Yogi Goswami, PhD PE - Story

Oil spills. Gas prices. Declining fossil fuel reserves. Hostile regimes in petroleum producing countries. Carbon emissions. Pollution. Global climate change debated not by scientists, but by politicians. Oil and coal companies spend millions on public relations campaigns psychologically designed to lull us into believing their messages of social responsibility and clean energy. Energy efficient cars are luxury items, and solar power installations for a single home costs more than a decade of conventional utility bills. In this madness, where is the progress? Who is going to get us out of this fossil fueled dependency? Is anybody working on this stuff? In other words, where are the good guys in the white hats?

They are here at the University of South Florida, and can be found in large numbers in the College of Engineering. On any day, one of these good guys can be found associating with free radicals, making very small antennas and mixing various liquids to improve the venerable steam engine. He could also be directing multi-million dollar energy research centers. Everything under the sun interests Professor Yogi Goswami, PE, and he had devoted his professional career to the clean and limitless energy that the sun provides.

“My interests in clean energy are very broad. When I started teaching 35 years ago, clean energy was not a very important area at the time,” Goswami recalls. “But I saw it as the future, not just for me, but for all people. So I decided to concentrate on solar energy.” His early work involved solar thermal conversion, working with solar water and space heating and cooling. “Even though I got started in conversion, I quickly got into other fields that, in some cases, were totally unrelated to each other, except that the source of energy was the sun,” he recalls.

One area that particularly fascinated Prof. Goswami was the century-old thermodynamic Rankine Cycle that converts heat into work. It is the method used by solar thermal, biomass, coal, oil and nuclear power plants to heat water. This water is boiled to produce high pressure steam, which spins a turbine to create electricity. About 80% of the world’s power plants use this process, which is closely related to a simple steam engine. Looking at the system with a mechanical engineer’s eye, instead of using just water, he pioneered using a mixture of fluids to produce a more efficient method of heat exchange. His method is to mix water and ammonia, which boils at a lower temperature than water. Known as the Goswami Cycle, it pioneered the use of multiple liquids that can work with some of the lower temperatures that fuels, such as biomass requires. “In this case,” he explains, “I felt rather than patent it, I just put it out in the literature so people could take advantage from it, it is public.”

The segue from steam engines to concentrating solar power (CSP) technology boggles the mind, so Prof. Goswami takes over to gently explain some of the newest technologies he is working on. “Yes, CSP refers to the mirrors that concentrate sunlight onto collectors. It has the potential to achieve grid parity, which means that the cost of power using renewable or clean energy sources will become equal to the cost of using sources such as coal.” But what about producing power during non-sunlight conditions? “Increase the size of the solar field and with that extra heat you collect you store it as a hot liquid in a tank. That liquid in storage is hot enough to create steam that in turn spins a turbine to create electricity.” So not only does CSP technology hold the promise of become economically feasible, it has the potential for continuous production, what is called dispatchable power. “And another reason why concentrating solar power is attractive to utilities around the world is you can use conventional fossil fuel as backup,” he continues. “Because both use the same thermodynamic process to create steam, you can attach CSP to an existing conventional power plant.” The U.S. Department of Energy recently granted USF $3.9 million dollars to develop thermal energy storage technology whose cost will be about one-fifth of the present cost of thermal energy storage.

Just when you think you have the thermodynamic part figured out Goswami explains that you can create energy directly from sunlight and, evidently, not from your father’s photovoltaic panels. “I call it beyond photovoltaics,” he explains. “Traditional silicon-based systems use the quantum nature of light. They have limitations based on the band gap, or what portion of the solar spectrum it uses. What we are developing uses the wave nature of light.” Again, Prof. Goswami comes to the rescue. “The wave nature of light is electromagnetic radiation. You are familiar with antennas for radio waves, right?” he asks. “Well those radio antennas pick up electromagnetic radiation, called radio waves, and convert them to electrical signals,” he explains, “and then on to audio if you are listening to a radio. FM broadcast wavelength is about three meters. We are going to use exactly the same method except instead of having antennas a meter in length to catch radiowaves, they will be a fraction of a micron to catch sunlight.” With the advent of nanotechnology, the concept is becoming feasible. Will future panels have a forest of tiny antennas? “No,” laughs Goswami, “The antennas will be so small you won’t be able to see with naked eyes. The skin of a building may be covered with billions of such antennas providing electricity for the building”.

**Air Purification and Disinfection using Photocatalytic Technology**

While the sun is a clean source of energy, it can also clean things. Prof. Goswami has developed an innovative method to remove harmful bacteria, spores, mold, viruses and volatile organic compounds (VOC) from indoor air systems. Imagine a simple air filter like you purchase at a hardware store, coated with a thin layer of catalyst. Shine an inexpensive “black light” (almost the last wavelength humans can see before the ultra-violet part of the light spectrum) on to the filter as the air is forced through it. As the bacteria come in contact with the catalyst on the fibers, they are completely oxidized, burned completely. “This is an important distinction between just being killed and completely converted to carbon dioxide and water,” Goswami explains. “Some bacteria may be more lethal after being killed than when they were alive. Some microorganisms have a poison just under their skin called endotoxins which they use to protect themselves while they are alive. But when they are dead, the remains are released into air, where some people have severe reactions to these toxins.”

The catalyst used on the filter is a simple compound, titanium dioxide. A harmless white powder used for white paint pigment, toothpaste and sunscreens. Nanotechnology allows titanium dioxide to be layered onto the fibers of the filter. When installed into heating and air conditioning ductwork, the combination of the catalyst and the ultra-violet light removes pollutants and odors in a safe and economical manner. It can also protect against certain forms of bioterrorist attacks. It is interesting to note that in the nano world substances can behave in totally different ways than they do in standard quantities. In Prof. Goswami’s thin layer of titanium dioxide the substance amplifies the ultra-violet light to kill cells and alter DNA. When used as a sunscreen, titanium dioxide protects cells from ultra-violet radiation.

These filters are available commercially, but Goswami and USF are currently working on a third-generation version that will be even more effective. This self-cleaning property of the catalyst can be applied to glass and even paint.

**Solar Photocatalytic Detoxification and Disinfection in Water**

Yogi Goswami has successfully demonstrated that his titanium dioxide catalyst method works in water as well as in the air. Years of leaking petroleum storage and aircraft refueling has contaminated the groundwater at Tyndall Air Force Base in western Florida. The polluted water was mixed with the titanium dioxide, forming a milky solution. It was then pumped through a solar reactor, a series of long slender transparent tubes that exposes the solution to the greatest amount of ultra violet radiation from the sun. The UV photons act on the suspended catalyst creating free hydroxyl radicals which break the chemical bonds of the hazardous organic chemicals and micro-organisms. Unlike some oxidation methods which can create another whole set of pollution issues, Prof. Goswami’s goal is the complete destruction of the polluting hydrocarbons back into carbon dioxide and water. “Hydroxyl free radicals are one of the most potent oxidizing agents known to us,” he explains. “Medical science people tell us our own internal aging process is because we produce these same free radicals inside our bodies. That is why we need to take antioxidants. But in this case, we use these free radicals to our advantage.”

This process also works on industrial wastewater. A pharmaceutical manufacturer needed to clean up water that was very high in chemical oxygen demand, termed COD. This test measures the organic compounds such as dioxins and PCB’s in water. The manufacturer had tried conventional methods to reduce the COD to no avail. Again, using the titanium dioxide catalyst and sunlight, Goswami successfully reduced the COD to the point where the water was so clean it could actually be re-used in the manufacturing process. “This safe detoxification technology has so many more applications than we first imagined,” muses Goswami. “For a long time, chemists worked on these kinds of problems, but I brought an engineering point of view to make cleaning water with sunlight practical.”

Goswami’s next project is to build a pilot solar thermal power plant across the street from the Engineering II Building at USF. The Florida Energy Systems Consortium (FESA), created by the Florida State government to coordinate energy research among the 11 universities and energy technology, is helping fund this project. “We will use the technologies we have been working on at USF at this pilot plant,” explains Goswami. “I am hoping we will have construction started within this year,” he says with genuine enthusiasm. “It will be about 100 kilowatts, enough to power about ten to twenty homes. We will start with a conventional cycle proceed to organic Rankine cycles, super-critical cycles and the Goswami cycle. We will do thermal energy storage technology. It will be a working model for students and industry, and it will allow us to experiment and demonstrate all the new technologies we have developed.”

Prof. Goswami holds almost a dozen patents, and has published 16 books. He is a principal investigator on several projects ranging from fuel cells and hydrogen research to residential air conditioners. He has served as the President of the International Solar Energy Society (ISES), a Governor of the American Society of Mechanical Engineers (ASME) and many other leadership positions in the professional world. With over 50 awards and certificates from major engineering and scientific societies, he has testified on energy policy matters to the U.S. Congress, the United Nations and the Government of India. He is the John & Naida Ramil Professor at the College of Engineering. Professor, researcher and inventor, Yogi may actually be a source of energy all by himself. Oh, and definitely one of the good guys.