Sunrise for Energy Harvesting Products

Jan Krikke

Fifty years from now, children visiting the Smithsonian will probably chuckle at the sight of windup radios, cell phones with chargers, and laptops with huge batteries. They'll look at mock-ups of early 21st century soldiers carrying 150 pounds of equipment, a third of it batteries. They'll see pictures of suburbia with power cables strung above roads, and gas stations at nearly every corner. In 2050, children will grow up with electrotextiles, thermoelectricity, and thin solar film that will cover everything from portable electronics to parking lots. Energy harvesting will be ubiquitous, inexpensive, and practically invisible.

Steady progress in nanotechnology conjures up this optimistic scenario. Hundreds of companies and research institutes in the US, Europe, and Japan are working on energy harvesting technology, and the industry is attracting millions of dollars in venture capital.

But despite these considerable investments, progress in bringing this technology to market has been slow. Alternative power sources contribute only a fraction to worldwide power generation, and the load on the environment, much of it toxic, is still increasing. Billions of batteries are discarded every year.

POSITIVE SIGNS

But there are several bright spots. In Japan, electronics giant Hitachi teamed up with Renesas Technology Corp. to develop new chip technology that promises to lower the power requirements of electronic equipment by up to 90 percent. The breakthrough, involving a CMOS (complementary metal-oxide semiconductor) transistor for current control in mobile phones and other small terminals, will be available in 2007.

Researchers are also deploying energy harvesting technology in architecture projects. A team at Bangkok's Chulalongkorn University, under the leadership of Professor Soontorn Boonyatikarm, developed the world's first self-reliant house. Solar panels on the roof power all household appliances, including a computer linked to 140 thermal sensors that lets occupants monitor the system and adjust the temperature in different parts of the house. The house produces a surplus of energy that can be used to drive an electric car 50 miles a day. Excluding the solar panels (which are rather expensive), the house has a price tag of about US$75,000, roughly twice the cost of a conventional house of similar size in Thailand.

Hundreds of companies and research institutes are working on energy harvesting technology, attracting millions of dollars in venture capital.

And for some time now in Africa, innovative energy harvesting projects have saved thousands of lives. When someone writes the history of energy harvesting, one project deserving special mention will be the Camel Fridge. In the 1980s, Naps Systems of Finland used solar-powered refrigerators to deliver vaccines to hundreds of remote villages in the central African country of Chad. Thousands of African villages lack electricity, depriving children of potentially life-saving vaccinations. (Vaccines must be refrigerated to be effective.) Naps technicians mounted small refrigerators on one side of each camel's back, and solar panels on the other side. The solar panels generated enough power to keep the vaccines at or below the required maximum temperature of 8°C.

The camels have since been retired, but over the past two decades Naps installed thousands of stationary solar-powered refrigerators in rural health centers throughout Africa. The fridges retain their mobile predecessor's name: CFS or Camel Fridge Systems. Naps' flagship model, the Vaccine Fridge CFS49IS System, has a 49-liter freezer and four solar modules generating 50 watts each. The fridge can maintain 30 to 35 liters of vaccine at 2°C to 8°C.

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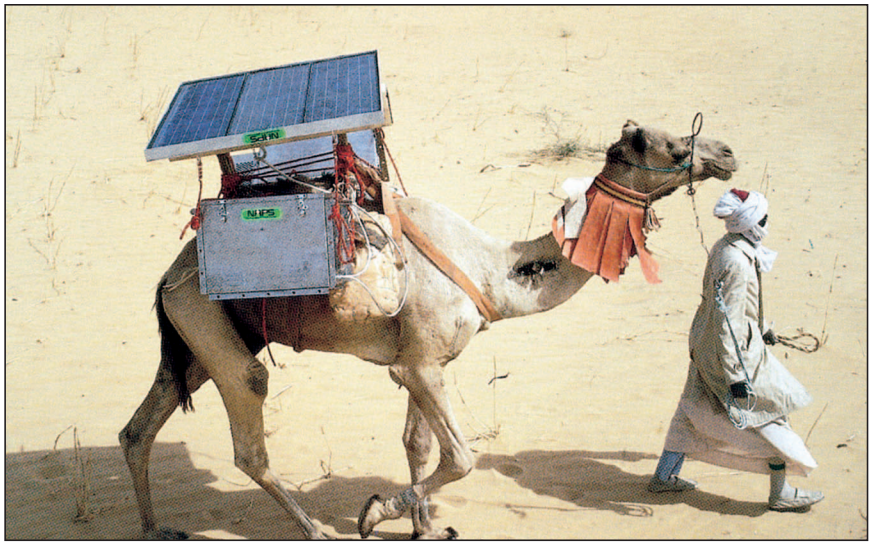
WINDUP POWER TO THE PEOPLE

Africa also inspired the development of the famous windup radio. In 1993, British inventor Trevor Baylis watched a BBC broadcast on the spread of AIDS in Africa that highlighted a central problem in fighting the disease: the lack of information among the most vulnerable. In large parts of Africa, the radio is the only viable means of communications, but an estimated three-quarters of Africans lack access to electricity. Batteries for portable radios are either too expensive or unavailable.

The problem moved Baylis to develop the clockwork radio. Turning a hand crank coiled a steel spring from one spool to another. As the spring unwound, a system of gears drove a generator that produced enough electricity to power a radio. The prototype yielded 14 minutes of play on a two-minute windup. Baylis sold the prototype to the South African entrepreneur and philanthropist Rory Stear, who founded the FreePlay Energy Group to commercialize the windup radio. Production started in Capetown in 1997. Nelson Mandela and Bill Clinton were on hand when the first windup radios rolled off the assembly line.

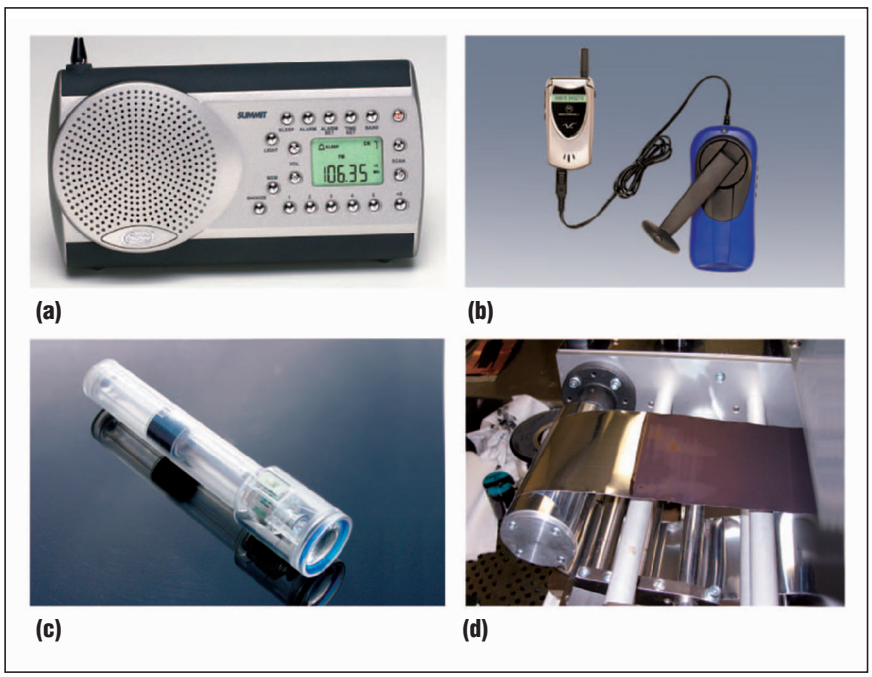
FreePlay Energy sold three million windup radios in the past seven years and donated thousands of units to aid agencies. Phil Goodman, the company's group product manager, points out that the current model, the Summit, is a vast improvement over the original. "We replaced the clockwork with a directly wound generator and an internal rechargeable battery to store the energy," he says. "A 30-second windup will now provide one hour's play." Goodman adds that the Summit now has a solar panel integrated into the body. "The radio plays on solar energy when placed in direct sunlight, and, if the generator has been wound up, it switches automatically to stored energy when moved in the shade." The Summit weighs in at only 700 grams, just over 1.5 lbs.



The "Camel Fridge." Camels wearing solar-powered refrigeration units helped deliver vaccines to remote African villages in the 1980s. (photo courtesy Naps Systems)

EVER-READY CHARGERS

In 2002, FreePlay Energy teamed up with Motorola to produce the FreeCharge, a compact cell phone charger measuring 13.5 × 5 × 6 cm and weighing 310 grams. (The two companies recently parted ways.) Winding the charger for one minute enables about five minutes of talk time and several hours of standby time. The unit can also be charged from an electrical outlet or a car using the phone's normal adapter.



Energy harvesting products: (a) the Summit, a windup-powered radio; (b) the FreeCharge, a windup charger for cell phones; (c) the NightStar, a magnetic-force flashlight; (d) Nanosolar's thin-film solar-cell material. (photos courtesy of (a, b) Free Energy Group, (c) Applied Innovative Technologies, and (d) Nanosolar)

NEWS

in brief...

Will .mp and .mobi Make Life Easier for Mobile Users?

Bernard Cole

By mid-2005, two top-level domains designed for mobile systems' viewing constraints and needs will be available, finally achieving Internet equality with their wired desktop and server brethren.

One of these TLDs is .mp. Now in the "sunrise" phase, it's signing up Web site developers. "[D]otMP was purposely held off the market while the Internet and mobile phone market sectors merged," said Gib Bintliff, president of Saipan Telecom, which administers the domain. "With device types proliferating and total numbers worldwide expected to reach 2 to 3 billion by 2006, now is the time."

The second is .mobi, originally proposed by Nokia in 2000 but turned down by the Internet Corp. for Assigned Names and Numbers (ICANN) for insufficient industry support. However, Microsoft, Vodafone, Hutchison 3G, Hewlett-Packard, Orange, Samsung Electronics, Sun Microsystems, Telecom Italia, T-Mobile, Ericsson, and the GSM Association renewed the effort in 2004.

THE FIGHT FOR AND AGAINST

So far, no opposition to .mp has risen because it's an already approved country TLD for the Commonwealth of the Northern Mariana Islands, for which Saipan Datacom is the registrar.

Just the opposite is true for .mobi, which has received numerous objections. Despite such opposition, ICANN tentatively approved formation of the new TLD in December. According to William Plummer, vice president of external affairs at Nokia, the sunrise period for creation of second-level domains and Web sites on .mobi will start by mid-year. While it's still too early to determine what specific services users can expect from .mobi Web sites, the TLD's backers will offer many of the first sites.

Plummer says that objections that .mobi will bifurcate the Internet into mobile and nonmobile areas are groundless. "We think .mobi will give mobile users the assurance that when they type in a domain name using their device, it will conform to best practices for mobile content viewing," he said. ".mobi will accelerate convergence of mobility and the Internet, not send them on different paths."

According to Plummer, .mobi will use IPv6 exclusively and will offer a virtually unlimited number of unique domain names. It will take advantage of IPv6's security features as well as several other protection schemes designed specifically for mobile devices. As a mobile-centric TLD, it will also accelerate the development of mobile devices, which are more than just thin clients—they're mobile servers in their own right.

Despite such ambitions, the Device Independence Working Group (DIWG) and others seriously oppose .mobi. The opposition contends that .mobi violates the basic premise underlying the Internet and Web: device independence. Moreover, according to Rotan Hanrahan, chief innovations architect at MobileAware, the DIWG's position is that .mobi is superfluous—that nothing about it can't be attained in other ways and without giving up device independence.

THE FUTURE'S IN USERS' HANDS

According to Bintliff, while the .mp TLD is open during the current sunrise phase to corporate trademark owners who want to protect their investment and identity on the Web, much of the .mp focus will be on individuals and small businesses. Although many of the capabilities offered by .mobi will also apply to .mp, he said, Saipan Telecom is taking a distinctly populist approach to mobile devices on the Web.

"The future of mobile computing and communications devices is in small businesses and individual users, not just as clients, but as owners and operators of online Web sites," said Bintliff. "So our strategy is to make .mp as attractive to the largest number of users and small operators as quickly as possible."

Saipan Telecom is offering two types of Web sites under .mp: personal and commercial. According to Bintliff, prices include site name registration and all the tools, building blocks, and services necessary to build and maintain a Web site specific to mobile devices' viewing limitations. The proprietary device detection system in .mp automatically recognizes a device requesting a .mp mobile site and delivers content properly formatted for that particular device.

"The demographics indicate that the users of mobile devices will not be satisfied with the way things have traditionally been done on the Web. They are looking for the new capabilities that the mobile providers want to offer," said Bintliff. "But to use them they do not want to waste time doing things that are not devoted to communicating, having fun, or doing business. They are interested in living their lives, not in being techno-whizzes."

"For many users of mobile devices, these units will be their main portal to the Web, their point of access to the compute and memory resources that will reside elsewhere but … be instantly accessible to mobile phone users and to maintainers of personal Web sites," he said, "and if our strategy pays off, they will be one and the same."

But industry watchers like Giles Richter of Mobile Media International and Martin Roscheisen of Nanosolar remain skeptical about the potential of portable chargers, pointing out that currently available solutions fail to excite consumers.

One of the few companies to have developed a healthy business selling portable chargers is Canada's ICP Solar Technologies. Its flagship product, the iSun, is a portable, modular solar DC generator with an output of approximately 2 watts. The unit is popular among owners of recreational vehicles. The iSun measures 184 × 114 × 32 mm and weighs a modest 311 grams. It has a replicator docking mechanism that allows daisy-chaining up to five iSuns for additional power.

MAGNETIC POWER

Plato famously said, "It is the magnet [magnetic force] that moves you." Steve Vetorino of Applied Innovative Technologies put the idea on its head. Vetorino developed the world's first magnetic-force flashlight. Shaking the flashlight gently moves a magnet through a wire coil, which charges a heavy-duty capacitor. The NightStar stores energy in the capacitor and delivers power to an ultrabright LED. Thirty seconds of shaking powers the LED for 20 minutes of light. In complete darkness, NightStar illuminates a 12 ft. diameter area at 50 feet. (There's more on such products in the article "Energy Scavenging for Mobile and Wireless Electronics" on page 18 in this issue.)

Linear magnetic generators have long been used on marine buoys to charge batteries that power ocean temperature and depth sensors. Improvements in that technology led Vetorino to apply it to the hand-powered flashlight.

POWER BOOTS

Among the veterans of energy harvesting from the human body are watch manufacturers. Self-powered watches rely on motion that causes a minuscule weight to rotate. The weight drives an ultrasmall generator that powers the watch. But other, more ambitious attempts to squeeze energy from the human body have proved difficult.

Four years ago, windup radio inventor Trevor Baylis conceived an electric shoe designed to power cell phones, PDAs, land mine detectors, and other electronic equipment. James Gilbert of the University of Hull in the UK produced the prototype. Gilbert mounted an off-the-shelf dynamo in the heel of a boot. Each time the heel hit the ground, the dynamo spun and generated a small trickle of current.

Gilbert says that gearing up the heel strike motion to suit the generator was a problem. Using conventional gears wasn't a good option because the forces involved required robust, heavy gears. "The solution I developed," Gilbert says, "was to use the heel strike to store energy in a spring. When the heel is lifted off again, this energy can be transferred, through a set of gears and a free wheel mechanism, to the generator. This avoids the need for heavy gears and is much more efficient. It's like a switched mode power supply where energy is stored in an inductor at one voltage and released at another voltage."

Nanosolar, Konarka, and other companies are developing energy-producing material with solar cells embedded in thin sheets of plastic.

Transferring the power supply to electronic devices was also a problem. In the prototype, Gilbert mounted a standard mobile-phone battery in a pocket on the shoe. "The idea was that the battery would be charged on the shoe and then transferred to the phone when needed," says Gilbert. "Effectively this required two batteries, one in use and one being charged." Field trials made it clear that reliability and cost were also difficult issues.

Other researchers tried to develop electric shoes with piezoelectric material. Piezo, used in electronic ignition switches on gas stoves, depends on the property of certain crystals to generate electrical charges under mechanical load. But that material is considered brittle, and the electric power it generates is difficult to harness. Gilbert says a piezoelectric shoe has yet to emerge from the laboratory. The Electric Shoe Company, set up by Baylis to commercialize the power shoe, failed to attract investors willing to pay for further development.

SOLAR POWER FOR ALL

Attracting most of the attention (and money) in the energy harvesting community is solar power. The sun already powers millions of machines, both small (watches) and large (homes), and US companies are spending millions to improve the technology. Nanosolar, Konarka, and other companies are developing energy-producing material with solar cells embedded in thin sheets of plastic, which promises to drastically reduce solar power's cost. This "power plastic" can be laminated onto any surface, from rooftops to laptops to automobiles.

Konarka's executive vice president Daniel McGahn says the company's solar material is made from flexible, durable plastic that can be used for roofing and other outdoor surfaces exposed to the weather. "We'll be able to color and pattern the roofing materials so that they look like a conventional roof—you won't even realize the [photovoltaic material] is there," says McGahn. He claims that future versions of the material could be integrated into mobile phones, PDAs, laptops, and other personal electronics—essentially any device made with plastic that has a battery and is exposed to light. "The material is complementary to battery technology. It extends and enhances device functionality by augmenting battery life."

Nanosolar is gearing up for production of SolarPly, a 14 × 10 ft. solar-electricity module delivering 110 V. The

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product closely matches the performance of conventional solar panels but at a fraction of the cost. Nanosolar's CEO Martin Roscheisen says, "We developed proprietary techniques that use nanostructured components and printable semiconductors to make it possible to utilize solution-coating processes [printing-like technology] to deposit all of the most critical layers of a solar cell. Printing processes are simple and robust in comparison with other vacuum-based thin-film deposition techniques. It can be applied at high speeds in a continuous fashion using roll-to-roll production methods."

Roscheisen says SolarPly's light weight makes it possible to install a solar-electric solution on any rooftop without triggering the expense of structural enhancements. "Conventional modules based on crystalline silicon can be too heavy for the roofing structure to support the weight in a structurally safe way, especially in commercial buildings like shopping centers and office buildings," Roscheisen says. Pilot production of SolarPly starts this year, and the product will be commercially available in 2006. Roscheisen believes SolarPly will make solar power competitive with conventional energy sources; it will ultimately cost one-fifth of conventional solar panels.

THERMOELECTRICITY

Another energy harvesting technology already being used, but hardly known among the general public, is thermoelectricity. Most of this technology has been in use for thermal stabilization of electronics and optoelectronic components for some time. But Rama Venkatasubramanian of the Research Triangle Institute (RTI) made headlines last year when he announced a major breakthrough in new materials that could double or triple the output of thermoelectric generators.

Rama argues that this technology has several advantages over solar power. "Thermoelectrics are based on temperature differentials, so they are 24/7/365 as opposed to photovoltaics that are 10/7/200, depending on where on earth we are located. Photovoltaic materials operate on line of sight of solar radiation, while heat can be directed anywhere and from anywhere."

The RTI is now gearing up for production of its superlattice thermoelectric technology. The first applications are likely to be in microprocessor and laser thermal management in optoelectronics. The technology might also find application in small-scale refrigeration systems and lightweight, portable power systems. A thermoelectric module with one square centimeter of the RTI's superlattice material produces 700 watts of cooling under a nominal temperature gradient.

"The cost demands and manufacturability of this technology would lead into other applications in automotives and refrigeration," says Rama. "The more exciting applications are likely to be in yet unthought-of uses as in fine temperature control of physical, chemical, and biological processes."

Researchers have also developed "electrotextiles" that generate electricity when exposed to light. If we can solve the main challenge of solar fiber—creating contacts with each strand in a fabric—this material could be woven into washable clothing, tent canvas, and even ships' sails. Electrotextiles could power GPS systems and other electronic gear and keep people warm in winter.

Incremental but steady progress in energy harvesting technologies should ultimately replace fossil fuels and those pesky toxic contraptions called batteries.

"Electricity has made angels of us all," said media guru Edmond Carpenter 30 years ago. He was referring to the wonders of transatlantic phone calls and global satellite TV broadcasts. Thirty years from now, children visiting the Smithsonian are likely to say, "Energy harvesting has made power generators of us all." P

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