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DAWN OF THE SOLAR ERA

A Wake-Up Call

The sun is the only energy source that can meet the oil depletion challenge. But solar energy ramp-up must be large-scale and immediate.

By Francis de Winter and Ronald B. Swenson

This issue of *SOLAR TODAY* focuses on the Global Hubbert Peak, the point in time when petroleum (and natural gas) will go into unavoidable decline. Here we explore the options available in light of dwindling fossil fuel resources, and we speculate on the scale of solar energy development that will be needed to overcome the expected oil and natural gas shortfall.

Peak oil is an emerging reality. With production already declining in all but a few major oil regions, an energy shortfall is inevitable. As demand for oil continues to grow, this shortfall can only mean disappointment for those around the world who aspire to live more like Americans, consuming their body weight in oil every week (150 pounds on average). Never mind price. Even if price is no object, production will begin to drop and shortages will become increasingly acute. There will be great temptation to exploit high-carbon, non-conventional fossil fuels that could accelerate global warming. To avoid disaster, solar energy must rise, and rapidly, to meet the challenge of oil depletion.

A Coming Crisis

Peak oil is an emerging reality. To avoid disaster, solar energy must rise to meet the oil depletion challenge. *Photo by Ronald B. Swenson*

In 1994 we established contact with leading geologists who were studying oil depletion and created a website, www.oilcrisis.com. Much earlier, one prominent petroleum geophysicist spoke out about the future of oil. In 1956, the late Dr. M. King Hubbert predicted correctly that oil production in the United States would peak around 1970, after which production would decline forever. In the 1960s and 1970s, he predicted that the worldwide "Hubbert Peak" would be reached around the year 2000. The world Hubbert Peak has been postponed a bit because the 1970s energy crisis made us more frugal, but experts agree that it remains imminent. Dr. Farrington Daniels, the founder of our International Solar Energy Society, was associated with Hubbert when he first introduced his peak oil analysis. *(See sidebar, "A Solar Future Long Anticipated.")* Dr. Colin J. Campbell, the most prominent successor of Hubbert, expects the Hubbert Peak in the very near future *(see "The Second Half of the Age of Oil Dawns," page 20)*.

Since the beginning of our short oil era around 1860, world population has increased dramatically. This population growth has been fueled substantially by oil. In the United States, food travels more than 1,000 miles on average, requiring over 10 times the petroleum energy to produce than its solar energy food value (calories). As a practical matter, we are eating mostly petroleum.

Many societies throughout history have faced resource depletion. History tells us that Plato deplored the deforestation in Greece, and that the Greeks started using passive solar orientation in their settlements when they ran out of firewood. Archeologists have found many societies that disintegrated beca16use they depleted their resources with no concern for the future. Some simply abandoned their settlements and moved to fertile land. Others, like the people on Easter Island, could no longer move. They had cut down all their trees and couldn't even make crude boats to fish.

Developed and developing countries alike are addicted to cheap oil. For the United States, depletion is going to be especially difficult. Americans use oil as if it will never run out. The country is designed and built around cars using cheap gasoline. With fossil fuel resources becoming scarce, we have to learn to make do with what we have peacefully or we will have war, depleting humanity's collective resources even further.

What might be the possible early reactions to peak oil?

Conservation: Whenever natural disasters or political disruptions shed light on our energy vulnerability, earnest appeals for conservation can be heard. Conservation can be voluntary: I can choose to buy a Toyota Prius and still go to the beach on the weekend. I will use less oil, but my lifestyle will be preserved.

Deprivation: As oil supplies continue to dwindle, energy conservation will cease to be voluntary. That may lead to rationing if we make a reasoned response. But if depletion is not managed effectively, *deprivation* will overwhelm efforts to conserve rationally. As shortages impact the industrialized world, trips to the beach will be sparse. Lifestyles will change.

Conflict: With oil as an essential foundation of productive modern agriculture and starvation already intense in certain regions, it can be argued that the poor of the world are already deprived, involuntary participants in energy conservation. Energy inequities will continue to grow between haves and have-nots, struggle over the remaining oil reserves will intensify. Some say the conflict in Iraq is a grab for oil. Whether true or not, how might we avoid conflicts over energy resources?

Substitution: We will inevitably have to find other energy sources, substituting new energy for oil and what oil does. Are there solutions close at hand?

No Answers in Non-Conventional Oil, Nuclear

One place where the peak oil message is being heard is at the margins of the oil, gas and coal industries. As energy prices rise exponentially, researchers are attempting to exploit carbon-intensive, non-conventional fossil fuels to replace transportation fuels. Massive investments have been made to extract tar sands in Alberta; research is ramping up to find a way to convert oil shale in Wyoming and Colorado; and improved technologies are being developed to convert coal to liquids, using the same process that fueled Hitler's desperate army.

But such attempts have produced inadequate amounts of net energy. For heat to extract oil from tar sands, natural gas equivalent to one-third of a barrel is used per barrel. This natural gas is in addition to the liquid fuels and electricity needed for mining, refining and environmental remediation. Recognizing rising natural gas prices, advocates are even suggesting nuclear power to replace natural gas for heat in the extraction process.

Nuclear power is also being examined for the extraction of oil shale. This misnamed substance (neither shale nor oil but marlstone and kerogen, an immature hydrocarbon) must be heated under pressure to convert it to oil. One proponent in Colorado envisions a nuclear facility generating more power to heat oil shale *in situ* than all electricity now consumed statewide. Water requirements and environmental impacts could be huge.

As the informed public becomes aware of the impact of greenhouse gases, nuclear power is being promoted again, this time as a carbon-free energy source. But the popular notion that nuclear is carbon-neutral is faulty. High-grade uranium ores have already been exploited, and the mining and refining of lower-grade uranium ores are increasingly fossil-fuel intensive.

If all bets are placed on marginal fossil fuels and nuclear power, the consequences for society will be dire. Perpetuating the automotive fleet, for example, may seem laudable. But propping up the fleet with low-grade fuels could be more dangerous than doing nothing because, as U.S. Rep. Roscoe G. Bartlett suggests in his article (page 27), these marginal sources too will run out, and humanity will be left high and dry.

Only Solar Energy Can Fill the Gap

Meanwhile, renewable energy technologies are being brushed aside by some peak oil “experts” as too intermittent or diffuse to merit serious attention. Let’s examine a few of these objections to a full-scale transformation to renewables.

“Solar energy, plant biomass and other renewable forms of energy are diffuse forms of energy.”

Direct sunlight is indeed *diffuse*, but thin collectors are a perfect match to diffuse. Mirrored surfaces on solar concentrators are thin. Solar cells are thin, and thin-film cells are even thinner. Furthermore, sunlight is far more evenly distributed around the globe than is oil.

“Photovoltaic electricity is expensive.”

The *profitability* test is often the result of accumulated political decisions favoring special interests. In economics it is formally assumed that oil and other natural resources have no value until they are “produced” (i.e., extracted), and then the only value assigned to the resources is the cost of extracting them. They are free for the taking, and so we have been paying nothing for the inherent value of oil. Lobbying efforts have provided large subsidies for oil. Externalities are not charged at the gas pump. Preferential tax treatments, highway construction and defense budgets underpin the oil economy. Renewable energy subsidies are beginning to level the playing field. As fossil fuel costs increase, the economics of renewable energy will transform the market. *(See January/ February* SOLAR TODAY *for features on the theme, “Solar Energy Cost Breakthrough Ahead?”)*

“The EROI (energy return on investment, or net yield) for fossil fuels tends to be large, while that for solar tends to be low.”

A hundred years ago, oil gushers yielded high net-energy recovery rates, but today solar, hydroelectric and wind power have net energy

A Solar Future Long Anticipated

When Hubbert predicted global peak oil, Farrington Daniels focused on the solution.

The afternoon of Sept. 15, 1948, was an important date for solar energy, the petroleum industry and the International Solar Energy Society (ISES). The American Association for the Advancement of Science (AAAS) was 100 years old, and AAAS President Edmund Sinnott, Ph.D., invited three prominent speakers for a Symposium on Sources of Energy at the Centennial Celebration in Washington, D.C.:

- **Dr. M. King Hubbert**, a geologist working for Shell Oil, addressed ***oil depletion***, as the “Golden Century of Oil” was getting under way.
- **Dr. Farrington Daniels**, a physical chemist who had been in charge of the Chicago branch of the Manhattan Project and later started the organization that would become ISES, addressed the future of ***solar energy***, while solar energy was still a dream.
- **Dr. Eugene P. Wigner** of Princeton, who would receive the 1963 Nobel Prize in Physics and who had worked on the Manhattan Project for Daniels, addressed the future of ***atomic energy***, about eight years before there were any commercial power reactors.

yields higher than conventional fuels such as oil, gas and coal, and an order of magnitude better than non-conventional fossil fuels. With their inherently high net-energy yields, renewables can be ramped up rapidly. *(See table, "Estimated Net Energy Yield of Conventional and Renewable Sources in the U.S.," page 16.)*

"Neither solar nor wind power is an immediate, large-scale solution to the energy problem. … Plants, on average, capture only about 0.1 percent of the solar energy reaching the Earth."

Humanity's "primary energy production," including all fossil fuels, nuclear power, hydroelectric and renewables, is 13 terawatts (equivalent to 13,000 large power plants), less than 1/100 of 1 percent of the 170,000 terawatts continuously delivered to the earth as sunlight. With 600 terawatts of terrestrial potential, solar energy far exceeds all other possible forms of substitution. *(See sidebar, "How Will We Fill the Fossil Fuel Gap?" page 17.)*

Transportation in a post-cheap-oil world poses special challenges. If non-conventional fossil fuels are untenable and transportation is powered almost exclusively by liquid fuels, it is tempting to propose biomass as a substitute for oil. In the United States, 1 billion tons of biomass are managed each year. To meet all our energy needs, 7 billion tons more would be required. Obviously, electric airplanes or cargo ships are impractical, so biomass will play an important role in our energy future. But liquid fuels exclusively from plant material will be possible for transport at only about one-tenth the present level worldwide. Something has to give.

Considering society's huge investment in the vehicle fleet and these limitations of biofuels, it is difficult to imagine the transformation of transportation to renewable energy sources. To make the shift, the premise that solar energy must be converted into fuel has to be challenged. A direct path from sunlight to electricity can be 10 times as efficient as photosynthesis. Solar energy can't be touched or put into a bottle. Solar is *radiant energy*, not a solid, liquid or gas.

Electricity from renewables is ideally suited for urban transportation. It is nonpolluting and well-suited for fixed guide rail and automated routing of traffic, and an electric vehicle is at least twice

At this symposium, Hubbert presented his first paper on what would become known as the "Hubbert Curve," the brief period in human history during which petroleum was discovered; adopted by society as its principal energy source; extracted in ever greater quantities; burned with no serious concern for the future; fostered affluence, wars and pollution; became ever harder to find and "produce"; and was destined to decline inexorably — leaving us no choice but to switch to sustainable energy sources.

Even in this first paper, Hubbert warned that the post-oil transition process would be extremely difficult. Neither Daniels nor Wigner had much to offer except hope; solar and atomic energy technologies were still primitive. Despite Daniels' experience in the Manhattan Project (or perhaps because of it), he decided to concentrate on solar energy, forming the society now known as ISES and creating a solar energy program at the University of Wisconsin-Madison that remains famous.

Getting to know Hubbert made Daniels aware of oil depletion and the energy deficiencies that solar energy would have to address. In 1964 Daniels wrote that U.S. oil "production" would peak about five years later, as Hubbert had predicted accurately in 1956, and that worldwide oil scarcity would begin shortly after 2010. As humanity now encounters the Hubbert Peak, the man who established ISES to meet the challenge of oil depletion will inspire members of the solar community in the decades ahead.

as efficient as a gasoline vehicle. We are ready for a good reason to get rid of the internal combustion engine in dense urban areas, where it is about as practical as a campfire in the kitchen. Efficiency in the face of oil depletion is that compelling reason.

Solar technologies continue to improve, and so do electric vehicles. A battery with three times the energy density of lead-acid and a charging time under two minutes is scheduled for introduction in 2007 or 2008. Shanghai has an electromagnetic propulsion maglev train that travels at 270 miles per hour.

Getting Up to Speed: Think Terawatts

According to Campbell and other leading peak oil experts, permanent oil decline will begin during this decade and will likely proceed initially at 2 to 8 percent per year. If oil declines at 4 percent and photovoltaic manufacturing grows at 40 percent per year until 2020, PV would meet less than 20 percent of the oil shortfall without meeting any demand growth. If the PV industry sustains growth averaging 50 percent or more per year, it will contribute significantly. Though such growth is an aggressive goal, it is realistic under a scenario slightly more ambitious than the two-year doubling time projection that Ron Larson presents in this issue's "Chair's Corner" (page 4). As nonsilicon-based solar products quickly become commercialized, this goal is even more feasible. *(See graphic, "As Oil Supplies Decline, Photovoltaic Capacity Grows," left.)* Developing similar growth rates for all renewables, it will be possible for sustainable solutions to realize their potential for oil, gas and coal substitution. The sidebar, "Making the Transition," (page 29), samples some industry proposals.

France converted from zero to nearly 100 percent nuclear power in less than 20 years. Renewable energy technologies have higher net-energy yield than nuclear by far and are faster to install, so it will be possible to ramp up in even less time. If others continue to insist that nuclear power, tar sands or coal-toliquids are options, the move to renewables will be even more critical as the only pathway that avoids potential nuclear terrorism and curbs global warming.

We must recognize the limits of our fossil fuel reserves and begin to push for rapid growth in solar energy. For the first time in history, all of humanity will share the same problem. This common challenge can help unify us, to recognize the futility of war and to make governments more responsive to our needs. We will need large national and international programs, similar in ambition and spirit to the Apollo "Man on the Moon" program, to reduce our oil consumption and to create alternative energy sources. This transition will provide many good local jobs that cannot possibly be outsourced, and we will need a significant grassroots effort.

If we get it right, we will be able to share a future of clean air and fresh water, viable oceans, thriving forests and peaceful coexistence. We must get it right, and be proud that we are members of the generation entrusted with the task.

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