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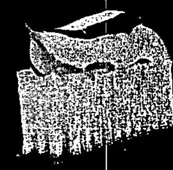

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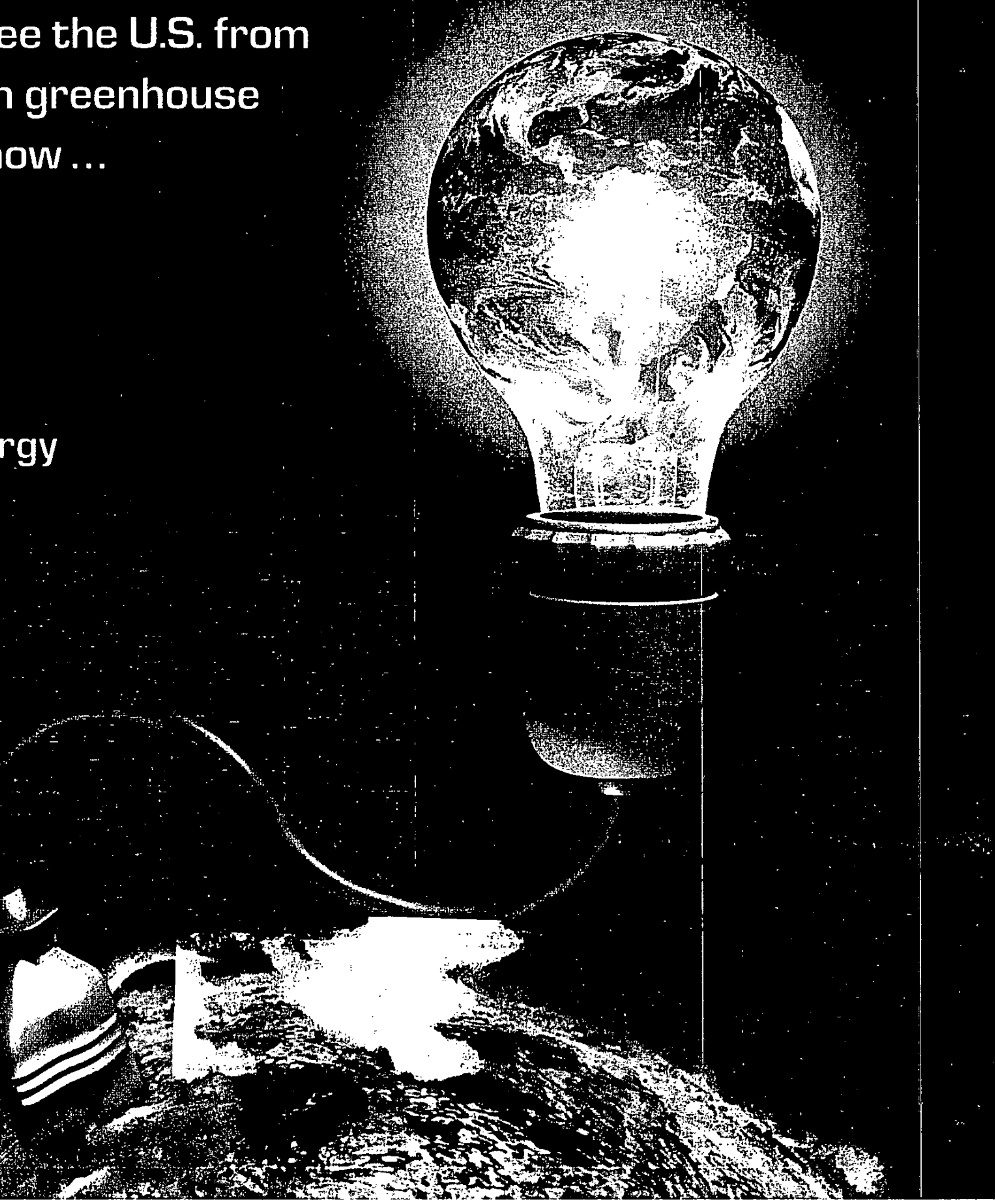
A GRAND PLAN FOR SOLAR ENERGY

By 2050 it could free the U.S. from foreign oil and slash greenhouse emissions. Here's how ...



Tiny Devices Reclaim Wasted Energy

It Kills Tumors by Repairing Them

The Physics of the Voice

By 2050 solar power could end U.S. dependence on foreign oil and slash greenhouse gas emissions

By Ken Zweibel, James Mason and Vasilis Fthenakis

High prices for gasoline and home heating oil are here to stay. The U.S. is at war in the Middle East at least in part to protect its foreign oil interests. And as China, India and other nations rapidly increase their demand for fossil fuels, future fighting over energy looms large. In the meantime, power plants that burn coal, oil and natural gas, as well as vehicles everywhere, continue to pour millions of tons of pollutants and greenhouse gases into the atmosphere annually, threatening the planet.

Well-meaning scientists, engineers, economists and politicians have proposed various steps that could slightly reduce fossil-fuel use and emissions. These steps are not enough. The U.S. needs a bold plan to free itself from fossil fuels. Our analysis convinces us that a massive switch to solar power is the logical answer.

Solar energy's potential is off the chart. The energy in sunlight striking the earth for 40 minutes is equivalent to global energy consumption for a year. The U.S. is lucky to be endowed with a vast resource; at least 250,000 square miles of land in the Southwest alone are suitable for constructing solar power plants, and that land receives more than 4,500 quadrillion British thermal units (Btu) of solar radiation a year. Converting only 2.5 percent of that radiation into electricity would match the nation's total energy consumption in 2006.

To convert the country to solar power, huge tracts of land would have to be covered with photovoltaic panels and solar heating troughs. A direct-current (DC) transmission backbone would also have to be erected to send that energy efficiently across the nation.

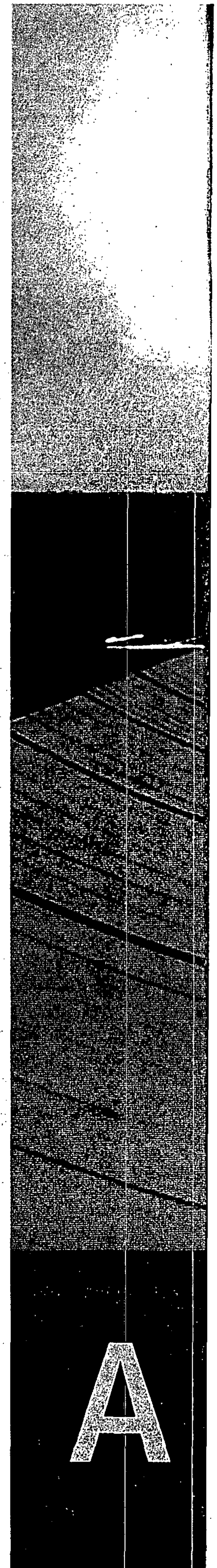
The technology is ready. On the following pages we present a grand plan that could provide 69 percent of the U.S.'s electricity and 35 percent of its total energy (which includes transportation) with solar power by 2050. We project that this energy could be sold to consumers at rates equivalent to today's rates for conventional power sources, about five cents per kilowatt-hour (kWh). If wind, biomass and geothermal sources were also developed, renewable energy could provide 100 percent of the nation's electricity and 90 percent of its energy by 2100.

The federal government would have to invest more than $400 billion over the next 40 years to complete the 2050 plan. That investment is substantial, but the payoff is greater. Solar plants consume little or no fuel, saving billions of dollars year after year. The infrastructure would displace 300 large coal-fired power plants and 300 more large natural gas plants and all the fuels they consume. The plan would effectively eliminate all imported oil, fundamentally cutting U.S. trade deficits and easing political tension in the Middle East

KEY CONCEPTS

- A massive switch from coal, oil, natural gas and nuclear power plants to solar power plants could supply 69 percent of the U.S.'s electricity and 35 percent of its total energy by 2050.
- A vast area of photovoltaic cells would have to be erected in the Southwest. Excess daytime energy would be stored as compressed air in underground caverns to be tapped during nighttime hours.
- Large solar concentrator power plants would be built as well.
- A new direct-current power transmission backbone would deliver solar electricity across the country.
- But $420 billion in subsidies from 2011 to 2050 would be required to fund the infrastructure and make it cost-competitive.

—*The Editors*



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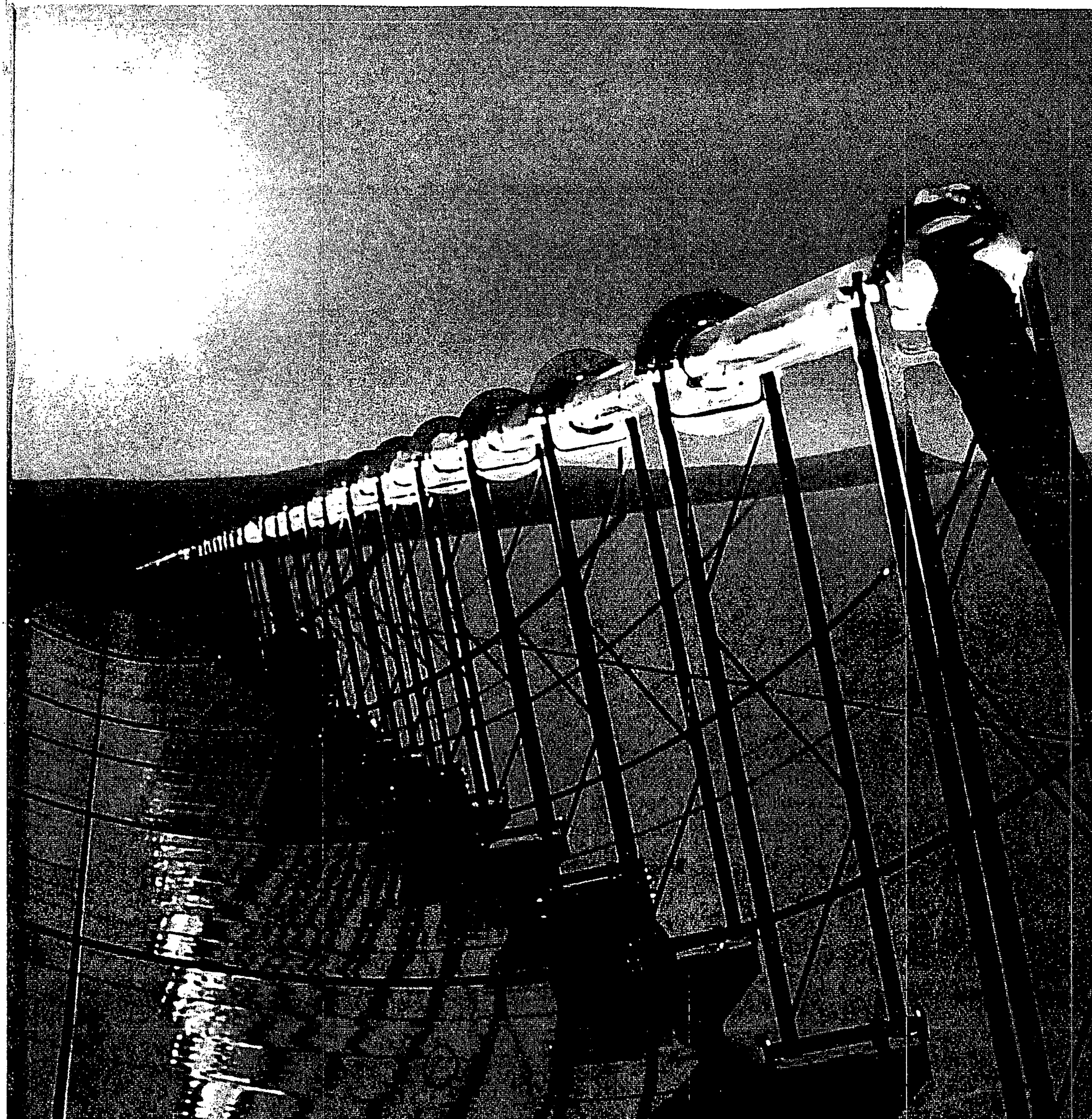


Solar Grand Plan

and elsewhere. Because solar technologies are almost pollution-free, the plan would also reduce greenhouse gas emissions from power plants by 1.7 billion tons a year, and another 1.9 billion tons from gasoline vehicles would be displaced by plug-in hybrids refueled by the solar power grid. In 2050 U.S. carbon dioxide emissions would be 62 percent below 2005 levels, putting a major brake on global warming.

Photovoltaic Farms

In the past few years the cost to produce photovoltaic cells and modules has dropped significantly, opening the way for large-scale deployment. Various cell types exist, but the least expensive modules today are thin films made of cadmium telluride. To provide electricity at six cents per kWh by 2020, cadmium telluride modules would have to convert electricity with 14 percent efficiency, and systems would have to be installed at $1.20 per watt of capacity. Current modules have 10 percent efficiency and an installed system cost of about $4 per watt. Progress is clearly needed, but the technology is advancing quickly; commercial efficiencies have risen from 9 to 10 percent in the past 12 months. It is worth noting, too, that as modules improve, rooftop photovoltaics will become more cost-competitive for homeowners, reducing daytime electricity demand.

In our plan, by 2050 photovoltaic technology would provide almost 3,000 gigawatts (GW), or billions of watts, of power. Some 30,000 square miles of photovoltaic arrays would have to be erected. Although this area may sound enormous, installations already in place indicate that the land required for each gigawatt-hour of solar energy produced in the Southwest is less than that needed for a coal-powered plant when factoring in land for coal mining. Studies by the National Renewable Energy Laboratory in Golden, Colo., show that more than enough land in the Southwest is available without requiring use of environmentally sensitive areas, population centers or difficult terrain. Jack Lavelle, a spokesperson for Arizona's Department of Water Conservation, has noted that more than 80 percent of his state's land is not privately owned and that Arizona is very interested in developing its solar potential. The benign nature of photovoltaic plants (including no water consumption) should keep environmental concerns to a minimum.

The main progress required, then, is to raise module efficiency to 14 percent. Although the

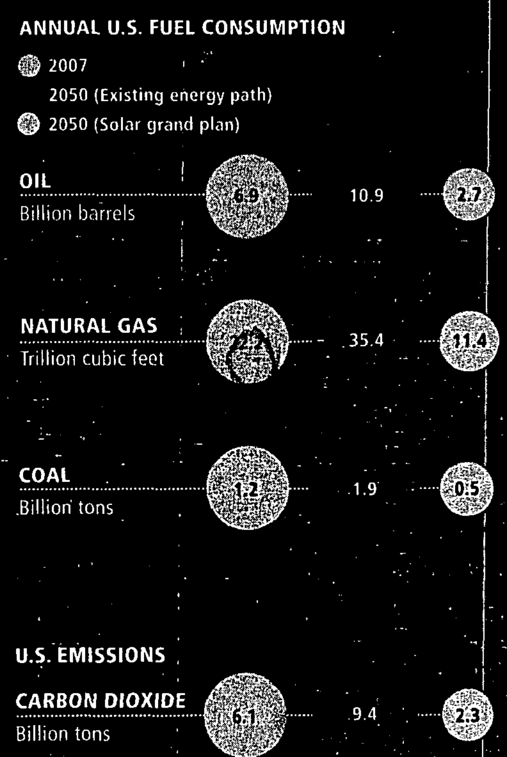
JEN CHRISTIANSEN (*graph*); KENN BROWN AND CHRIS WREN *Mondolithic Studios* (*illustration*)

U.S. Plan for 2050

Solar Power Provides . . .

69% of electricity | **35%** of total energy

By 2050 vast photovoltaic arrays in the Southwest would supply electricity instead of fossil-fueled power plants and would also power a widespread conversion to plug-in electric vehicles. Excess energy would be stored as compressed air in underground caverns. Large arrays that concentrate sunlight to heat water would also supply electricity. A new high-voltage, direct-current transmission backbone would carry power to regional markets nationwide. The technologies and factors critical to their success are summarized at the right, along with the extent to which the technologies must be deployed by 2050. The plan would substantially cut the country's consumption of fossil fuels and its emission of greenhouse gases (*below*). We have assumed a 1 percent annual growth in net energy demand. And we have anticipated improvements in solar technologies forecasted only until 2020, with no further gains beyond that date. —*K.Z., J.M. and V.F.*



TECHNOLOGY

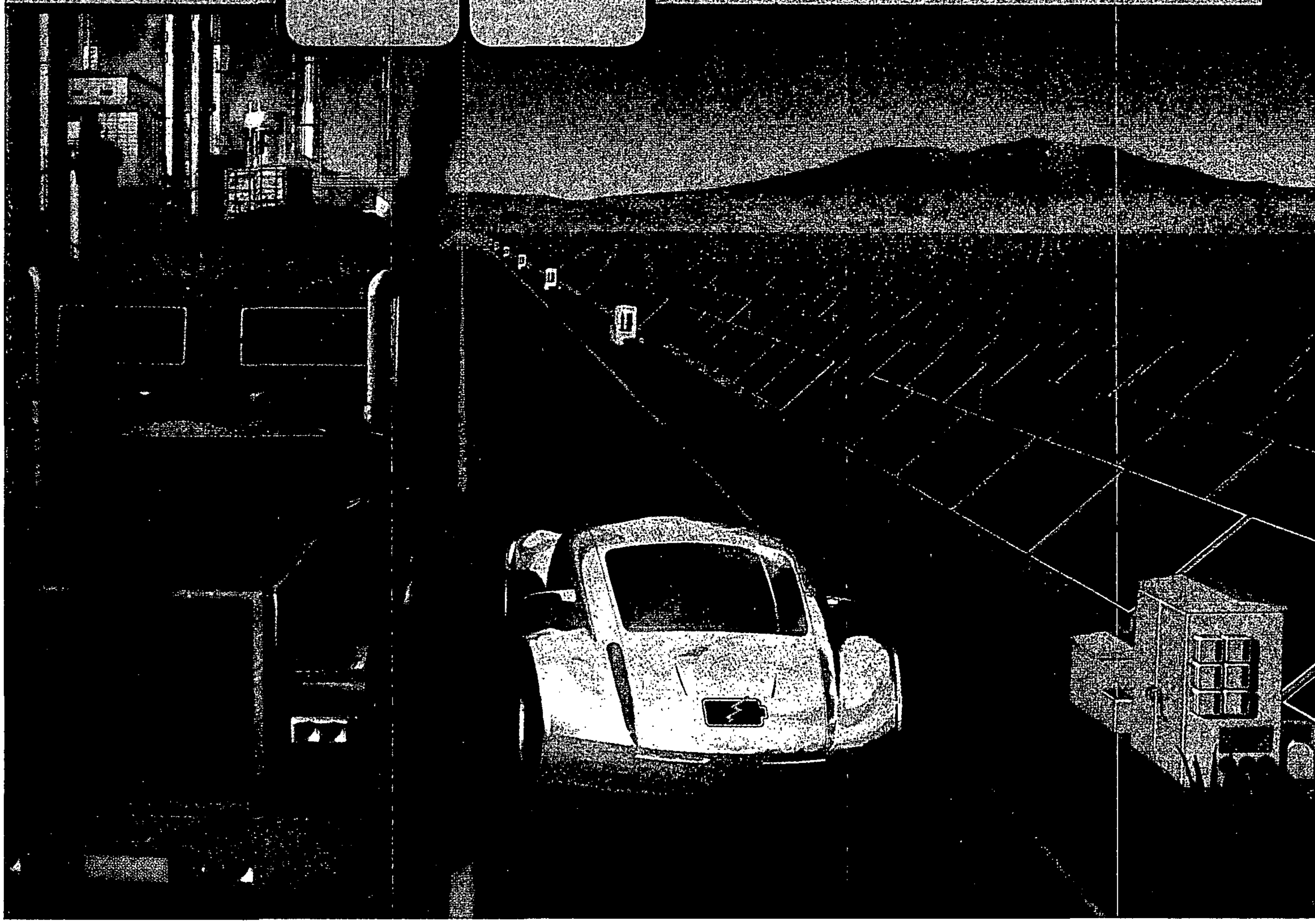
PHOTOVOLTAICS

COMPRESSED-AIR ENERGY STORAGE (with photovoltaic electricity)

CONCENTRATED SOLAR POWER

DC TRANSMISSION

CRITICAL FACTOR	2007	2050	ADVANCES NEEDED
Land area	10 sq miles	30,000 sq miles	Policies to develop large public land areas
Thin-film module efficiency	10%	14%	More transparent materials to improve light transmission; more densely doped layers to increase voltage; larger modules to reduce inactive area
Installed cost	$4/W	$1.20/W	Improvements in module efficiency; gains from volume production
Electricity price	16¢/kWh	5¢/kWh	Follows from lower installed cost
Total capacity	0.5 GW	2,940 GW	National energy plan built around solar power
Volume	0	535 billion cu ft	Coordination of site development with natural gas industry
Installed cost	$5.80/W	$3.90/W	Economies of scale; decreasing photovoltaic electricity prices
Electricity price	20¢/kWh	9¢/kWh	Follows from lower installed cost
Total capacity	0.1 GW	558 GW	National energy plan
Land area	10 sq miles	16,000 sq miles	Policies to develop large public land areas
Solar-to-electric efficiency	13%	17%	Fluids that transfer heat more effectively
Installed cost	$5.30/W	$3.70/W	Single-tank thermal storage systems; economies of scale
Electricity price	18¢/kWh	9¢/kWh	Follows from lower installed cost
Total capacity	0.5 GW	558 GW	National energy plan
Length	500 miles	100,000–500,000 miles	New high-voltage DC grid from Southwest to rest of country



By 2100 renewable energy could generate 100 percent of the U.S.'s electricity and more than 90 percent of its energy.

efficiencies of commercial modules will never reach those of solar cells in the laboratory, cadmium telluride cells at the National Renewable Energy Laboratory are now up to 16.5 percent and rising. At least one manufacturer, First Solar in Perrysburg, Ohio, increased module efficiency from 6 to 10 percent from 2005 to 2007 and is reaching for 11.5 percent by 2010.

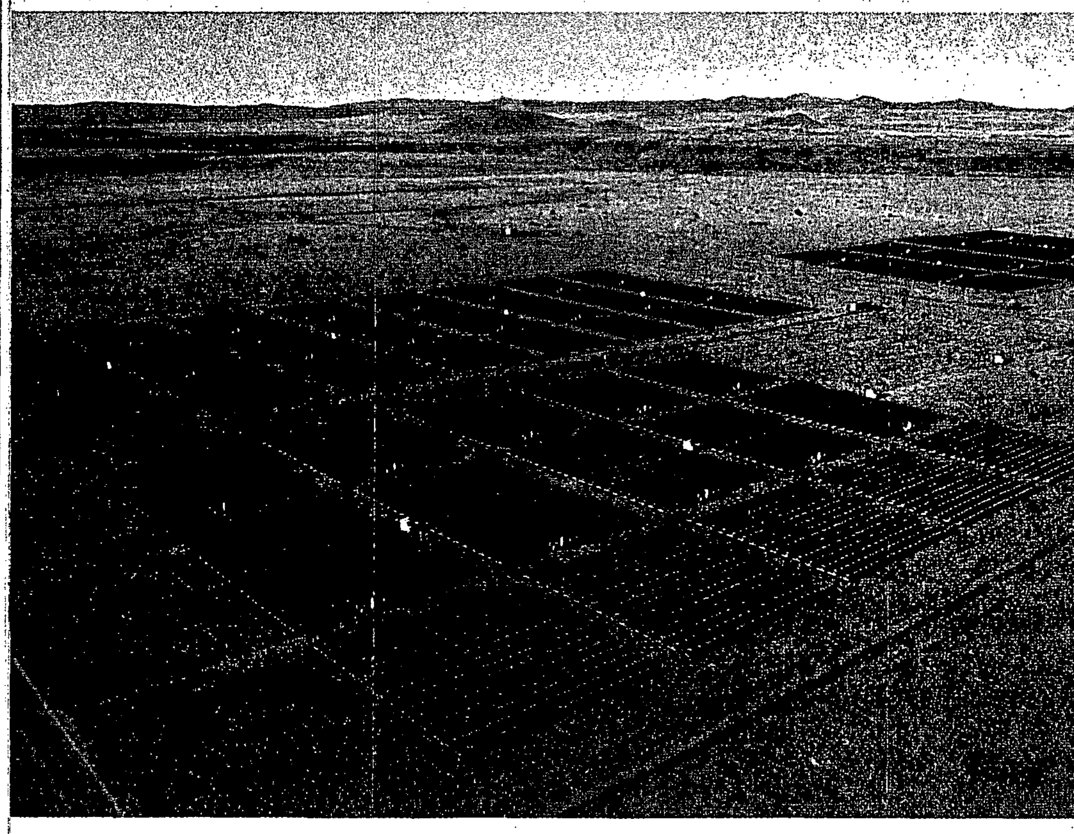
Pressurized Caverns

The great limiting factor of solar power, of course, is that it generates little electricity when skies are cloudy and none at night. Excess power must therefore be produced during sunny hours and stored for use during dark hours. Most energy storage systems such as batteries are expensive or inefficient.

Compressed-air energy storage has emerged as a successful alternative. Electricity from photovoltaic plants compresses air and pumps it into vacant underground caverns, abandoned mines, aquifers and depleted natural gas wells. The pressurized air is released on demand to turn a turbine that generates electricity, aided by burning small amounts of natural gas. Compressed-air energy storage plants have been operating reliably in Huntorf, Germany, since 1978 and in McIntosh, Ala., since 1991. The turbines burn only 40 percent of the natural gas they would if they were fueled by natural gas alone, and better heat recovery technology would lower that figure to 30 percent.

Studies by the Electric Power Research Institute in Palo Alto, Calif., indicate that the cost of compressed-air energy storage today is about half that of lead-acid batteries. The research indicates that these facilities would add three or four cents per kWh to photovoltaic generation, bringing the total 2020 cost to eight or nine cents per kWh.

Electricity from photovoltaic farms in the Southwest would be sent over high-voltage DC transmission lines to compressed-air storage facilities throughout the country, where turbines would generate electricity year-round. The key is to find adequate sites. Mapping by the natural gas industry and the Electric Power Research Institute shows that suitable geologic formations exist in 75 percent of the country, often close to metropolitan areas. Indeed, a compressed-air energy storage system would look similar to the U.S. natural gas storage system. The industry stores eight trillion cubic feet of gas in 400 underground reservoirs. By 2050 our plan would require 535 billion cubic feet of storage, with air pressurized at 1,100 pounds per square inch. Although development will be a challenge, plenty of reservoirs are available,



TUCSON ELECTRIC POWER COMPANY

Photovoltaics

In the 2050 plan vast photovoltaic farms would cover 30,000 square miles of otherwise barren land in the Southwest. They would resemble Tucson Electric Power Company's 4.6-megawatt plant in Springerville, Ariz., which began in 2000 (*left*). In such farms, many photovoltaic cells are interconnected on one module, and modules are wired together to form an array (*right*). The direct current from each array flows to a transformer that sends it along high-voltage lines to the power grid. In a thin-film cell (*inset*), the energy of incoming photons knocks loose electrons in the cadmium telluride layer; they cross a junction, flow to the top conductive layer and then flow around to the back conductive layer, creating current.

and it would be reasonable for the natural gas industry to invest in such a network.

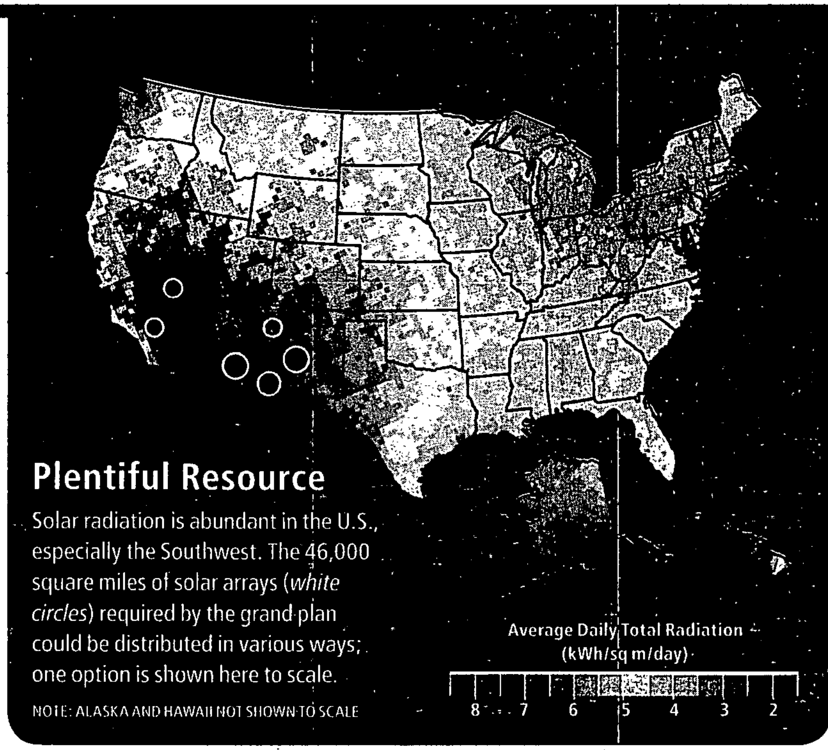
Hot Salt

Another technology that would supply perhaps one fifth of the solar energy in our vision is known as concentrated solar power. In this design, long, metallic mirrors focus sunlight onto a pipe filled with fluid, heating the fluid like a huge magnifying glass might. The hot fluid runs through a heat exchanger, producing steam that turns a turbine.

For energy storage, the pipes run into a large, insulated tank filled with molten salt, which retains heat efficiently. Heat is extracted at night, creating steam. The molten salt does slowly cool, however, so the energy stored must be tapped within a day.

Nine concentrated solar power plants with a total capacity of 354 megawatts (MW) have been generating electricity reliably for years in the U.S. A new 64-MW plant in Nevada came online in March 2007. These plants, however, do not have heat storage. The first commercial installation to incorporate it—a 50-MW plant with seven hours of molten salt storage—is being constructed in Spain, and others are being designed around the world. For our plan, 16 hours of storage would be needed so that electricity could be generated 24 hours a day.

Existing plants prove that concentrated solar power is practical, but costs must decrease. Economies of scale and continued research would help. In 2006 a report by the Solar Task Force of the Western Governors' Association concluded that concentrated solar power could provide electricity at 10 cents per kWh or less by 2015 if 4 GW of plants were constructed. Finding ways to boost the temperature of heat exchanger fluids would raise operating efficiency,



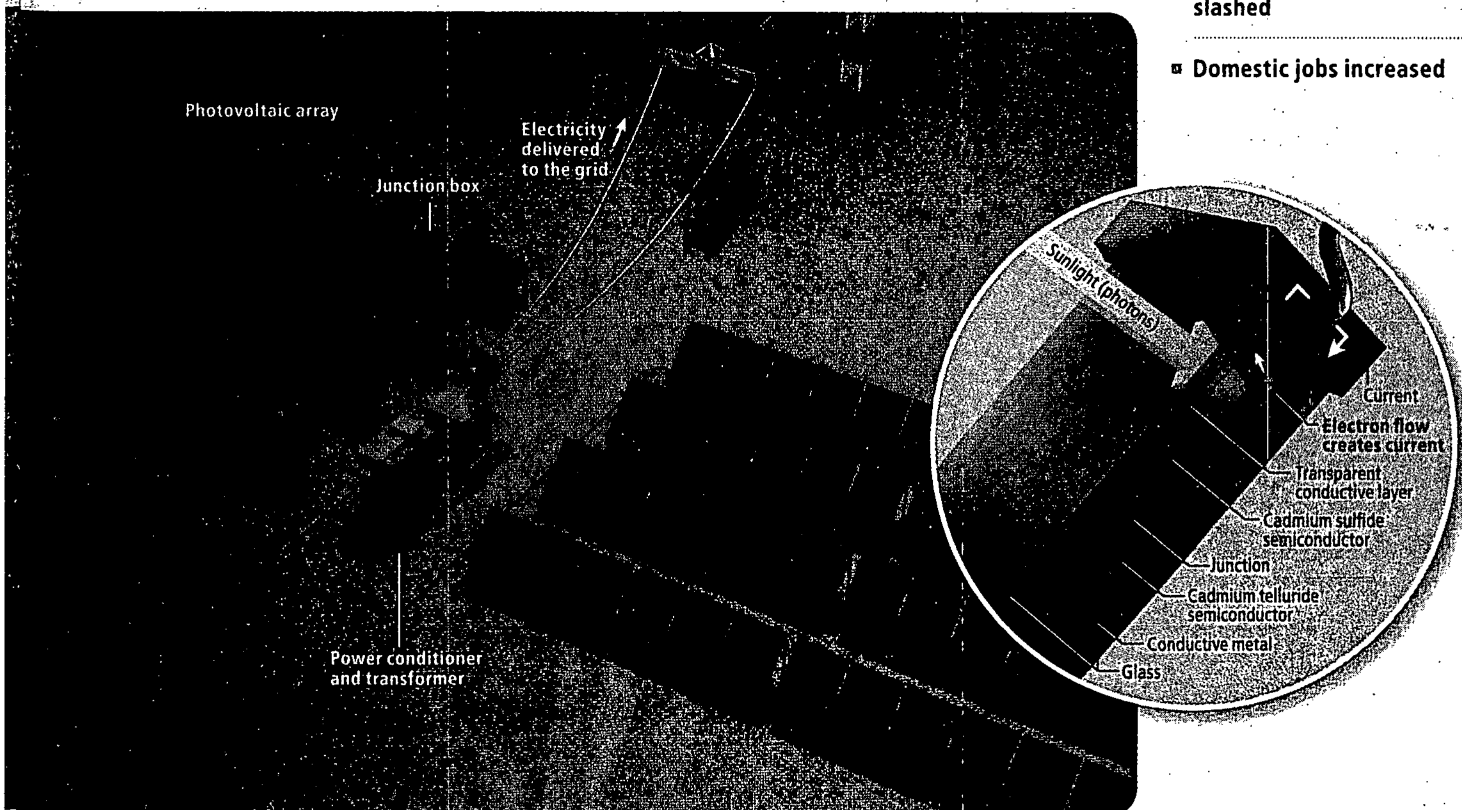
Plentiful Resource

Solar radiation is abundant in the U.S., especially the Southwest. The 46,000 square miles of solar arrays (*white circles*) required by the grand plan could be distributed in various ways; one option is shown here to scale.

NOTE: ALASKA AND HAWAII NOT SHOWN TO SCALE

PAYOFFS

- **Foreign oil dependence cut from 60 to 0 percent**
- **Global tensions eased and military costs lowered**
- **Massive trade deficit reduced significantly**
- **Greenhouse gas emissions slashed**
- **Domestic jobs increased**



SOURCE FOR MAP: COURTESY OF NATIONAL RENEWABLE ENERGY LABORATORY; DON FOLEY (*illustrations*)

too. Engineers are also investigating how to use molten salt itself as the heat-transfer fluid, reducing heat losses as well as capital costs. Salt is corrosive, however, so more resilient piping systems are needed.

Concentrated solar power and photovoltaics represent two different technology paths. Neither is fully developed, so our plan brings them both to large-scale deployment by 2020, giving them time to mature. Various combinations of solar technologies might also evolve to meet demand economically. As installations expand, engineers and accountants can evaluate the pros and cons, and investors may decide to support one technology more than another.

Direct Current, Too

The geography of solar power is obviously different from the nation's current supply scheme. Today coal, oil, natural gas and nuclear power plants dot the landscape, built relatively close to where power is needed. Most of the country's solar generation would stand in the Southwest. The existing system of alternating-current (AC) power lines is not robust enough to carry power from these centers to consumers everywhere and would lose too much energy over long hauls. A new high-voltage, direct-current (HVDC) power transmission backbone would have to be built.

Studies by Oak Ridge National Laboratory indicate that long-distance HVDC lines lose far less energy than AC lines do over equivalent spans. The backbone would radiate from the Southwest toward the nation's borders. The lines would terminate at converter stations where the power would be switched to AC and sent along existing regional transmission lines that supply customers.

The AC system is also simply out of capacity, leading to noted shortages in California and other regions; DC lines are cheaper to build and require less land area than equivalent AC lines. About 500 miles of HVDC lines operate in the U.S. today and have proved reliable and efficient. No major technical advances seem to be needed, but more experience would help refine operations. The Southwest Power Pool of Texas is designing an integrated system of DC and AC transmission to enable development of 10 GW of wind power in western Texas. And TransCanada, Inc., is proposing 2,200 miles of HVDC lines to carry wind energy from Montana and Wyoming south to Las Vegas and beyond.

PINCH POINTS

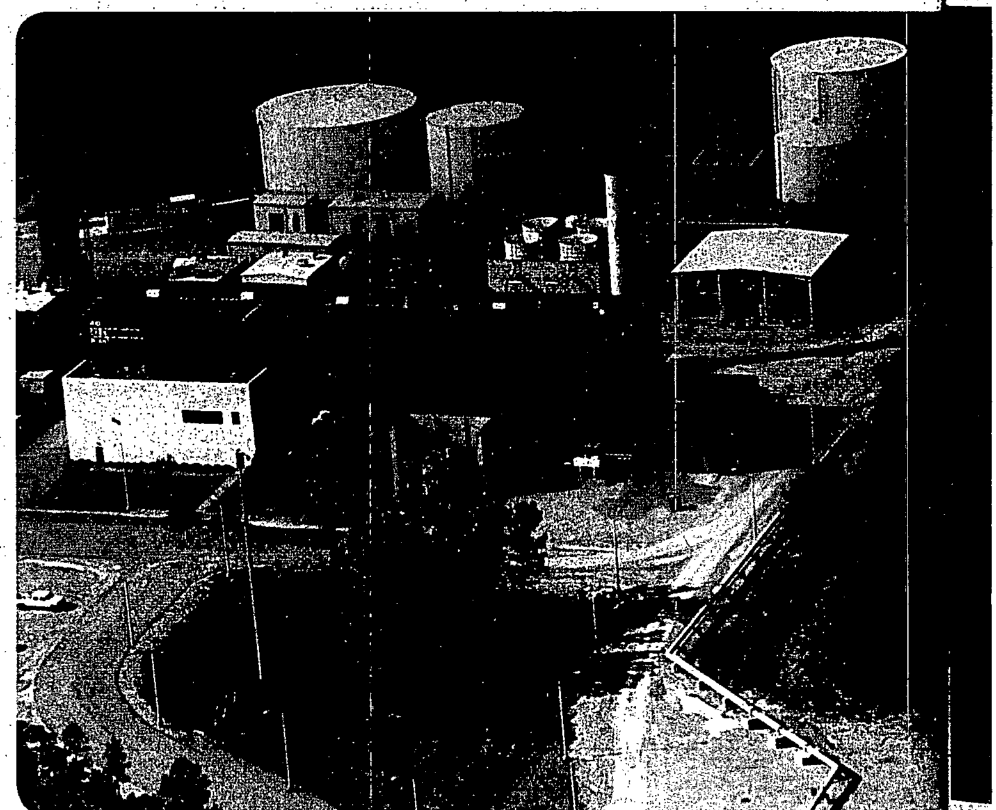
- **Subsidies totaling $420 billion through 2050**
- **Political leadership needed to raise the subsidy, possibly with a carbon tax**
- **New high-voltage, direct-current electric transmission system built profitably by private carriers**

Stage One: Present to 2020

We have given considerable thought to how the solar grand plan can be deployed. We foresee two distinct stages. The first, from now until 2020, must make solar competitive at the mass-production level. This stage will require the government to guarantee 30-year loans, agree to purchase power and provide price-support subsidies. The annual aid package would rise steadily from 2011 to 2020. At that time, the solar technologies would compete on their own merits. The cumulative subsidy would total $420 billion (we will explain later how to pay this bill).

About 84 GW of photovoltaics and concentrated solar power plants would be built by 2020. In parallel, the DC transmission system would be laid. It would expand via existing rights-of-way along interstate highway corridors, minimizing land-acquisition and regulatory hurdles. This backbone would reach major markets in Phoenix, Las Vegas, Los Angeles and San Diego to the west and San Antonio, Dallas, Houston, New Orleans, Birmingham, Ala., Tampa, Fla., and Atlanta to the east.

Building 1.5 GW of photovoltaics and 1.5 GW of concentrated solar power annually in the first five years would stimulate many manufacturers to scale up. In the next five years, annual



POWERSOUTH ENERGY COOPERATIVE

construction would rise to 5 GW apiece, helping firms optimize production lines. As a result, solar electricity would fall toward six cents per kWh. This implementation schedule is realistic; more than 5 GW of nuclear power plants were built in the U.S. each year from 1972 to 1987. What is more, solar systems can be manufactured and installed at much faster rates than conventional power plants because of their straightforward design and relative lack of environmental and safety complications.

Stage Two: 2020 to 2050

It is paramount that major market incentives remain in effect through 2020, to set the stage for self-sustained growth thereafter. In extending our model to 2050, we have been conservative. We do not include any technological or cost improvements beyond 2020. We also assume that energy demand will grow nationally by 1 percent a year. In this scenario, by 2050 solar power plants will supply 69 percent of U.S. electricity and 35 percent of total U.S. energy. This quantity includes enough to supply all the electricity consumed by 344 million plug-in hybrid vehicles, which would displace their gasoline counterparts, key to reducing dependence on foreign oil and to mitigating greenhouse gas emissions. Some three million new domestic jobs—notably in manufacturing solar components—would be created, which is several times the number of U.S. jobs that would be lost in the then dwindling fossil-fuel industries.

The huge reduction in imported oil would lower trade balance payments by $300 billion a year, assuming a crude oil price of $60 a barrel (average prices were higher in 2007). Once solar power plants are installed, they must be maintained and repaired, but the price of sunlight is forever free, duplicating those fuel savings year after year. Moreover, the solar investment would enhance national energy security, reduce financial burdens on the military, and greatly decrease the societal costs of pollution and global warming, from human health problems to the ruining of coastlines and farmlands.

Ironically, the solar grand plan would lower energy consumption. Even with 1 percent annual growth in demand, the 100 quadrillion Btu consumed in 2006 would *fall* to 93 quadrillion Btu by 2050. This unusual offset arises because a good deal of energy is consumed to extract and process fossil fuels, and more is wasted in burning them and controlling their emissions.

To meet the 2050 projection, 46,000 square miles of land would be needed for photovoltaic and concentrated solar power installations. That area is large, and yet it covers just 19 percent of

[THE AUTHORS]

Ken Zweibel, James Mason and Vasilis Fthenakis met a decade ago while working on life-cycle studies of photovoltaics. Zweibel is president of PrimeStar Solar in Golden, Colo., and for 15 years was manager of the National Renewable Energy Laboratory's Thin-Film PV Partnership. Mason is director of the Solar Energy Campaign and the Hydrogen Research Institute in Farmingdale, N.Y. Fthenakis is head of the Photovoltaic Environmental Research Center at Brookhaven National Laboratory and is a professor in and director of Columbia University's Center for Life Cycle Analysis.

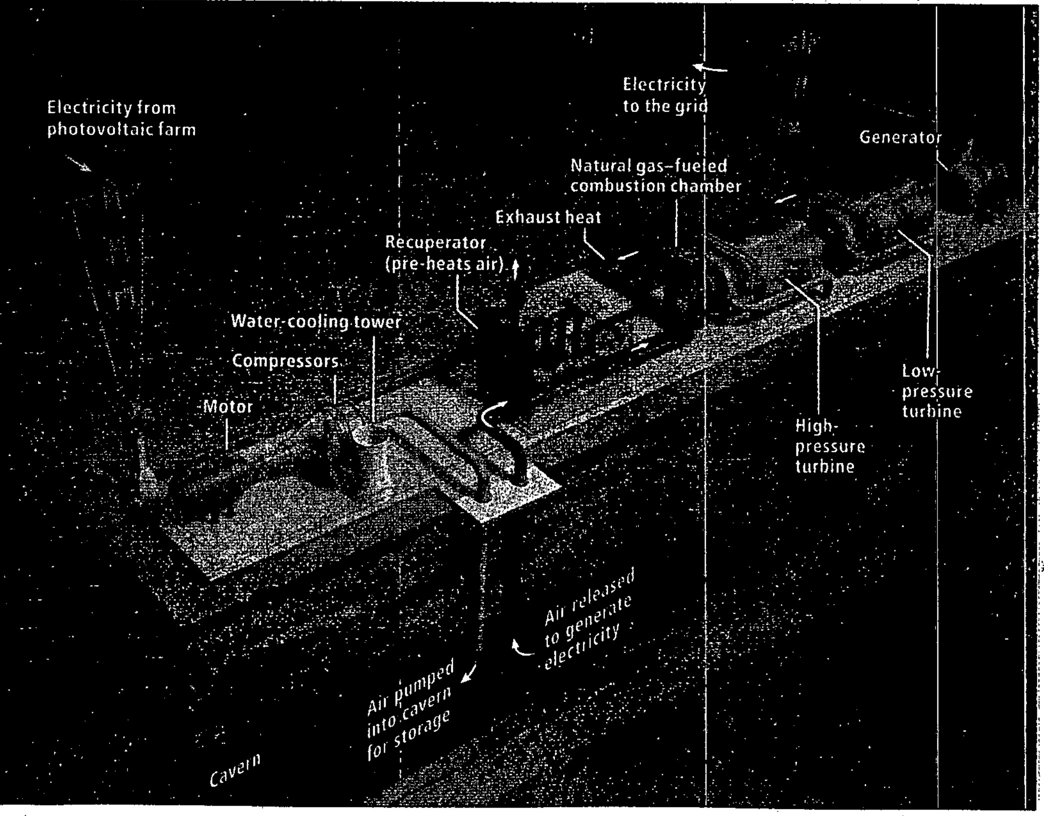
Brilliant? Far-fetched?

For a discussion with the authors about the solar grand plan, please visit our Community page at **http://science-community.SciAm.com**; click on Discussions, then Technology.

DON FOLEY

Underground Storage

Excess electricity produced during the day by photovoltaic farms would be sent over power lines to compressed-air energy storage sites close to cities. At night the sites would generate power for consumers. Such technology is already available; the PowerSouth Energy Cooperative's plant in McIntosh, Ala. (*left*), has operated since 1991 (the white pipe sends air underground). In these designs, incoming electricity runs motors and compressors that pressurize air and send it into vacant caverns, mines or aquifers (*right*). When the air is released, it is heated by burning small amounts of natural gas; the hot, expanding gases turn turbines that generate electricity.



Although \$420 billion is substantial, it is less than the U.S. Farm Price Support program.

the suitable Southwest land. Most of that land is barren; there is no competing use value. And the land will not be polluted. We have assumed that only 10 percent of the solar capacity in 2050 will come from distributed photovoltaic installations—those on rooftops or commercial lots throughout the country. But as prices drop, these applications could play a bigger role.

2050 and Beyond

Although it is not possible to project with any exactitude 50 or more years into the future, as an exercise to demonstrate the full potential of solar energy we constructed a scenario for 2100. By that time, based on our plan, total energy demand (including transportation) is projected to be 140 quadrillion Btu, with seven times today's electric generating capacity.

To be conservative, again, we estimated how much solar plant capacity would be needed under the historical worst-case solar radiation conditions for the Southwest, which occurred during the winter of 1982–1983 and in 1992 and 1993 following the Mount Pinatubo eruption, according to National Solar Radiation Data Base records from 1961 to 2005. And again, we did not assume any further technological and cost improvements beyond 2020, even though it is nearly certain that in 80 years ongoing research would improve solar efficiency, cost and storage.

Under these assumptions, U.S. energy demand could be fulfilled with the following capacities: 2.9 terawatts (TW) of photovoltaic power going directly to the grid and another 7.5 TW dedicated to compressed-air storage; 2.3 TW of concentrated solar power plants; and 1.3 TW of distributed photovoltaic installations. Supply would be rounded out with 1 TW of wind farms, 0.2 TW of geothermal power plants and 0.25 TW of biomass-based production for fuels. The model includes 0.5 TW of geothermal heat pumps for direct building heating and cooling. The solar systems would require 165,000 square miles of land, still less than the suitable available area in the Southwest.

In 2100 this renewable portfolio could generate 100 percent of all U.S. electricity and more than 90 percent of total U.S. energy. In the spring and summer, the solar infrastructure would produce enough hydrogen to meet more than 90 percent of all transportation fuel demand and would replace the small natural gas supply used to aid compressed-air turbines. Adding 48 billion gallons of biofuel would cover the rest of transportation energy. Energy-related carbon dioxide emissions would be reduced 92 percent below 2005 levels.

COURTESY OF NREL

Concentrated Solar

Large concentrated solar power plants would complement photovoltaic farms in the Southwest. The Kramer Junction plant in California's Mojave Desert (*left*), using technology from Solel in Beit Shemesh, Israel, has been operating since 1989. Metallic parabolic mirrors focus sunlight on a pipe, heating fluid such as ethylene glycol inside (*right*). The mirrors rotate to track the sun. The hot pipes run alongside a second loop inside a heat exchanger that contains water, turning it to steam that drives a turbine. Future plants could also send the hot fluid through a holding tank, heating molten salt; that reservoir would retain heat that could be tapped at night for the heat exchanger.

Who Pays?

Our model is not an austerity plan, because it includes a 1 percent annual increase in demand, which would sustain lifestyles similar to those today with expected efficiency improvements in energy generation and use. Perhaps the biggest question is how to pay for a $420-billion overhaul of the nation's energy infrastructure. One of the most common ideas is a carbon tax. The International Energy Agency suggests that a carbon tax of $40 to $90 per ton of coal will be required to induce electricity generators to adopt carbon capture and storage systems to reduce carbon dioxide emissions. This tax is equivalent to raising the price of electricity by one to two cents per kWh. But our plan is less expensive. The $420 billion could be generated with a carbon tax of 0.5 cent per kWh. Given that electricity today generally sells for six to 10 cents per kWh, adding 0.5 cent per kWh seems reasonable.

Congress could establish the financial incentives by adopting a national renewable energy plan. Consider the U.S. Farm Price Support program, which has been justified in terms of national security. A solar price support program would secure the nation's energy future, vital to the country's long-term health. Subsidies would be gradually deployed from 2011 to 2020. With a standard 30-year payoff interval, the subsidies would end from 2041 to 2050. The HVDC transmission companies would not have to be subsidized, because they would finance construction of lines and converter stations just as they now finance AC lines, earning revenues by delivering electricity.

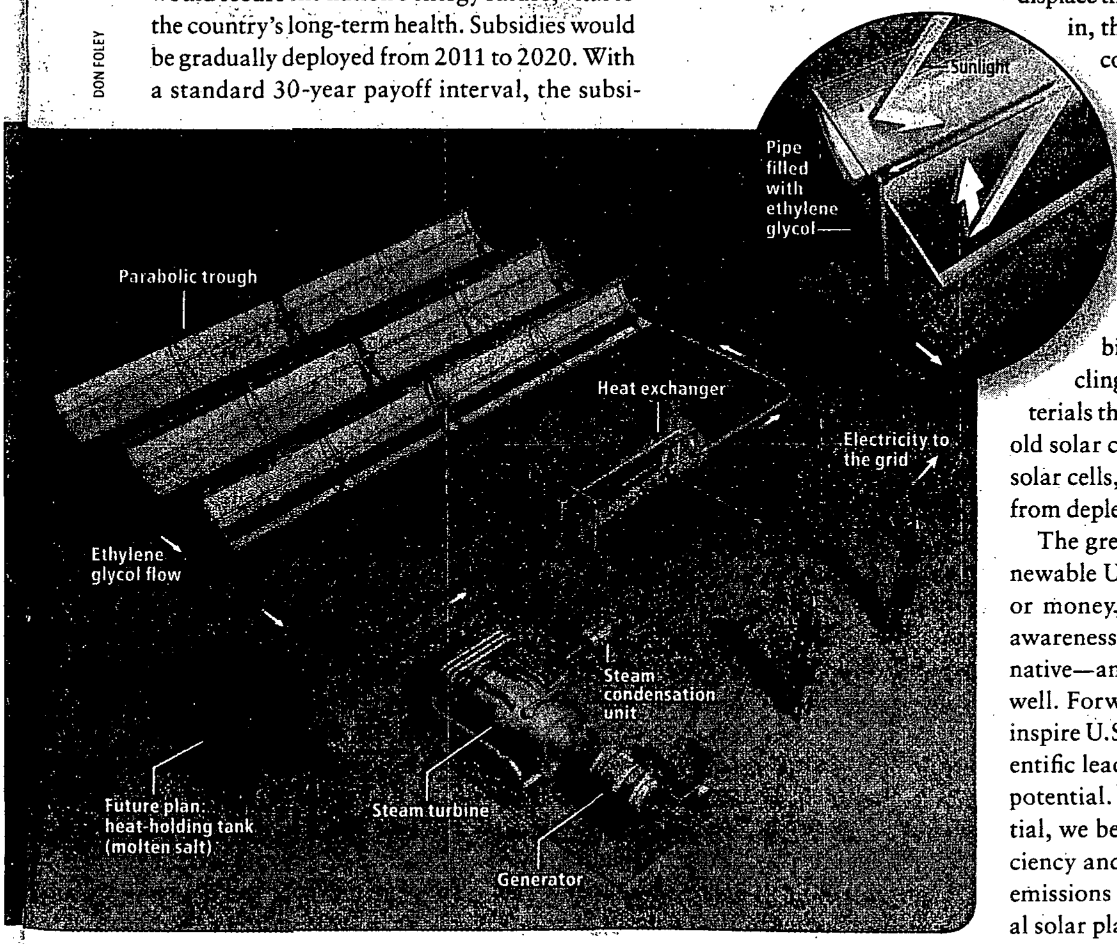
Although $420 billion is substantial, the annual expense would be less than the current U.S. Farm Price Support program. It is also less than the tax subsidies that have been levied to build the country's high-speed telecommunications infrastructure over the past 35 years. And it frees the U.S. from policy and budget issues driven by international energy conflicts.

Without subsidies, the solar grand plan is impossible. Other countries have reached similar conclusions: Japan is already building a large, subsidized solar infrastructure, and Germany has embarked on a nationwide program. Although the investment is high, it is important to remember that the energy source, sunlight, is free. There are no annual fuel or pollution-control costs like those for coal, oil or nuclear power, and only a slight cost for natural gas in compressed-air systems, although hydrogen or biofuels could displace that, too. When fuel savings are factored in, the cost of solar would be a bargain in coming decades. But we cannot wait until then to begin scaling up.

Critics have raised other concerns, such as whether material constraints could stifle large-scale installation. With rapid deployment, temporary shortages are possible. But several types of cells exist that use different material combinations. Better processing and recycling are also reducing the amount of materials that cells require. And in the long term, old solar cells can largely be recycled into new solar cells, changing our energy supply picture from depletable fuels to recyclable materials.

The greatest obstacle to implementing a renewable U.S. energy system is not technology or money, however. It is the lack of public awareness that solar power is a practical alternative—and one that can fuel transportation as well. Forward-looking thinkers should try to inspire U.S. citizens, and their political and scientific leaders, about solar power's incredible potential. Once Americans realize that potential, we believe the desire for energy self-sufficiency and the need to reduce carbon dioxide emissions will prompt them to adopt a national solar plan. ■

DON FOLEY



➥ MORE TO EXPLORE

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The National Solar Radiation Data Base. National Renewable Energy Laboratory, 2007. **http://rredc.nrel.gov/solar/old_data/nsrdb**

The U.S. Department of Energy Solar America Initiative: **www1.eere.energy.gov/solar/solar_america**

The Yucca Mountain Dump Plan Would Launch Up to 326 Barges of Deadly High-Level Radioactive Waste Onto the Waters of the Chesapeake Bay

As part of its plan to transport high-level radioactive waste to Western Shoshone Indian land at Yucca Mountain, Nevada, the U.S. Department of Energy (DOE) proposes up to 326 barges carrying giant high-level radioactive waste containers onto the waters of the Chesapeake Bay from the Calvert Cliffs nuclear power plant to the Port of Baltimore. See the second page of this fact sheet for a map of the proposed route.

Accidents happen. But what if high-level radioactive waste is involved? U.S. Nuclear Regulatory Commission (NRC) design criteria for atomic waste transport containers are woefully inadequate. Rather than full-scale physical safety testing, scale model tests and computer simulations are all that is required.

The underwater immersion design criteria are meant to "test" (on paper, at least) the integrity of a slightly damaged container submerged under 3 feet of water for 8 hours. An undamaged cask is "tested" (on computers, at least) for a 1 hour submersion under 656 feet of water.

But if a cask were accidentally immersed under water, or sunk by terrorists, is it reasonable for NRC to assume that the cask would only be slightly damaged, or not damaged at all? Given that barge casks could weigh well over 100 tons (even up to 140 tons), how can NRC assume that they could be recovered from underwater within 1 hour, or even within 8 hours? Special cranes capable of lifting such heavy loads would have to be located, brought in, and set up.

The dangers of nuclear waste cask submersion underwater are two fold. First, radioactivity could leak from the cask into the water. Each barge sized container could hold 200 times the long-lasting radioactivity given by the Hiroshima atomic bomb. Given high-level atomic waste's deadliness, leakage of even a fraction of a cask's contents into the Chesapeake Bay could spell unprecedented catastrophe. Second, enough fissile uranium-235 and plutonium is present in high-level atomic waste that water, with its neutron moderating properties, could actually cause a nuclear chain reaction to take place within the cask. Such an inadvertent criticality event in Sept. 1999 at a nuclear fuel factory in Japan led to the deaths of two workers; many hundreds of nearby residents, including children, received radiation doses well above safety standards.

STOP THE ACCIDENT BEFORE IT HAPPENS!

Don't let D.O.E. and N.R.C. get away with shipping high-level radioactive wastes on the Chesapeake Bay!

Urge Your U.S. Senators and Representative to oppose the Yucca Mountain dump plan!

Call their offices via the U.S. Capitol Switchboard: 202.224.3121.

For more information, contact Nuclear Information & Resource Service, 202.328.0002, nirsnet@nirs.org, www.nirs.org

"Mobile Chernobyl" High-Level Radioactive Waste Trucks, Trains, and Barges Would Travel on Maryland's Roads and Rails and the Chesapeake Bay if the Proposed National Dump-Site at Yucca Mountain, Nevada Is Opened

The U.S. Department of Energy (DOE) Final Environmental Impact Statement for the proposed national dump-site for high-level radioactive waste at Yucca Mountain (Feb. 2002) reveals that ***as many as 1,944 truckloads or 312 train carloads of irradiated nuclear fuel rods and highly radioactive waste could roll through Maryland if the Nevada dumpsite opens*** (pgs. 148-150). In addition, DOE has proposed ***up to 326 bargeloads of waste from the Calvert Cliffs nuclear reactor into the Port of Baltimore*** (pgs. J-78 and J-83; see also NIRS display panel).

According to Dr. Marvin Resnikoff of Radioactive Waste Management Associates (www.rwma.com), ***each truck-sized waste container would hold up to 40 times more long-lasting radioactivity than was released by the Hiroshima atomic bomb; each train-sized cask would hold over 200 times*** the long-lasting radioactivity released at Hiroshima (and this is a conservative calculation, for it accounts for only the cesium radioisotopes, which comprise but a handful of the hundreds of radioactive poisons that make up high-level radioactive waste). The barges would carry train-sized containers.

An unshielded irradiated nuclear fuel assembly could deliver a lethal dose of radiation to a person standing nearby in just a few minutes. Even with the shielding of the nuclear waste transportation container functioning properly, a person six feet away would receive the equivalent of a chest x-ray per hour. Thus, even without accidents, ***nuclear waste transport containers are like mobile x-ray machines that cannot be turned off.***

With accidents or terrorist attacks, these shipments could become "Mobile Chernobyls." According to a 1986 DOE environmental assessment, a severe transport accident in a rural area could contaminate a 42 square mile area, requiring a clean-up that would take a year and three months and cost $620 million, not to mention the economic losses due to stigma effects upon agricultural products from that region afterward. And, ***according to a report by Dr. Resnikoff about the July 2001 train tunnel fire in Baltimore, had high-level radioactive waste been aboard, hundreds to thousands could have later died from latent cancers attributable to the radioactive fallout, and the clean-up bill would have cost nearly $14 billion.*** See the report at: (http://www.state.nv.us/nucwaste/news2001/nn11459.htm).

To see how close your home, school, place of worship, and workplace is to a high-level radioactive waste transport route, just go to www.mapscience.org, type in the address, and find out. ***See the reverse side of this sheet for the DOE FEIS maps showing the targeted road and rail routes in Maryland*** (from pgs. J-78 and 151).

These transport containers are **NOT** even required to undergo rigorous full-scale physical safety testing for crashes, fires, or underwater submersions, begging the question: could they withstand severe accidents or terrorist attacks? A major radiation release from just one of these shipments through Maryland or on the Chesapeake would be catastrophic. These shipments would represent radioactive Russian roulette on the roads, rails, and the Bay -- and for what purpose? To ship this deadly waste to a leaky earthquake zone on Western Shoshone Indian land so that the nuclear utilities can make more waste at their still-operating reactors to quickly replace on-site that which is shipped away?! Even permanently closed reactors would need decades to ship away all the high-level radioactive waste that was generated there.

What YOU Can Do: Put a stop to DOE's proposed "Mobile Chernobyls" by phoning and/or faxing your U.S. Senators and U.S. Representative, urging them to do all they can to stop the dangerous Yucca Mountain plan dead in its tracks! ***Your Senators could start by opposing U.S. taxpayer subsidies***, which would build new reactors (for the first time in decades) using tens or hundreds of billions of dollars of taxpayer money, reactors which would generate YET MORE WASTE on top of the mountain -- 60 years high and growing -- which already exists.

U.S. Sen. Barbara Mikulski; Baltimore ph.: 410.962.4510; fax 410.962.4760
U.S. Sen. Ben Cardin; Baltimore ph. 410.962.4436; fax 410.962.4156

Also, call the U.S. Capitol Switchboard at 202.225.3121 to be patched through to your U.S. Representative. Ask your Reps.' office for their fax number when you call, and send them a concise, handwritten fax as well.

Phone Kevin Kamps at Beyond Nuclear at (301) 270- 2209 or visit www.beyondnuclear.org to learn more.

(see reverse →)

You Think There's a Lot of High-Level Radioactive Waste Stuck at Calvert Cliffs Right Now? How about Twice as Much?!

Total commercial high-level radioactive waste
generated in Maryland by certain dates

Reactors	1974	1995	(2008)	2011	2026	(2036)	(2056)	**Excess to Yucca by 2036**
Calvert Cliffs 1 & 2	0	641	(~1,050)	1,142	1,710	(2,052)	(2,736)	910

- In metric tons of heavy metal. To convert from metric to U.S. tons, multiply by 1.1023.
- 1974 refers to the year Calvert Cliffs Unit 1 began its operating license, and hence waste generation. Calvert Cliffs Unit 2 began commercial operations and waste generation in 1976.
- 1995, 2011, and 2026 data are from the U.S. Department of Energy (DOE) Yucca Mountain Final Environmental Impact Statement, Feb. 14, 2002, Table A-7 and A-8, pgs. A-15 and A-16 (http://www.ocrwm.doe.gov/documents/feis_2/vol_2/apndx_a/index2_a.htm)
- 2008, 2036, and 2056 data are calculated using the average annual generation rate for high-level radioactive waste at Calvert Cliffs. This was calculated by taking DOE's 1974 to 2026 grand total of 1,710 tons and dividing by 50 years, giving a 34.2 ton per year average rate.
- The U.S. Energy Information Agency, a subdivision of DOE, although in possession of the current figures for how much high-level radioactive waste has been generated at Calvert Cliffs, does not publicly report current waste inventories. The last data available from EIA were current as of December 31, 2002. The next update will not be available until late 2010. See http://www.eia.doe.gov/cneaf/nuclear/spent_fuel/ussnfdata.html.
- The year 2011 is when 63,000 metric tons of commercial high-level radioactive waste will have been generated in the U.S., enough to fill Yucca Mountain to its legal limit. All waste generated after 2011 will be excess to Yucca, and stuck in Maryland, even if Yucca were to open someday and fill up to capacity.
- DOE's year 2026 total for Calvert Cliffs assumes only a 10 year license extension at the two old reactors, but in the mid-1990s, the U.S. Nuclear Regulatory Commission (NRC) granted both Calvert Cliffs units 20 year license extensions. In fact, Calvert Cliffs received the first 20 year license extensions in the country. (Constellation Energy then spun off a subsidiary to help other nuclear utilities win rubberstamp license extensions from NRC.) Thus, assuming a 20 year license extension, and a 34.2 ton/year generation rate, over 900 tons of high-level radioactive waste could be generated at Calvert Cliffs that would be excess to Yucca's legal capability to accept it. That is, Calvert Cliffs' wastes from 2011 to the end of its 60 year operating license in 2036 will be excess to Yucca. In other words, over 25 years' worth of high-level radioactive waste generated at Calvert Cliffs will be excess to Yucca.
- 2056 refers to NRC's current toying with the idea that "80 is the new 60" – proposals to extend the operating licenses at nuclear plants like Calvert Cliffs to 80 years, twice the duration originally conceived. If Calvert Cliffs' current twin reactors operated till 2056, there would then be 1,594 tons of high-level radioactive waste excess to Yucca, more than is currently stored at the site.

Additional commercial high-level radioactive waste
that would be generated if a new reactor gets built (in metric tons)

New Reactor	40 Years of Operations	60 Years of Operations	80 Years of Operations
Calvert Cliffs-3	1,200	1,800	2,400

If an EPR (European, or Evolutionary, Pressurized-water Reactor) is built, it would generate an additional 30 metric tons, on average, of irradiated fuel per year (a conservative estimate). All of this waste, of course, would be in excess to Yucca's legal capacity to accept it.

If NRC allows Calvert Cliffs Units 1 and 2 to operate for 60 years, and allows Calvert Cliffs Unit 3 to operate for 60 years, then 2,700 metric tons of irradiated nuclear fuel excess to Yucca's capacity will be stuck on the shore of the Chesapeake Bay, with nowhere to go.

Of course, if Yucca never opens – which is looking more and more likely – then all the irradiated nuclear fuel ever generated at Calvert Cliffs will be stuck there indefinitely.

Prepared by Kevin Kamps, Radioactive Waste Watchdog at Beyond Nuclear, on March 18, 2008 (kevin@beyondnuclear.org)
Beyond Nuclear, 6930 Carroll Avenue, Suite 400, Takoma Park, Maryland 20912
Phone (301) 270-2209; Fax (301) 270-4000; www.beyondnuclear.org.

Granny's Questions For Mr. Spina of neighbor to neighbor:

1. How many of the County Commissioners live <u>south</u> of the nuclear power plant?

2. How many employees of Calvert Cliffs live <u>south</u> of Calvert Cliffs?

3. Ah yes, (a) "safety of our employees and <u>the community that surrounds our plant?</u>"; (b) "CCNPP Wildlife Habitat Team" ; ©) "improve the quality of life; (d) "create new challenges that must be addressed"; (e) "manage our treasured Chesapeake Bay environment"; (f) "work with the Nature Conservancy to protect threatened tiger beetles" "and with the Natural Sciences Estuarine Research Center to monitor the Bay's oyster population"; (g) In fiscal year 2008 "$17.3 million in taxes to Calvert County"; (h) "The U.S. Nuclear Regulatory Commission's licensing process provides for the resolution of <u>all issues</u> that arise: How about the possibility of a power plant "accident" ?

   How about the "Human Wildlife" Yes, I mean the <u>human residents living SOUTH of the power plant with no emergency plans in place.</u> An old and unrepaired TWO LANE BRIDGE out of here, will you pay for it to be expanded?. Not enough men (or women) power with the appropriate equipment to handle removing all the residents south of the plant (many of whom are very old and incapacitated). Don't tell us that our wonderful state police or sheriff officers can do it as they don't have the manpower or equipment!! Do you hear me Governor?!

Oh well, just call us Grandma Beetle and Grandpa Oyster, maybe then you'll come and help?

Anthony J. O'Donnell
Legislative District 29C
Calvert and St. Mary's Counties

House Minority Leader

Environmental Matters Committee

Annapolis Office
The Maryland House of Delegates
6 Bladen Street, Room 212
Annapolis, Maryland 21401
410-841-3314 · 301-858-3314
1-800-492-7122 *Ext* 3314
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P. O. Box 865
Solomons, Maryland 20688
Voice 410-326-0081
Fax 410-326-9169

THE MARYLAND HOUSE OF DELEGATES
ANNAPOLIS, MARYLAND 21401

March 19, 2008

Mr. Tom Fredrichs
Senior Project Manager
Division of New Reactor Licensing
Nuclear Regulatory Commission
M/S T-7E18
11545 Rockville Pike
Rockville, MD 20852

Dear Mr. Fredrichs:

I am writing to convey my unequivocal support of UniStar Nuclear Energy's (UNE) application for Combined License Partial Application for a potential advanced-design reactor at the Constellation Energy's Calvert Cliffs Nuclear Power Plant. If approved this reactor will be the third unit at Calvert Cliffs Nuclear Power Plant.

I have long recognized the importance of nuclear energy in the electric power industry as a primary source for supplying our country's energy needs. The additional unit will positively contribute to the economic health of not only Calvert County, but the entire state of Maryland and the United States, through the availability of safe and affordable power. Expansion of the Calvert Cliffs, allows diversification of energy sources through the use of non polluting nuclear fuel. The additional unit will meet the increasing energy demands of the state of Maryland and the entire Mid-Atlantic Region.

As a member of the Maryland House of Delegates Environmental Matters Committee, I am constantly looking for reasonable methods to reduce dangerous greenhouse gas emissions. Since nuclear energy has been proven to be a source of clean energy, I consider it a vital necessity for expanding our nation's energy resources. Newer technology has insured that U.S. nuclear power plants are inherently more safe then they have ever been.

Because Calvert Cliffs Nuclear Power Plant is in the heart of my district, I have had the opportunity to receive much input and support from the community regarding the potential expansion. I have had an overwhelming positive response from my constituency. Calvert Cliffs has served the citizens of Calvert County well over the past decades as the leading employer in our county. Additionally, Calvert Cliffs has contributed sixteen million dollars annually in taxes, which accounts for nine percent of the county's total revenue. Calvert Cliffs has assisted the county in numerous donations to various organizations and countless students. I have seen many positive results from their presence in Southern Maryland. I can truly say that Calvert Cliffs has greatly enriched our county and allowed for a better quality of live while helping to meet the energy needs of Maryland.

I thank you for taking the time to carefully review UniStar's application for an additional nuclear power unit at the Constellation Energy's Calvert Cliffs Nuclear Power Plant. I am hopeful that after reviewing their application, you will approve their application for an additional unit.

Sincerely,

Anthony J. O'Donnell
Delegate, District 29C

CC: Calvert County Board of Commissioners

TRI-COUNTY COUNCIL FOR SOUTHERN MARYLAND
P.O. BOX 745 HUGHESVILLE, MARYLAND 20637

(301) 274-1922
(301) 870-2520
FAX (301) 274-1924

RESOLUTION OF THE TRI-COUNTY COUNCIL FOR SOUTHERN MARYLAND ON THE SELECTION OF CALVERT CLIFFS NUCLEAR POWER PLANT AS THE SITE FOR A THIRD NUCLEAR REACTOR

WHEREAS, the 1,700 megawatt Calvert Cliffs Nuclear Power Plant (Calvert Cliffs), owned and operated by Constellation Energy Group, Inc. and located in Calvert County, Maryland, became operational and began generating electricity in 1975, more than 30 years ago, and added a second unit in 1977, and

WHEREAS, in March of 2000, Calvert Cliffs became the first nuclear plant in the United States to earn 20-year extensions of its operating licenses from the United States Nuclear Regulatory Commission–an extension to 2034 for Unit 1, and an extension to 2036 for Unit 2, and

WHEREAS, Calvert Cliffs, the State of Maryland's only nuclear power plant, has maintained an exceptional record of safety, is a significant regional employer, source of local tax revenue, environmental steward, and contributor to the economic prosperity of Southern Maryland, and has proven to be a good corporate citizen in Calvert County and the regional community; and

WHEREAS, in 2000, the Board of County Commissioners of Calvert County supported efforts by Constellation Energy to secure re-licensing for Calvert Cliffs, in 2005 the County Commissioners supported the selection of Calvert Cliffs for a potential site for a new reactor, and

WHEREAS, in 2006 the Maryland General Assembly passed and the Governor of Maryland signed into law House Bill 1183, sponsored by the Calvert County Delegation, providing for authorization of property tax credits for economic development purposes in Calvert County for projects such as expansion of Calvert Cliffs, and in 2006 the Commissioners of Calvert County enacted this legislation providing for a potential 50 percent tax credit for construction of a third nuclear reactor at Calvert Cliffs; and

WHEREAS, Calvert Cliffs was originally designed for four reactors, and on April 30, 2007, UniStar Nuclear, a jointly developed enterprise between Constellation Energy and AREVA NP Inc., notified the Nuclear Regulatory Commission that a location adjacent to the existing Calvert Cliffs Nuclear Power Plant had been selected as a site for UniStar Nuclear's first combined operating license application; and

WHEREAS, It has been more than 29 years since the Nuclear Regulatory Commission issued a construction permit for a new commercial nuclear reactor in the United States; and

WHEREAS, the construction of a third nuclear reactor at Calvert Cliffs would have a significant state, national and international impact, by enhancing the effectiveness of environmental strategies to reduce the consumption of fossil fuels and reduce greenhouse gas emissions that contribute to global warming, and by increasing domestic energy production and reducing America's dependence on imported oil; and

WHEREAS, the construction of a third nuclear reactor at Calvert Cliffs would dramatically increase Maryland's energy self-sufficiency, nearly doubling the plant's present capacity and generating enough electricity to serve approximately 2.5 million homes, more than the total number of households projected for the State of Maryland in 2015;

NOW, THEREFORE, BE IT RESOLVED, that the Tri-County Council for Southern Maryland supports the efforts of the Board of County Commissioners of Calvert County, Maryland to secure a third nuclear reactor at the Calvert Cliffs Nuclear Power Plant; and

BE IT FURTHER RESOLVED that this resolution shall become effective as of the date of its adoption.

DONE, this 13 day of December, 2007, by the Tri-County Council for Southern Maryland, sitting in regular session.

ATTEST:

Wayne E. Clark

Wayne E. Clark
Secretary-Treasurer

TRI-COUNTY COUNCIL
FOR SOUTHERN MARYLAND

Gary V. Hodge, Chairman

GVH:9-12-07