TBD

by Charles Hoes

This TBD column finds me in a rather different place than I was just a couple of years ago. At that time, I made an agreement with one of my senior engineers that I would keep my safety consulting business going until he reached his retirement age goal and I reached my 65th birthday. At that point, my plans were to "retire" in some way or another. Not *completely* retire, but reduce my staff and begin working part time instead of full time — and choose more interesting projects.

In preparation for this event, my wife and I made a few changes to our living arrangement. This mainly involved paying off the remainder of the mortgage on our house and installing a 7 kW solar array. Those investments resulted in our having almost no mortgage and close to zero energy costs. So far this year, our total electric bill is about $20 after 10 months — including our air conditioning, swimming pool and hot tub electricity use. Now, we can comfortably live on Social Security. We also managed to put aside a retirement nest egg that allows us some flexibility to do things besides just existing on Social Security. I no longer have to work for a living; I now only work for fun.

My idea for starting my "retirement" phase was to have no plans, but to just follow my nose and see where it leads. One of the first interesting things I found was a series of energy efficiency classes put on by Pacific Gas and Electric Company (PG&E is our local utility). They have a curriculum consisting of about a hundred classes on all sorts of energy efficiency topics. The students range from the complete novice homeowner to engineers, senior tradespersons and contractors. The instructors are all good, and have many years of actual experience in the field. Not only that, the classes are free, including free breakfast and lunch.

I started by taking whatever classes seemed interesting and fit into my schedule. I spent the first year taking a class or so a week. At first I was just being entertained, but as time went on, I started to gain knowledge and understanding that the problem of energy efficiency is a complex and interesting "systems" problem. To achieve an effective energy reduction strategy in a building, the "problem" quickly turns on itself. One can tighten up the building envelope to reduce energy losses through air exchanges with the outside environment. However, it is easy to make this "envelope" *too* tight, and then fresh air needs to be added, causing additional energy demands. Changing lights to lower-power LED lamps from incandescent bulbs is great, but then you lose the heating contribution from the hot incandescent lamp, meaning the heating system may need to be enlarged. It turns out that the system is so tightly bound together that every change impacts other parts, making finding an "optimal" solution an interesting challenge.

For several months, it looked as if I was moving back into my old career as a general building contractor, installing photovoltaic systems, fixing air leaks and doing other construction-related activities having little or no obvious connection to my career as a system safety engineer. I appeared to be walking away from my system safety background and into something entirely new.

However, it has become apparent that I am still in the system safety game, only from a much different point of view. The "undesired top event" seems to be something close to the "collapse of society" due to an overuse of fossil fuels leading to pollution, destruction of critical habitat, global warming and the loss of fisheries because of the acidification of the oceans. Realizing that my attention moved to such an important and high-level safety goal has led to some intriguing considerations. The problem is to identify the various risks and find cost-effective solutions. I have been looking at the problem using something similar to fault tree logic, working from the top event down the tree to finally addressing the basic events leading to the undesired top event.

My first step was to do a little research to see if we are advanced enough to shift to a global energy economy based on renewable, environmentally "friendly"

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energy sources, rather than on the three big fossil-fuel, high-carbon, sources of coal, oil and natural gas. While it might not be possible or desirable to eliminate all uses of fossil fuels, it is clear that these uses need to be reduced to the point where their use is sustainable without causing exponential increases in the problems we seem to be experiencing. Studying the entire world is a little daunting, so I narrowed my focus to California. I picked California because that is where I live; therefore, I am aware of subtle issues that might not be obvious in other locations. My research question was along the lines of "is there an affordable and environmentally benign way to provide the power that California needs without using any fossil fuels?"

As far as I can determine, there is a rather surprising answer: "Yes, there is a solution, and not only that, the solution is free." Not "free" in the sense of not requiring an initial investment of goods and capital, but "free" in the sense that it will cost more to *not* make the changes than to make them — considering the cost of energy itself, without even bringing in the cost of damage to the environment and the health impacts of not changing. For example, the electricity cost of using a 100W incandescent light three hours a day in California is about $22 a year. Replacing that light with a 12W LED lamp would result in an electricity cost of about $2.63 per year. Assuming a lamp cost of $15 for the LED bulb and zero cost for the incandescent one, the total annual cost of the light for the first year would be $17.63, saving a little more than $4 in the first year. Actually, it is much better than that because the incandescent bulbs cost about a dollar and would have to be replaced about once a year. After about nine months, making the "upfront" $15 investment is the same as not making the investment — the same amount of money would be spent in both cases. However, the LED light has a life of about 20 years, resulting in a lifetime savings of almost $400. Not a bad return on a free investment — consider it a "gift" from technology.

It turns out that there are enough simple, inexpensive ways to reduce energy use in California to easily reduce the entire energy budget to the point where all of the state's power needs can be met by a mix of existing large hydroelectric power plants, existing geothermal power plants, new and existing biomass power plants, and rooftop solar. No large solar or wind power-generating facilities are needed. Existing nuclear power may be needed during the transition period, but can be shut down in the future. The technology and knowledge exists for us to power our society without using fossil fuels for electricity, heating or transportation, and without needing large amounts of corn-based ethanol. The answer to the question of "are we there yet?" with regard to having the technology to make this transition is "yes" — in fact, we have been there for a couple of decades.

A large part of the total energy use in California is associated with heating, cooling, lighting and ventilating buildings. The part of the puzzle that I am currently focused on is how to bring homes to "net zero" (using no net energy throughout the year) in an affordable and environmentally sustainable way. The first obvious answer is that it is easy — just stick a lot of solar panels on every home and we are done. However, that doesn't solve the larger problem because energy use during non-solar times is too great to be able to be met using non-fossil fuel electricity production sources on the electrical grid. To be able to shut down coal, oil and natural gas power plants, we need to reduce the peak electricity use to an amount that can be met with sustainable sources. This means either reducing the energy demands of our lifestyle or increasing efficiency (achieving as much benefit for less energy). It turns out that the efficiency reduction path is by far the best solution because it saves much more energy than just not using the energy. Those reductions are then reflected in additional efficiency savings throughout the energy production and distribution system. The light bulb illustrates the problem. We can save $17.63 a year in power costs without using the light, but the light can only be run for about 20 minutes a day! Assuming the light is needed for three hours a day, it is practically impossible to achieve savings by cutting back use — energy efficiency improvements are necessary. Lower demand translates into lower production by electrical utilities. Since about 60 percent of the fossil fuels used to provide electricity is used (wasted) to make and distribute that electricity, the reduction from 100W to 12W in the building actually results in an additional 52W of fossil fuel energy not being used. The 100W lamp actually takes about 160W of energy, while the 12W only takes about 20W. Therefore, changing the lamp from 100W to 12W actually saves 140W of energy. Multiply this savings by 10,000,000 lamps and you start to save a substantial amount of energy. A further interesting aspect of this is that almost all energy efficiency improvements in a home or building also result in improvements in comfort, noise levels and general quality of life. We don't degrade our quality of life by implementing efficiency improvements, we *increase* it — for free!

I am focusing my attention on those improvements that have a rapid "payback" — generally short enough that they can be funded out of normal "cost of living" expenses. I have broken these opportunities into three main categories. The first is things that cost less than about $20 and "pay back" in less than a year. The investments are generally small enough that they can be paid for out of normal monthly expenses and the reduction in cost is significant enough to be enjoyed immediately. The light bulb example fits into this category. It costs $15 out of pocket, but it saves about $2 a month for nine months, then it saves about $1.50 a month for 20 more years. The expense is basically unnoticed in the short-term budget.

The second category includes things that cost more upfront, but pay for themselves in a slightly longer period of time. These are the items that pay back in approximately less than three years. Typically, they are items that cost $1,000 or $2,000, and therefore require more investment than can typically be paid for out of daily budgets. They might require dipping into savings, but probably not into investment accounts or taking out loans. Refrigerators, washing machines and similar equipment fall into this category.

The third category is those larger investments that have great long-term returns, but generally require adjusting investment accounts, taking out loans or some other means of funding. These investments include things like solar systems and new heating and air conditioning (HVAC) systems that cost in the $10,000 to $30,000 (or more) range, with "payback" times between five and 10 years. Longer "payback times" may not be viable because of issues and concerns related to the equipment's lifetime, future technological improvements and how long the investor (homeowner) is going to be able to enjoy the benefits of his or her investment before moving or dying. These investments take careful economic evaluations.

It is relatively easy to reduce energy use for lighting by as much as 90 percent. Lighting may seem like a seemingly small item for a home, but since residential lighting accounts for about 22 percent of the total electricity use in the United States, it represents an important opportunity to reduce our total use of electricity by about 20 percent and our overall energy use by about 30 percent just by switching to better lights. High-efficiency incandescent lights are close at hand, which will reduce energy use even further, at a much lower cost per lamp.

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Possibly the largest unrecognized opportunity is in designing and installing HVAC systems that work much more efficiently. In California (and most of the rest of the U.S.), heating and air conditioning systems are selected and installed in such a way as to waste approximately 80 percent of their energy. It is a relatively easy task to install a properly sized system to reduce energy use by 80 percent or more, bringing the annual heating and cooling bill to about $200 a year instead of the now-common amounts of $2,400 a year or more. In California, summer cooling bills of $350 per month for a modest-sized home are not uncommon, with similar heating bills in the winter months. Older homes can be upgraded to achieve this by modest air sealing of the boundary between the conditioned space and the attic, bringing attic insulation up to levels of R38 and sizing the air conditioning system properly for the building. More than a third of energy use in homes is associated with heating and cooling air.

The inefficiencies in HVAC systems are mainly created by manufacturers' failure to provide systems that can be easily tailored to a specific environment, and by energy regulations (laws) that result in highly inefficient installations. The problems are created by poorly designed regulations, poor training and the refusal of the HVAC manufacturing industry to provide easy solutions to help the HVAC designer/installer to select equipment that matches the needs of the building. The equipment selections reflect decades-old "rules of thumb" that were not correct in the first place, and do not reflect the modern infiltration air control and reasonably insulated buildings. The high seasonal energy efficiency ratio (SEER) values used to advertise the equipment apply to a test that is highly artificial and not reflective of the actual use environment. HVAC engineering societies provide standards and guidelines for achieving high efficiencies and comfort, but these are not well understood or followed, and are not reflected in the current energy efficiency codes such as California's Title 24 Building Energy Efficiency Standards. It is currently not possible to both follow engineering guidelines provided by the American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE), the Air Conditioning Contractors of America (ACCA) standards and guidelines, or other science-based guidance for HVAC design while meeting the requirements of codes and laws such as Title 24.

Once the easily achieved, low-cost improvements are made, a much-smaller amount of roof-top solar can be used to effectively bring the annual energy use of homes and most small- to medium-sized buildings to net-zero consumption. The cost of fixing efficiency problems is often offset by the resulting reduced size of a solar-based system to offset the building's power use.

Currently, energy systems employed in the United States and elsewhere are broken. Huge amounts of money are spent on approaches that provide little or no reduction in the use of fossil fuels (such as large-scale wind energy), while little or no attention is paid to fixing the many low-tech "free" approaches to fixing the problems associated with our excessive use of fossil fuels. A systems engineering approach is required to properly size all uses and appliances to work together in buildings, in a way that is helpful to the grid rather making the grid control problem worse. It can be done, and it can be done quickly if the various parts of the entire system are aligned to work together.

In my way of thinking, achieving this goal of solving the problems associated with the excessive use of fossil fuels falls into the realm of being a large, complex system safety problem. It requires understanding the system, as well as understanding the hazards and associated risks, and requires creativity and hard work to find the path(s) to achieve "optimal" safety for society and the environment in a cost-effective and safe way.