The Answer My Friend is…is not

Or

When Dr. Sorenson Misspoke

Mr. Zane loved basketball—especially Duke basketball. In November 1965 the defending NCAA champion UCLA Bruins would make a fateful visit resulting in a subsequent article in Sports Illustrated titled "Lost Weekend in the Carolinas." Back-to-back losses to Duke Friday night in Durham and Saturday in Charlotte would establish Duke as a contending number one team in the nation (Do you remember who won the title that year? Texas Western—changing the course of college basketball forever—but that's another story). Mr. Zane was the physics grad student in charge of our Friday afternoon 2:00 to 5:00 PM lab. No one wanted a science lab Friday afternoon; and I'll bet there are few Friday afternoon labs even scheduled nowadays (how about that Ken, Julius?). When we assembled for the lab—yet another exercise to determine the local value of "g"—gravity, Mr. Zane noted that we could do the 3 hr lab as scheduled which would certainly make us late to line up with the Cameron Crazies for this important game, or he could summarize the results and we'd be out in about 20 minutes. There was no serious debate. A great game and my most memorable physics lab. However, this was part of my dark period in pre-med studies. Let me explain.

As a high school student I received (and deserved) C's in physics. The pre-med curriculum at Duke recommended a more challenging course preparing you for admission to Duke School of Medicine. On a more worrisome note for myself, the pre-med curriculum also changed the make-up of the freshman men's class from 900 pre-med candidates out of 1000 that 1st year to 100 by the 4th year. Most med schools required basic physics and one semester of calculus. Duke wanted its pre-meds to take Physics 41 and 42 with the engineering students which added the 2nd semester of calculus. I quickly eliminated Duke med school on the basis of this requirement and started the fall of that year taking Physics 1 and 2 with the nursing students. Heaven. The 1st semester of calculus was a memory—and a vague one, at that, but out of the way the previous year.

I already had 3 afternoon labs that semester with one chemistry and two comparative anatomy labs. I was working part-time as an attendant on Meyer Ward, the locked psychiatric unit at Duke Hospital, to make ends meet financially. The wisdom of less calculus and easier physics seemed obvious—at least to me. However, about 2 weeks into the semester I was summoned to Dean Cox's office—Dean of Pre-Med Studies. "There's been a mix-up in your schedule, Mr. Wilson." No, Sir, I assured him. I would apply to schools other than Duke without these extra requirements. "But I want you to go to Duke Med School and I have taken the liberty to change your schedule," he replied. End of argument.

At the end of the semester I approached finals with a C in physics. Exams were after Christmas and I spent many hours that holiday break preparing for the upcoming physics fiasco. I read one book simply about taking exams. Go through the test doing the problems you knew first then go back to the ones you weren't sure of. To enhance the adrenaline anxiety rush, the exam was a night exam from 7:00 to 10:00 PM. I walked over to the old chemistry building with fraternity brother Jon Elmendorf, a tall fellow who was entering the test with a B(+) to A (-) average. It had snowed and was unusually cold yet I was sweating and shaking. With my new knowledge for taking exams, I began. It took me 15 minutes to cover the items in the 3 hr exam which I thought I knew. Time to revert to my old test-taking technique; write down as many formulas you can remember and pray for partial credit. After the exam as Jon and I walked back to the Sigma Nu quad, Jon felt confident about his performance on a test he thought was not too bad. I said nothing. Amazingly, when the grades came out, I had aced the exam and Jon got a hook (C) with our final grades the same "B". My delight; his dismay.

Unfortunately, at the end of the spring semester, the 11 PM to 7AM shifts on the psych ward caught up with me, and I developed a terrific case of mononucleosis. I was hospitalized for a week with my 24/7 slumber interrupted only by med students on physical diagnosis poking the left upper quadrant of my abdomen because I had a palpable spleen. I missed all my exams and looked apprehensively toward returning to Duke mid-summer to make up 2nd semester calculus and chemistry at one sitting and then physics later just before the start of the year. I'd leave the worst for last.

Returning to Duke a week before regular classes, I had made arrangements for the exam on a Tuesday afternoon. Mr. Zane was responsible for administering the exam. The first page started with a comment that the 2nd semester of the course had been strongly influenced by Gauss' Law. Relate that to the following problems. I skimmed the questions and approached Mr. Zane explaining that there apparently was a mistake and this exam must be for a different course. For make-up exams, as you might guess, the teacher had to devise a new test so the make-up student couldn't get answers from classmates taking the exam at the regularly scheduled time. I should have known better. "Look, Wilson, I didn't have time to make up a separate exam; that's the same one your classmates took last spring." At the end of the 3 hour exam, I stumbled out of the physics building anticipating the misery of repeating the course and the probable end of my pre-med career.

Clearly, at his last SPHEX presentation "A whole lot of shaking going on," my friend Dr. Eric Sorenson misspoke. I was the worst physics student of all time. Sandra and I were dating at that time, and she shared my anxiety as I went back to the physics department each week to get my final grade. The department had a beautiful secretary married to one of the assistant football coaches. Each week for the next 3 weeks I trudged back to the dorm with the information that the grade had not been turned in yet. At the 4th visit she confided in me, "Look, Mr. Wilson, Mr. Zane lost your exam and said to give you whatever grade you got first semester." OK, a B! Maybe the worst physics student but definitely the luckiest.

I remember telling Julius Sigler after his presentation—"Someday, Sir, you will tax it" that I was a terrible physics student. The following will probably confirm it. With respect to my deficiency in physics several years ago I went through a Teaching Company course titled "Great Ideas of Classical Physics". Note: you may not be much of an aficionado of physics either unless you are holding your sides in laughter after reviewing the equations on page one of the handout. In the sections on electric and magnetic fields the lecturer Dr Pollock from U. of Colorado at Boulder comments that Faraday, noting how moving magnets generate electric fields, may have provided the most practically important discovery in the history of physics. You may recall that Michael Faraday (1791-1867) was a self-educated book-binder who was hired as a lab assistant to Humphrey Davy. Although he had no formal training in mathematics he was the first to appreciate electromagnetic induction—the use of changing electric and magnetic fields to create currents—and to build the first dynamo, a device that converts mechanical energy into electric current and serving as the basis for modern electric generators.

Well, how can we best spin large coils of wire through magnetic fields to produce electricity? Do we burn oil or coal to produce steam and turn turbines? Do we try to develop renewable sources of energy? Does it matter? If we are concerned about dependence on foreign oil (imported oil accounts for 42% of our trade imbalance—*Discover* magazine 2011), is it comforting to consider ourselves the Saudi Arabia of coal and gas? Many of my W.Va first cousins like this idea. However, a recent article in Bloomberg Businessweek points out that there are 17000 jobs waiting to be filled for coal miners. No one wants those risky jobs. My brother was a miner for one day.

One of my wife's favorite artists is Hunderwasser. I was struck by one of his posters; a picture of earth with the message, "Behave yourself, you're a guest here." Maybe as part of my native American heritage or more likely my role as a grandparent, I am concerned about our future resources especially energy. The first question to be addressed is whether there really is any reason for concern about non-renewable energy sources ?

Currently 86% of U.S. energy comes from carbon based fossil fuels (oil, natural gas, coal). If you add nuclear based energy (non-renewable uranium 235 and plutonium 239) we have 92% of our energy from non-renewable sources. At a rate of oil consumption of 31 billion barrels/year and estimated world reserves of one trillion barrels of oil, there is a <u>32</u> year reserve. Some estimate a 50 year reserve including shale oil. Does anyone here think that 32 to 50 years is a long time? This is my 32^{nd} year in practice and the time has flown by. These reserves will likely be strained further as we see large populations in India and China increasing their use. Currently, the US uses ¼ of the world's oil and has 2% of the oil reserves (a <u>3 year</u> supply without foreign oil). Should the turbulence in the Middle East as witnessed by the conflicts in Yemen, Bahrain, and deposition of President Mubarak in Egypt in February 2011 and Qaddafi in Libya in August 2011 and the Iranian threat to shut down the Straits of Hormuz coming out of the Persian Gulf (thru which estimates vary from 20 to 40% of the world's oil is transported) serve as stimulus for energy independence? Would things like offshore oil drilling and shale oil technology only be a temporary fix without producing significant reserves of oil? The BP gulf oil spill in April 2010 reminded us of environmental risks with offshore drilling and an AP article in our July 2010 *News and Advance* warns of 27,000 abandoned oil and gas wells in the Gulf of Mexico which are not monitored for leaking. At one point during the past year as oil reached $130 a barrel, T. Boone Pickens was interviewed about the promise of shale oil such as found in the Bakken shale deposits in N. Dakota. He felt the technology would cost $200/barrel. He is more interested in our gas reserves.

Natural <u>gas</u> use is around 2.6 trillion cubic meters yearly with 180 trillion cubic meters reserve giving us about a <u>70</u> year reserve. In 2009 87% of natural gas consumed in the U.S. was produced domestically. Unlocking the reserves of shale gas would increase to 100 year reserve. The Marcellus Shale Formation lies under most of Pa and W Va and large parts of New York and Ohio. There is an estimated 363 trillion cubic feet of natural gas lying 5000 to 9000 feet deep. There is debate about the fracking process potentially contaminating water supplies. The January 2012 *Discover* Journal presents a summary of EPA concerns of excess methane contaminated water and fracking wastewater too radioactive to be handled safely by water treatment plants. Did you see the documentary Gasland showing the residents living close to one area with fracking lighting the water coming out of their kitchen faucet? Coal, likewise is limited. With 5.5 billion tons used/ year and reserves of 1 trillion tons we have 180 year reserve. The US has ¼ of the global coal reserves which would last 275 years if restricted to domestic use only.

Nuclear power has had more social and safety concerns than geologic issues. Think of Chernobyl and more recently the Fukushima Dai-Ichi nuclear plant near meltdown after the March 11, 2011 tsunami in Japan. According to the World Nuclear Association, as of March 1, 2011 there were a total of 60 new reactors under construction: one in the U.S., 10 in Russia, and 27 in China. Of interest, a Feb 12,2012 article in Bloomsberg Business Week mentions that Japan has been shutting down their 54 nuclear reactors for safety checks. As of May, the country will have no nuclear-generated power. There is concern that local governments and local citizens will block authorities from firing up the reactors again. The country currently has just 3 operating reactors. A recent poll shows that 70% of the Japanese want to reduce or end the use of nuclear power. Before the Fukushima disaster nuclear power provided 30% of Japan's electricity. A switch to fossil fuels would require 323 million barrels of oil a year (adding $34 billion to the country's import bill). Japan's consumption of liquefied gas jumped 32% in December with most reactors idle while crude oil use increased fivefold. At the same time US federal regulators have voted to grant a license for 2 new reactors at a site in eastern Georgia. The $14 billion reactors should be operational by 2016 at a location south of Augusta. The NRC (National Regulatory Commission) last approved construction of a nuclear plant in 1978. Two others are expected to win approval in South Carolina in the next few months.

Nuclear power produces 15% of the world's electricity; 21 % of US electricity, and over 50% of European electricity. It is efficient with 1 kg of uranium (2.2 lbs) equivalent to 1500 tons of coal. The cost of uranium has gone up from $10/lb in 2000 to $110/lb in 2007. The US has 10 million tons of uranium reserves which would provide 100-150 years of nuclear power. We continue to see newspaper articles regarding debate over the safety of uranium mining in Virginia. Remember Graham Gilmer's SPHEX presentation "NIMBY" –Not In My Back Yard. Safe or not, it certainly is not renewable. The Jan 20, 2012 News and Advance has an editorial supporting Governor McDonnell's recommendation that the General Assembly continue the 30 year moratorium on uranium mining in Virginia for another year. Walter Coles' farm outside Chatham is felt to hold 119 million pounds of uranium. A January 27,2012 newspaper article notes that this is considered the largest undeveloped uranium deposit in the U.S. Virginia Uranium Inc. proposes to employ 300 workers to mine and mill the site. The National Academy of Sciences concluded in a December report that it was possible to mine the uranium but "steep hurdles" had to be overcome first. Local residents who oppose the project rally to slogans like "Hell no, we won't glow."

It would seem that for a not-so-distant future (at least in geologic time), we need to look at renewable energy sources. According to a March 31, 2011 *Wall St J* article, renewable energy accounts for 8% of our total energy (conventional, non-renewable sources include 37% oil, 25% natural gas, 21% coal, and 9% nuclear). Of the renewable forms Hydropower makes up 35%, Wood 24%, Biofuels 20%, Wind 9%, Biomass wastes 6%, Geothermal 5%, and solar 1%. 2009 data shows the % of electricity generated from renewable sources in the U.S. Top states for renewable energy use include Idaho with 86% (mainly hydroelectric with small amts from biomass/waste and wind); Washington state 75% (mainly hydroelectric with small amt from wind); Oregon 66% and S. Dakota 59% (similar proportions of mainly hydroelectric and wind); and Maine 50% with about equal amts hydroelectric and biomass/waste and small amt of wind. Virginia at that time (2009) had less than 5% of electricity generated from renewable sources.

The importance of the cleaner forms of energy was reviewed from a medical perspective in the March 25, 2010 *New England J Med:* "Climate change is occurring as a result of an imbalance between incoming and outgoing radiation in the atmosphere. As solar radiation enters the atmosphere, some of it is absorbed by the earth's surface and remitted as infrared radiation, which is then absorbed by greenhouse gases—primarily CO2; methane, and nitrous oxide—which result from the combustion of fossil fuels and cannot be effectively removed from the atmosphere because of deforestation. Sources of carbon emissions include 33% from electricity production; 27% from transportation (one of the adds for my Prius—license "SAVN NRG"—claims it goes from 0 to 60 mpg with no emissions); 20% from industry; 12% from homes and businesses; and 7% from agriculture (source EPA). This process generates heat. As the concentrations of greenhouse gases in the atmosphere have reached record levels, global temperatures have risen at a faster rate than at any time since records began to be kept in the 1850's, and temperatures are expected to increase by another 1.8 to 5.8 degrees by the end of this century. The hydrologic cycle will be altered, since warmer air can retain more moisture than cooler air. Some geographic areas will have more rainfall and some more drought , and severe weather events. For these reasons, the term "climate change" is now preferred over the term "global warming." Because of changing rainfall patterns, climate change is expected to have a substantial effect on the burden of infectious diseases that are transmitted by insect vectors and through contaminated water."

<u>Is there a sunny outlook</u>? The earth receives 174,000 terrawatts of energy from the sun; more than 10,000 x's the amount of the 15 TWs humans use yearly. There are different forms of solar energy: active solar, passive solar, wind power (sun-driven atmospheric circulation), hydroelectric (sun-driven water cycle), and biomass (sun-driven photosynthesis).

<u>Passive solar power</u> utilizes the sun that directly hits the home or building via solar panels for heat or photovoltaic cells to produce electricity. In July of 1972 half of our intern group started their medical rotations at the Durham VA Hospital. It is a huge red brick building with 12 stories. In 1972 it was not air-conditioned. On the medical service if a patient developed a fever the work-up included a general physical re-examination, CBC, urinalysis, chest xray, EKG, and spinal tap. During the July rotations and dog days of August, you could count on spending the evenings working up fevers. Finally one of our no-nonsense retired military nurses pointed out that after absorbing the sun's rays all day, the heat

radiating out in the evening made the ambient temperature on the ward around 100 degrees Fahrenheit. We all—patients, nurses, and doctors had fevers. Our nurse did not call it passive solar power but she knew it produced a lot of heat. The new Boeing plant in Charleston, S.C. has gone green and in conjunction with S.C. Electric and Gas Co. will power the site with renewable energy sources. This is the plant the National Labor Relations Board wants to close, claiming that Boeing set up the plant in S.C. to avoid union hassles and this would cause a loss of jobs in the Seattle plant. That has not proven to be the case with no jobs lost in Seattle and 3800 workers employed in the Charleston expansion. The solar panels are 18 inch wide laminated strips in 1000 foot long sections supplied by Uni-Solar, part of a Michigan based Energy Conversion Devices Company. These photovoltaic panels will pump out enough power for 250 homes. Remaining power needs for the plant will be from wood chips and other biomass sources from a generator operated by SCE&G at a nearby paper mill.

In North America the land receives 125 to 375 watts per square meter of passive solar energy. A square region of 600 km by 600 km could generate all the world's energy needs. Good news, Iran. You won't have to develop nuclear power for your "energy" needs. The early solar panels may have been disappointing but silicon solar panel technology is improving and this form should be more reliable and there is no shortage of silicon. Will there be a future for solar collectors orbiting in space? See page 2 of handout showing some innovative uses of passive solar power in boats, planes, and even your bikini! Active solar power is the conversion of sunlight into electricity. The decreasing cost of silicon has made passive solar power more economical than developing active solar power through solar thermal installations which make electricity by using reflecting mirrors to concentrate sunlight to boil water, creating steam that drives turbines (Oct 2011 Bloomberg Businessweek).

Fortunately, only science decides on the future of solar power without the taint of government influence—right? Maybe you saw my letter to the editor last October. "The Solyndra fiasco (527 million dollars of tax payers' money lost for a government bailout) confirms that Obama is a poor businessman. No surprise from someone who has never created nor run a business. However, in this time of bogus government transparency, it does demonstrate that he is still a good politician. The October 8, 2011 *News and Advance* "Other Voices" editorial from *The Washington Post* fails to mention the political capital gained. In an article by the Associated Press in the Charleston *Post and Courier* Sept 17, 2011 "Solyndra loan favored Obama donor" the writers point out that "private investors—including a fundraiser for President Barack Obama—moved ahead of taxpayers for repayment in case of a default." George Kaiser raised between $50,000 and $100,000 for Obama's 2008 campaign according to federal election records. His investment organization Argonaut Ventures LLC is one of the favored private investors, and Kaiser has made at least 16 visits to the White House. A subsequent George Will editorial "Faith in 'federal family' is misplaced" notes that the now bankrupt Solyndra has resulted in the loss of more than 1100 jobs.

An article in Sept 12-18, 2011 *Bloomburg Businessweek* explains the failure of this green energy enterprise. Several years ago the prices for silicon wafers used in the solar panels were soaring. Solyndra bet on a different panel they developed that would be cheaper than the silicon panels. When silicon prices dropped 90% from their peak in 2008, the conventional solar panels were more cost effective. Solyndra blames the cost disadvantage on the Chinese government subsidizing its own solar panel industry. Ironic, give Solyndra's reliance on our government bailout. The article notes that the day after Solyndra's failure, the Energy Department awarded $145 million to 69 solar energy projects in universities, government research labs, and major corporations. "Steering small amounts of money to many early stage researchers is a far better way for government to operate." Government stimulus for research and development is good business—but may not serve political interests. "

The most utilized solar energy source is hydroelectric power—harnessing the energy of the work water does as it washes off the land. Didn't realize this is solar power? The hydrologic cycle (water cycle) is driven by the sun with solar radiation responsible for the evaporation of water from the ocean surface and the thermal convection in the atmosphere that carries water vapor over the land. Of interest is the greenhouse effect with warmer air holding greater amounts of moisture (alluded to in the NEJM article)—perhaps portending more severe rainstorms in the future. I believe we are seeing this effect. Rainfall, water flow in streams and rivers result in erosion with water ultimately back to the ocean completing the cycle. Advantages of this form is it is inexpensive and clean. Disadvantages are loss of water to evaporation, increase in mosquito-borne diseases (as noted in the *NEJM* article above) , effect on animal and fish life, and area limitation to regions with large streams and steep slopes. Largest producers are China, Canada, Brazil, and the US. The Smith Mt APCO operation is a good example.

Maybe, the answer my friend is blowing in the wind (tip of the hat to Peter, Paul, and Mary and Bob Dylan). This is the energy source with the most rapid advances in technology. While only about 1 to 3% of sunlight goes into wind, that is still a lot of energy. Wind power could provide 5 times the current global energy use. Currently wind power accounts for less than 1% of electric power (in Denmark 20% of all electricity is from wind). As the wind makes the blades turn, the shaft inside the nocelle (box at the top of the turbine) rotates. The shaft goes into a gear box which increases rotational speed enough for the generator (using magnetic fields) to convert rotational energy into electrical energy. Power output goes to a transformer and converts electricity out of the generator at approximately 700 volts to the right voltage for the distribution system. A national grid transmits power around the country. Controls at the top of the nocelle measure wind speed and direction. In response, motors turn the nocelle and blades to face the wind. Brakes allow the turbine to be switched off in high winds.

Undependable winds present a problem. Current wind energy development depends on the regularly strong winds in the plain states, mountainous regions, and shorelines. On a Baltic cruise several years ago, Sandra and I were impressed with the number of wind turbines along the shore—particularly as we sailed into Copenhagen. In these locations there is a daily shift of wind from sea to shore during the day and shore to sea at night corresponding to daily temperature changes. The Feb 3, 2012 *News and Advance* and *Wall St J* have articles proposing off shore wind turbines. The US gets about 3% of its electricity from land-based wind turbines, but doesn't have any offshore. Interior Secretary Ken Salazar announced that an agency study found there would be no significant environmental impact from issuing leases and allowing developers to pursue wind farm development. Possible projects are being considered off the coasts of Md, Delaware, N.J., and Virginia. Only one lease has been executed so far in the US—in Nantucket Sound off the coast of Mass. The project owner Cape Wind Associates would pay the government about $88,000 in annual rent for 33 years, plus 2% to 7% of electricity sales. Dominion Resources is interested in building up to 400 wind turbines off our Va shores. They have a $500,000 Dept of Energy Grant to study offshore wind development, and have found that they have the necessary transmission lines to deliver power from turbines 20 miles off Va Beach. However, even with the go ahead it will take at least 2 years to see an operation underway.

An article in *Forbes* August 30, 2010 discusses wind energy efforts in Montana. It mentions two common problems for wind energy: intermittent wind requires cost efficient storage and windy spots are often far from populous areas, so money has to be spent to transport the energy. Storage depots are needed to pour energy into on windy days and allow energy to be drawn down at a steady rate. Giant batteries would be expensive. Pumped storage is considered: pump water uphill when there is excess power, and let it run downhill through a hydroturbine when power is needed. Storage and transmission remain major problems affecting the economic feasibility of wind energy especially in these remote areas. The March 2012 Scientific American has an article "Gather the Wind" by Davide Castelvecchi which states that some utility companies use excess solar or wind power to pump water to uphill reservoirs, where it can later fall to turn turbines. This system could be installed in many more locations. Other solutions include facilities that compress air into large underground caverns, that heat fluids or molten salts that later create steam to turn turbines, or that can charge advanced batteries.

Stronger and more constant winds occur high in the atmosphere. Winds at an altitude of 30,000 feet carry 20 times as much energy as those near the ground, representing a source of power that could be a fraction of the cost of coal, and there are inventors looking at high altitude wind turbines in the forms of kites, single wing planes, blimps, and gliders(discussed in a *Discover* December 2010 article "Inherit the Wind" about inventor JoeBen Bevirt's efforts). Perhaps this is one solution for undependable winds.

Wildlife kills of birds and bats present another problem. With technological advances the blades turn more slowly, are more efficient and durable, and less of a threat to birds and bats. A *National Geographic* article from November 2010 showed a picture of 32 bats and four songbirds felt to be an average yearly toll for each wind turbine in a Pennsylvania wind farm. In Chile we heard for the first time the term "Condor cuisinart." An article in January 2012 *Forbes* magazine titled "Wind vs Bird," presents some of the conflicts. Outside the medically infamous San Joaquin Valley of California (internists immediately think of coccidioidomycosis infx "Valley Fever") motorists climb into the Tehachapi Mtns and encounter hundreds of gleaming white wind turbines. In this area the wind industry has attracted $3.2 billion in investment in a region where the unemployment rate is 64% higher than the U.S. average. 4500 megawatts of renewable energy will be directed to coastal cities. At peak output that's the equivalent of 4 or 5 nuclear power plants. The shadow following over the project is that from a nine and a half foot wingspan of the California condor. This bird has been on the verge of extinction with about 200 in the wild in California and 400 total worldwide (most of the others in Chile). The flight path of the condor riding the same thermal currents that generate wind power make most experts feel that it is only a matter of time till a condor hits one of the 500 foot high wind machines. The developers feel one incident could shut down their operation.

Dr Davis and Sally VonOeson's daughter Britta with a major in environmental science and an MBA from Columbia is working in this field. Large and unsightly turbines are giving way to different designs for safer turbines—different forms of rotating turbines. *The Post and Courier* Charleston newspaper had an article April 19,2011 about a local plant that makes prefab housing planning to add a new production line for small wind turbines 6 feet in diameter for use in residential, commercial, and military uses (silent with no heat signature). These can go on rooftops or poles and may be designed to capture hot air released from air conditioning units. Titan Atlas Manufacturing makes these units which weigh 185 # and produce 2000 kwatt hours per year. The gearless turbine uses a system of magnets and coils surrounding its outer ring to capture power at the blade tips where speed is greatest to eliminate mechanical resistance and drag. A local wind power effort in Bedford was mentioned in a May 9, 2011 editorial in the News and Advance. The Board of Supervisors approved an ordinance allowing small scale wind energy systems on private property. The systems can produce no more than 20 kwatts of electricity from a tower no higher than 85 feet. Taller towers and a large-scale wind farm is being considered in Highland County, Wise, and Rockingham counties.

The largest wind farm project in the U.S. is under construction in Oregon along the Columbia River Gorge. When completed this year it can provide electricity to one million customers. The project will cost $1.9 billion and includes a 1.06 billion$ loan guarantee from the Energy Dept. A comparable natural gas power plant would cost about $865 million and would not require government support. However, while gas costs are cheap now the costs have been volatile over the last 10 years. Will the higher cost of renewables now look like a wise investment in 10 or 20 years? A counterpoint is offered by Robert Bryce senior fellow at the Manhattan Institute in his book "Power Hungry: The Myths of 'Green' Energy and the Real Fuels of the Future". Lower natural gas prices will hinder wind development. In 2010, only 1600 megawatts of new wind capacity were installed in US; a decline of 72% compared with 2009. This trend is likely to continue as long as renewable sources of electricity are more expensive than nonrenewable resources. Perhaps you saw his recent Letter to the Editor in the March 8, 2012 *Wall St J* titled "Windmills vs Birds." He feels the wind energy industry has had essentially a license to kill golden eagles and other migratory birds. About 70 golden eagles are killed every year in turbines at California's Altamont Pass. He calls for more oversight. The Sierra Club has joined several other groups in bringing a lawsuit to block the construction of 2 proposed wind projects in Kern Co., California—due to concerns about their impact on local bird populations. These projects would be in close proximity to the Pine Tree facility which the Fish and Wildlife Service believes is killing 1595 birds per year (or about 12 birds per megawatt). In the past two decades he points out that the federal gov't has prosecuted hundreds of cases against oil, gas, and electricity producers for violating wildlife protection laws: the Migratory Bird Treaty Act and Eagle Protection Act. The Obama administration, like the Bush administration had never prosecuted the wind industry.

In Feb 2008 Sandra and I made a fly-fishing trip to the southern tip of Chile. Patagonia has an incredible fishery for brown trout most notably. Coihaique served as the headquarters for our trip. A city of around 30,000. In this southern area of Chile coal is imported to produce their electricity. Three windmills on the outskirts of town provide 30 % of their electricity. Heading out to fish one morning we noted that one of the windmills was not working; facing an opposite direction from the other two with no movement of the blades. Since this represented 10% of their electric power, I presumed there would be some urgency to repair the malfunctioning windmill. Our Chilean guide was nonplussed. Why would he be concerned? This was a government run enterprise and they would fix it whenever they wished. While Chile is evolving toward a capitalistic economy, at that time there was no concept of a private enterprise to address their energy needs. However, this may be changing. They have a natural setting for hydroelectric power—large rivers flowing steeply down toward the ocean. At that time there seemed to be no notion for private enterprise to pursue this, but a recent article in *Flyfisherman* magazine suggests this is changing and warns of plans to damn up two rivers (Rio Baker and Rio Pascua) similar to the Columbia River hydroelectric system—termed the HydroAysen project proposed by a Spanish energy company (Endesa) and a Chilean corporation (Colburn). A battle of ecological, economic, and political interests is likely to ensue. While exploiting wind power could help save their natural resources and preserve their sport fishing enterprise, I'll bet that economic and political forces prevail and hydroelectric power is developed along with wind energy.

Geothermal and Tidal Power—Two major sources of renewable energy not powered by sunlight include earth's heat (geothermal) and gravitational pull of the sun and moon (tides). Geothermal power is used in volcanic regions where shallow drilling allows access to hot rock that provides steam to run turbines. Iceland gets 50% of its electricity from geothermal sources . The largest single steam field in the world comes from the geysers in California. Tidal power can run turbines but only in limited areas. Wave energy and ocean power is getting further consideration. Scotland has developed machines used by the Pelamis Wave Power company in Portugal. The Oyster and Anaconda are other wave energy converters developed.

Biomass Power converts sunlight into energy through photosynthesis converting crops into biofuels. Most know problems of ethanol added to gasoline. With increasing world population there is more sentiment that crops should be used to feed people rather than make fuel. Cultivating algae for biofuel would consume far less land than growing corn for ethanol (*Discover 2011).* Biogas may be a source of methane extracted from garbage. The economics of energy production from our garbage don't seem feasible yet.

Maybe the ultimate decision will be all economics based (**Huffman's Law**). Most recently data from the Energy Information Administration compared cost per megawatt-hour of electricity by different generation methods. Conventional coal was $ 95; natural gas $66; Nuclear $114; Onshore wind $97; Offshore wind $243; solar photovoltaics $211; hydroelectric $86; geothermal $102; biomass $113. They also point out that the European nations with the largest installed bases of alternative energy (Germany and Denmark) pay the highest electricity rates in the EU. The October 24-30, 2011 Bloomberg Businessweek issue confirms these different costs and points out the further problem of grid storage. In Germany solar and wind power on "sunny, gusty days generate so much alternative energy that utilities pay industrial customers to take it away. Cloudy, calm weather creates shortages that can send prices as high as $220 a megawatt hour." Improved grid-level storage is needed but achieving next-generation storage will likely take years—not attractive to private sector investment, but suited to government support. The U.S. Energy Dept was felt to take a step in the right direction with many $3million and smaller grants to labs exploring alternatives. In 2009, however, governments worldwide doled out $312 billion in subsidies to the fossil fuel industry while giving just $57 billion to renewable energy initiatives (*Discover* 2011). Security of an improved grid is another worry.

In summary, consider: The importance of clean energy with decreased emissions contributing to the greenhouse effect and global warming/climate change. Wind energy is clean and inexpensive to maintain.

What about geopolitical implications if we had worldwide, cheap renewable energy?

What about the geologic effects of assaulting the earth's crust drilling and extracting oil, gas, uranium?

I'll leave you with a final thought expressed by Enrico Fermi—Italian physicist; Nobel Prize winner in 1938; noted for his work on the atomic bomb: "Before I came here I was confused about this subject. Having listened to your lecture I am still confused, but on a higher level." Questions and Comments?

Selected References

National Geographic Magazine "Future Power" August 2005

U.S. News and World Report issue "The Future of Energy" April 2010

Periodicals: Discover, Forbes, News and Advance, S.C. Post and Courier

Teaching Company: "Great Ideas of Classical Physics" Pollock

"How the Earth Works" Wysession

The Essentials of The Environment, Simon Ross and Joseph Kerski (2005)

Lecture Eighteen

Unification II—Electromagnetism and Light

And God said:

$$\nabla \cdot E = \frac{\rho}{\varepsilon_0}$$

$$\nabla \cdot B = 0$$

$$\nabla \times B = \mu_0 J + \mu_0 \varepsilon_0 \frac{\partial E}{\partial t}$$ – Ampere's law

$$\nabla \times E = -\frac{\partial B}{\partial t}$$ Faraday's law

and there was light.

—Maxwell's Equations on a t-shirt popular at MIT when I was an undergraduate

Scope: Maxwell's equations synthesize and describe every aspect of classical electromagnetism, from lightning bolts, to electric circuits, to kitchen magnets. But Maxwell made another observation that went far beyond his original equations: He discovered they predicted a "new" phenomenon, an electromagnetic traveling wave, ultimately recognized to be light. All of optics, the remaining great branch of physics, was suddenly completely and deeply unified with electric and magnetic phenomena. Maxwell had provided a grand synthesis of all known fundamental forces of that era (*besides* gravity), allowing us to make sense of the spectrum of radiation and an enormous span of physics, as well as setting a compelling tone for ongoing physics research.

Outline

I. The most common motion in the universe is oscillation. The Earth, an atom, and a pendulum all oscillate. Maxwell asked: How would an electric charge behave if it were moving in this most common way?

A. A static electric charge (an electron) generates an electrical field with straight lines pointing, in this case, in toward the charge. You might think of these lines as similar to the gravitational field lines pointing in toward a star.

B. As the charge moves back and forth, the electrical field lines must move also in order to constantly point toward the charge.

C. A moving electrical field, according to Maxwell's "extra term," will produce a magnetic field; the resulting magnetic field will oscillate.

D. According to Faraday's law, a changing magnetic field will produce an electrical field.

E. The original source in this system was a charge, which created an electrical field, which in turn, created a magnetic field, which in turn, created an electrical field, and so on.

1. We can visualize this phenomenon by thinking of a pebble dropped into a pond. The pebble (the original charge) starts a disturbance (a wave) in the water that is self-propagating.
2. In Maxwell's case, there is no water or other medium. The ripples from the original charge are fields in otherwise empty space.

II. These fields exist, but we have to think about them mathematically.

A. We can find evidence for the existence of electrical and magnetic fields. Can we find similar evidence for the self-propagating phenomenon that Maxwell discovered?

B. We already know that we can detect the oscillation of an electrical field by looking for a similar oscillating response in a test charge.

C. Maxwell found that he could calculate the speed of propagation of an electromagnetic wave. The wave travels at a speed that is dependent on the two constants of nature from Maxwell's original equations. In fact, the answer turns out to be 300 million meters, or 186,000 miles, per second—precisely the speed of light!

D. This result implies that the electromagnetic disturbance we've been talking about is light; light is nothing more than a traveling electromagnetic wave.

III. Maxwell's discovery unified electricity, magnetism, and light.

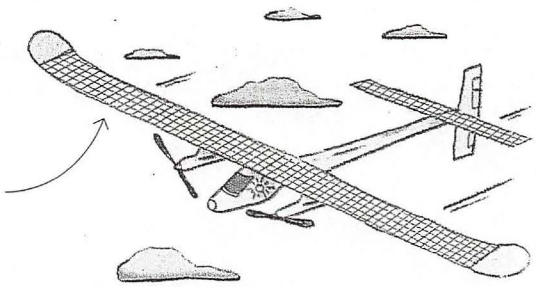
Energy

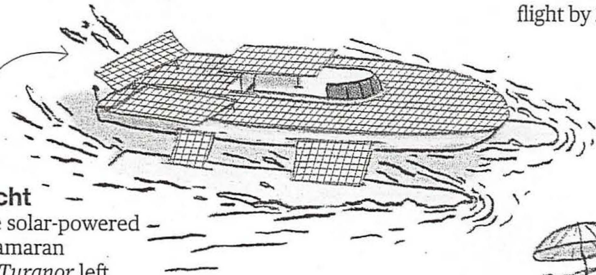
Technology

Solar-Powered *What?*

Inventors and entrepreneurs are harnessing the sun's energy for everything from swimwear to boats and planes.
—*Randall Hackley*

Airplane
Solar Impulse, a plane with 11,600 solar cells on top of gangly wings, is the brainchild of Swiss adventurer Bertrand Piccard. Last year it flew through the night using sunlight-fueled batteries. Next up: an around-the-world flight by 2014.



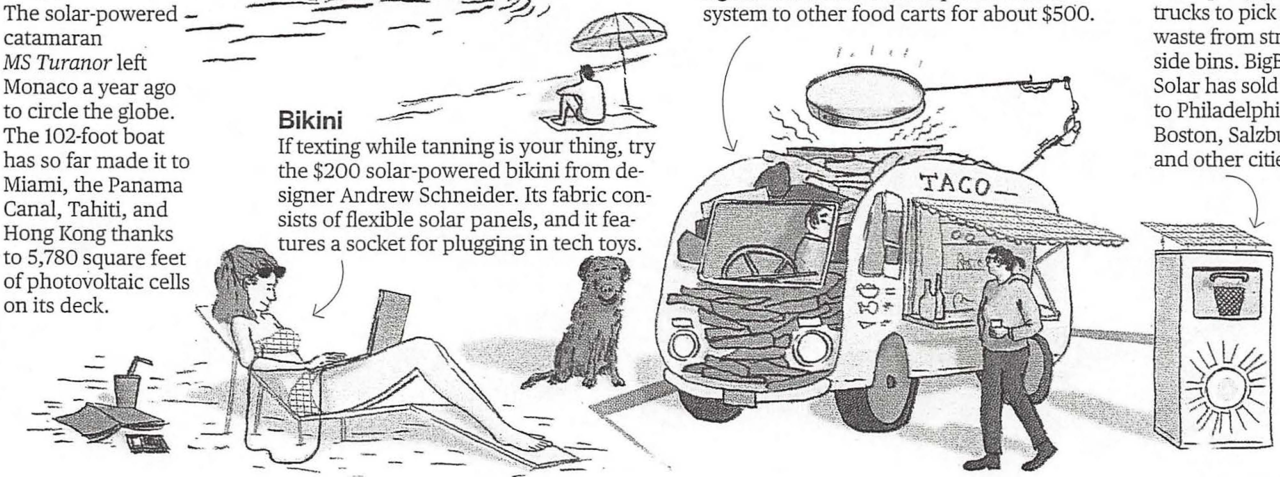


Yacht
The solar-powered catamaran *MS Turanor* left Monaco a year ago to circle the globe. The 102-foot boat has so far made it to Miami, the Panama Canal, Tahiti, and Hong Kong thanks to 5,780 square feet of photovoltaic cells on its deck.

Bikini
If texting while tanning is your thing, try the $200 solar-powered bikini from designer Andrew Schneider. Its fabric consists of flexible solar panels, and it features a socket for plugging in tech toys.

Tacos
In sunny Oaxaca, Mexico, Alfredo Garcia's taco stand sports a reflector that concentrates sunlight for cooking. The Swiss designer behind the idea hopes to sell the system to other food carts for about $500.

Trash Bin
Solar-powered trash compactors can cut trips by garbage trucks to pick up waste from streetside bins. BigBelly Solar has sold them to Philadelphia, Boston, Salzburg, and other cities.



gas industry, but it happens far deeper underground and uses only water, which is injected at a lower pressure than the solutions used in "fracking."

In early October, Calpine planned to start piping water two miles into the ground near The Geysers, a Northern California area that's home to the world's largest cluster of geothermal power plants. The challenge is to create enough "fractures to heat up a sufficient volume of water," says Calpine geologist Walters. The Energy Dept. provided $6.2 million in grants for Calpine's $11 million project, the second EGS installation in the U.S. to reach the injection phase. A year ago, **Ormat Technologies** began injecting water at Desert Peak in western Nevada. Four other projects may be active by late next year, Majer says.

While a handful of small EGS plants are operating overseas, some have experienced setbacks ranging from blowouts to minor earthquakes caused by fracturing rocks deep underground. A project in Switzerland was shut down in 2006 after residents nearby started feeling tremors and fretted that the installation might destabilize surrounding areas. In 2009, Seattle-based **AltaRock Energy** suspended a project at The Geysers because of drilling problems. And it's not yet certain that EGS projects can create enough steam to make them profitable, warns Ann Robertson-Tait of energy consultancy GeothermEx. While the technology has long-term potential, "there are few places where EGS can be considered commercial at present," she says.

Proponents of EGS say it can breathe new life into geothermal installations that are running out of steam. Calpine generates roughly 725 megawatts of capacity at 15 traditional geothermal plants around The Geysers, some 100 miles northeast of San Francisco. Problem is, the steam output there today is about half its 1987 peak. By introducing more water, Calpine expects to add at least 5 Mw of capacity to an existing plant at The Geysers. The company may expand the use of EGS to other plants in the area if the test is successful.

Geothermal has many advantages over solar and wind: It's typically far cheaper to operate and generates electricity 24 hours a day (though there's no guarantee how much power can be produced until a costly well is drilled). EGS could give the industry a lift by opening up development in regions that lack underground steam pockets. AltaRock is working on an EGS test near the Newberry National Volcanic Monument in Oregon, where there's plenty of heat but little steam, says William Osborn, who manages the project. "The same technologies will be applicable ... across the U.S.," he says, "where you have high temperatures at depths everywhere, but you don't have open cracks."
—*Andrew Herndon*

The bottom line *Adding water to geothermal installations could help power companies boost the output of existing facilities and develop new ones.*

ILLUSTRATION BY LEIF PARSONS

NON-RENEWABLE ENERGY RESERVES

1. Oil—32 years (50 with shale oil); U.S. uses ¼ of world's oil and has 2% of the reserves
2. Gas—70 years (100 with shale gas—fracking concerns)
3. Coal—180 years; U.S. has ¼ of global coal; 275 year reserve if domestic use only
4. Nuclear—100-150 year reserves if we can mine uranium

% of U.S. Energy From:

1. Non-renewable sources 92%--37% oil; 25% gas; 21% coal; 9% nuclear
2. Renewable sources—8%
3. Of the Renewable sources—35% Hydropower
   24% Wood
   20% Biofuels
   9% Wind
   6% Biomass waste
   5% Geothermal
   1% Solar
4. Top States for % of electricity generated from renewable sources (2009 data)
   Idaho—86%
   Washington State—75%
   Oregon—66%
   S. Dakota—59%
   Maine—50% (Virginia < 5%)

   Hydropower makes up over 90% in each state except Maine where 45% made up of biomass/waste renewable use

SOLAR ENERGY

1. Active Solar
2. Passive Solar
3. Hydropower (sun driven water cycle)
4. Biomass (sun driven photosynthesis)
5. Wind

WIND IS/ISN'T

1. 1-3% of sunlight goes into wind (still a lot of energy)
2. Mechanics: As wind turns blades, shaft inside the nocelle (box at top of turbine) is turned; goes into a gear box which increases rotational speed enough for generator (using magnetic fields) to

convert rotational energy into electrical energy. Controls to adjust nocelle and blades according to wind direction and speed.

3. Undependable wind—high altitude winds (30,000 feet carry 20 x's as much energy); kites, blimps, gliders; storage of energy—batteries, pumped storage
4. Areas of dependable winds such as plain states often remote—transport energy
5. Condor cuisinart
6. Technological advances—Bedford, Columbia River

HUFFMAN'S LAW

1. Cost per megawatt-hour of electricity (Energy Information Administration data—2011): coal—$95; natural gas $66; nuclear $114; onshore wind $97; offshore wind $243; solar photovoltaics $211; hydroelectric $86; geothermal $102; biomass $113
2. European nations with largest installed bases of alternative energy (Germany and Denmark) pay highest electricity rates in EU; grid storage; variable sun and wind
3. In 2009—worldwide governments gave out $312 billion in subsidies to fossil fuel industry; $57 billion to renewable initiatives (*Discover* 2011)
4. Robert Bryce's book (fellow Manhattan Institute) "Power Hungry: The Myths of 'Green' Energy and the Real Fuels of the Future"—lower gas prices will hinder wind development. In 2010, only 1600 megawatts of new wind capacity installed in US; decline of 72% compared with 2009
5. Boeing experiment in Charleston

Enrico Fermi—Italian physicist; Nobel Prize 1938 for work on the atomic bomb: "Before I came here I was confused about the subject. Having listened to your lecture I am still confused, but on a higher level."