levels during the past two decades have gone up over roughly 16 percent of the land area in the Western Hemisphere. Ten million birds a year may be killed by communication towers, both from attraction to the lights and hitting unseen guy-wires. More than 174 million birds may be killed by transmission lines, with additional deaths from power plant stacks and towers. After it was discovered that the 9/11 memorial lights were disrupting navigation of more than a million birds a year, a monitoring program was set up. Volunteers watch the lights, and when the number of birds crossing through them reaches 1,000, the lights are turned off for 20 minutes to give the birds time in the darkness to resume their natural migrations.

Lights may also encourage migration in the wrong direction for other species. They can lead baby turtles to walk away from beaches, stop fish migration, and cause many other problems for a remarkably wide range of organisms. Artificial lights are often bright enough to induce a physiological response in plants, affecting their phenology, growth form, and resource allocation. The physiology, behavior, and ecology of herbivores and pollinators are also impacted. Understanding the ecological consequences of artificial light at night is critical to determine the full impact of buildings and development on ecosystems.

Buildings, lights and other hazards have contributed to the alarming decline of once common birds. The Audubon Society's Christmas Bird Count and Breeding Bird surveys have revealed the crises facing many of our most common and beloved birds. Since 1967, the average population of the common birds in steepest decline has fallen by 68 percent; some individual species have dropped 80 percent.

True cost accounting will include the value of birds, other species, and ecosystem stability in design. This will shift building and development design and lighting choices to reduce the risk. The choice of lighting type, fixture design, light placement, shielding, and time of operation all matter. The International Dark Sky program has helped many communities reduce lighting impacts and preserve the dark night sky so residents can see stars and planets. This helps migration and reduces other risks. Towns, cities, municipalities, and other legally organized communities that have shown exceptional dedication to the preservation of the dark night sky are recognized for their efforts.

Noise Pollution

The 2000 United States Census found that 30 percent of Americans complained of noise, and 11 percent found it to be bothersome. Urban areas are particularly noisy, which affects human health along with that of many other species. Gas-powered lawn tools can hit 100 dB while electric models may top out at 75 dB. Several cities have banned gas-powered garden equipment to cut noise.

Humans can barely perceive a one-decibel difference, but one study found that for every 1 dB increase in noise, owls in the area were 8 percent less successful at catching prey. Noise can also impact feeding and navigation of many species. Buildings don't emit too much sound, but transportation to and from buildings can.

Disease Vectors

Pets contribute to the external costs of buildings and communities. Although a favored companion with significant health benefits for owners, cats are among the world's most destructive predators. One study suggested free-ranging domestic cats kill a median estimate of two billion birds and 14 billion mammals annually. Un-owned cats, as opposed to owned pets, cause the majority of this mortality. Dog and cat feces add nutrients, but also bacteria, parasites, and viruses to the environment. Although seemingly insignificant, the half a million tons of cat feces produced a year introduce parasites such as the single-celled *Toxoplasma gondii* organism in people and if outside, into stormwater. This parasite has wreaked havoc on California's endangered southern sea otter population. Post mortem studies found almost 10 percent of more than 100 sea otters examined died primarily due to *T. gondii*, and in another 20 percent, the parasite was a "contributing" cause of death.

This single-celled parasite enters the brain and changes the behavior of prey animals like rats, which develop a strange attraction to cat urine. From 10 to 20 percent of Americans also harbor the parasite, which can be absorbed through contact with litter boxes, drinking contaminated water or eating undercooked meat. Scientists now believe that Toxoplasma may actively change the connections between neurons—shifting dopamine levels, altering personalities and even triggering diseases.

The external cost of a dead bird is not easy to compute, but a simple bird from a pet store may cost $25. For buildings and other structures the cost at $25 each for 300 million birds would still reach $7.5 billion. Cats are in another league altogether, with certainly more than a billion birds killed or a nominal cost of $25 billion. But the cost of the native bird species lost is really much higher, perhaps $100 or even $1,000 or more for replacement cost. The cost of efforts to save the California condor, a species that has been done in by poison, lead bullets in carrion, antifreeze, hunters, and habitat loss, has passed $35 million. There are now 337 flying free and 175 in captivity at a cost of about $68,000 each.

Transportation Costs of Design Choices

When commercial buildings are put outside of towns and developed areas where construction costs are lower and regulations are weaker, the buildings increase commute time and distance, add stress on drivers and families, and increase energy use and CCG emissions for transportation. All of these have external costs.

Very few architects and designers have the opportunity to participate in location decisions. The designer of the NMB Bank in Amsterdam did, and he used worker home locations to determine the best placement for their new building. Even a minor difference can have an enormous impact. Imagine an office with fifty workers and a 260-day work year. The developer places the building outside the city limits to minimize cost and regulations. If the average worker has to drive an extra seven miles each way, this design choice leads to 182,000 miles driven by the workers in the office every year. Because there are detailed studies of auto external costs, we can estimate these external costs. If the workers all drive Dodge Ram pickups, which have an external cost of 40¢ per mile, it will total $72,800. If they all drive Lexus RS350s at 20¢ per mile, it would still be $36,400—enough to make a difference. Over the thirty-year life of the building, it could make more than a million-dollar difference and increase CO2e by 250 tons.

Toxic and Hazardous Compounds

True cost accounting for buildings also includes releases in sewage and the use of pesticides in and around the building. The drugs found in sewage include hormones and hormone mimics, antibiotics, antidepressants, and other legal drugs as well as cocaine and other illegal drugs. These have caused a range of problems in aquatic ecosystems, including changes in fish development. Fish may be affected by estrogen from birth control pills at 0.1 nanogram/liter, well below the concentrations found in some streams and lakes. Researchers found that 50 to 75 percent of male small mouth bass collected in the South Branch Potomac River exhibited signs of feminization, as did 100 percent of those collected at sites in the Shenandoah. Other types of hormones and hormone mimics are also released from livestock farms, CAFOs, and natural sources.

Pesticide use around and in buildings is excessive and can be reduced by better building design and use of materials, wiser landscaping, better maintenance, and true cost accounting. More than four billion pesticide applications are made every year to American homes, gardens, and yards. According to surveys by the US Environmental Protection Agency, more than three quarters of American households use pesticides, with 66 percent treating major living areas in the home one or more times per year. Sales exceed $2 billion a year. Health costs from pesticide use in the US (including agricultural use) have been estimated as high as $1.5 billion. The share of that cost for pesticides used in homes, buildings, and gardens would be $225+ million based on use. Frequent use of any household pesticide has been found to increase the odds of getting Parkinson's disease by 47 percent.

Insecticides are the most commonly used pesticides in and around homes and buildings and carry some of the largest health risks for humans. Residential pesticide exposure significantly increased risks for all types of leukemia, and specifically for exposure during pregnancy, indoor exposure, prenatal exposure to insecticides and whatever the age at diagnosis. The impact falls hardest on the poor, Black, and LatinX people. The six million children living in poverty in America's inner cities are at high risk of exposure to pesticides used extensively in urban schools, homes, and daycare centers to combat roaches, rats, and other vermin. The rate of use of fumigants is markedly different depending on location. Neighborhoods that have been under-invested and have older, poorly maintained buildings may have less trash pickup as well. These factors can lead to more common pest problems and increase the use of fumigants. This was reflected with blood levels of fumigants six times higher in Black and four times higher in Mexican-Americans.

True cost accounting will reduce the use of pesticides in the home. In Europe, the costs are higher, and more hazardous chemicals are banned outright. Currently, eighty-five pesticides approved for agricultural applications in the US are banned in the EU, or in the process of complete phase-out. Pesticides banned in the EU account for more than a quarter of all agricultural pesticide use in the USA. There wasn't a breakout for residential or interior use. The EPA notes that insecticides and disinfectants are most commonly used indoors and suggest that 80 percent of most people's exposure to pesticides occurs indoors. Measurable levels of up to a dozen pesticides have been found in the air inside some homes.

True Cost, Better Health, Better Buildings

The goal of True Cost Accounting for buildings is to improve comfort and health of the built environment while maximizing use of renewable resources and minimizing life cycle costs. The life cycle savings are particularly important for retirees and for institutions that cannot count on increasing income in the future to offset large increases in the costs of energy, water, and other resources. True cost accounting should consider costs over the 30, 50, or 100+ year service life of a building from creation to deconstruction (not demolition).

Comfort and health, security and safety in power outages, energy and water use, waste, recyclability, and cost are key issues. Environmental and social considerations are critical in building siting, design, and operation, but are usually ignored.

True cost accounting will lead to dramatic changes in design and behavior. Increasing consideration of true costs will improve building design, operation, and maintenance, and will help us all stay healthier. With creative design and true cost accounting, we know that some of these external costs can be not only reduced but eliminated. Building sustainable buildings has never been easier. Improved sensors and control systems can markedly increase performance. These new sensors will also enable readily visible meters to monitor and manage energy and water use. More complete information is now available about materials, appliances, and equipment, enabling wiser decisions.

Integrated design solutions for both large and small buildings and homes have demonstrated that energy demand can often be cut 50-90 percent for a cost increase in construction of only zero to 15 percent. Life cycle savings are outstanding, and the design choices we make today will affect climate change gas emissions for tens or hundreds of years. The cost of avoiding energy demand is often much less than the cost of energy generation. Solar-oriented design using thermal mass and careful window placement can reduce energy demand for heating and cooling by 50-90 percent. In a study of a more sustainable home design (validated by actually building the home) in Davis, California, the summer peak energy demand dropped from 3.6 kWh to 2 kWh, and annual energy use for heating and cooling dropped 67 percent. The improvements didn't cost anything—in fact, they reduced construction costs.

A synagogue in San Luis Obispo, California, using solar-oriented design, daylighting, and microclimate-based cooling and ventilation cut energy use for space conditioning more than 80 percent. The 538,000 square foot NMB Bank in Amsterdam cost little more than conventional construction, but used only one-tenth as much energy. NMB's former headquarters consumed 422,801 BTUs per square foot (4.8 GJs per square meter) per year, but the new one consumed less than one-tenth as much: 35,246 BTUs per square foot (0.4 GJs per square meter). It was beloved by workers, and absenteeism dropped 15 percent. Unfortunately, it was redone to accommodate more workers, and some of its features were diminished. In another case, a sustainably designed factory complex doubled worker productivity! A very modest retrofit of a typical office building in San Diego reduced seasonal energy use 70 percent and improved comfort.

Better development design can minimize runoff and cut runoff pollution to near zero. Floodproofing and moving out of flood zones can minimize flood damage. Good design, material choices, and maintenance can minimize the risk of mold and sick building syndrome—increasing health and productivity. Sustainable design increases security and safety during power outages. A well-designed building will keep its occupants warm in winter and cool in summer even when the power goes off. A sustainably designed building will also be able to provide emergency water supplies from its rainwater harvesting system during a water main break or power outage. An integral solar hot water heater will provide hot water for showers and cleaning even when the electrical grid is disrupted.

Developers, designers, and cities should develop accounting systems for the inflow and outflow of nitrogen, phosphorus and other elements and compounds. To be sustainable in the long term requires balance, yet as the study in Sweden revealed, even coping with a nontoxic element like phosphorus can be difficult. Developing nutrient balance will require local recycling, growing more food locally, using co-composted waste in town, and returning nutrients to farms to balance the phosphorus nutrient cycle. Local food production also reduces the energy cost and nitrogen pollution associated with fossil-fueled long-distance food transport.

Building materials can be environmentally friendly. Wood buildings sequester carbon for decades or hundreds of years. A wood home may use 25 tons of wood and sequester 12 tons of carbon. The renewed interest in large wood buildings is encouraging. The T3 wood high rise in Minnesota used 2.2 million board feet of wood and sequesters 700 tons of CO2e. The managed forest that provided the wood also sequesters carbon. The shake table at the University of California, San Diego is conducting a test of a ten story mass wood building. This is likely to confirm the benefit of mass wood buildings in seismic risk areas.

A straw bale house can do even better, perhaps 40 tons for the straw and another four for wood used in framing and sheathing. These buildings are now recognized in the international building cods and are permitted in most areas. Super-insulated straw bale buildings also minimize energy use for heating and cooling. This could save another 900 tons of CO2e over the building lifetime. The most important considerations in the calculation of the true costs of buildings are comfort, health, and productivity. These have not traditionally been considered when the goal has been to find the lowest cost per square foot or artistically stunning design. Regulations have favored bad design by focusing on just energy, and the sealed buildings that have answered this call save energy at the cost of bad air quality, resulting in human suffering. It is particularly important to get building designs right for high-occupancy buildings like schools, where carbon dioxide levels and moisture loads are elevated. Poor ventilation and air quality can increase the risk for the flu, COVID-19, and other lung diseases. Comfort and health demands good lighting with daylighting strategies and responsive electric lights.

What You Can Do!

Every local action must be made with consideration of the long-term global implications. Take a close look at your home (house, condo, apartment) and workplace energy use and environmental impact. What can you do, now? Do you need more insulation in the attic? Can you replace inefficient windows and doors? Can you install solar tubes for natural lighting? Would exterior shutters help reduce overheating in summer and cold in winter? Can you use a clothesline to dry laundry? Can you afford photovoltaic solar panels and backup batteries? Do you need HEPA air filtration?

If you can manage it, have your home (and workplace) analyzed by energy pros. Some utilities and extension services will help you figure this out for free. In other areas, you may have to pay for a careful review and recommendations for change. Over future years, this will pay for itself many times over. Encourage the company, school, or organization where you work to have an energy and comfort analysis done as well Ask them to consider upgrading your work place with daylighting, improved ventilation and filtration, and as needed, better insulation and light-colored roofing. It is a win-win situation.

Examine your current water use. How much can be saved? Can more water-efficient appliances and fixtures be installed? Can the landscape be redone? Rethink how you irrigate your garden. Install a rainwater harvesting system and cistern if you can. Switch to less harmful cleaners and detergents. Use less toxic pest controls.

Support the groups that are working to calculate and reduce the true costs of constructing and operating buildings. Consider joining organizations like the Healthy Building Network that promote more healthy buildings. Help improve building materials and design with the Ecological Building Network, the Rocky Mountain Institute, the Healthy Building Program at Harvard, and the Green Building Councils.

True cost accounting will bring us all to better health and improved comfort at home and where we work.

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The definition of ACCOUNTABILITY in the Merriam Webster dictionary: ***A willingness to accept responsibility and account for one's actions.*** More info at www.truecostalways.com

About the author

I grew up in the Western US, spending my formative years in the dry lands east of the North Cascade Mountains. I completed a BA in Earth Sciences at UC San Diego and MS in Ecology at UC Davis. My research on passive solar heating and cooling in the 1970s led to the Passive Solar Pioneer Award from the American Solar Energy Society in 2004 (book **Passive Solar Architecture** 2011). In the 1980s I started research on sustainable agriculture and desert and dryland restoration and completed many projects for a range of clients, including the Sustainable Agriculture Research and Education Program, National Parks, BLM, US Forest Service, State Parks, California Department of Transportation and the Department of Defense (**A Guide for Desert and Dryland Restoration** 2007). In my spare time I helped advance the understanding and use of straw bales in buildings (**The Straw Bale House** 1994). In 1995 I returned to the classroom and retired in 2010 after fifteen years as Associate Professor of Sustainable Management at Alliant International University. I taught graduate and undergraduate courses on resources, ethics, management, and economics. I won university awards for teaching, research and community service. My research focus in recent years has been on environmental history and true cost accounting. www.sustainabilityleader.org